THE ROLE OF HOME FOOD PRODUCTION IN THE PREVENTION OF VITAMIN A DEFICIENCY IN CHILDREN

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ABSTRACT

BACKGROUND: Vitamin A deficiency is one of the most prevalent micronutrient deficiencies and the main cause of preventable blindness in children below five years old. Home food production may have the potential to tackle vitamin A deficiency in children.

OBJECTIVE: To investigate the role of home food production in the prevention of vitamin A deficiency in children below the age of five.

METHODS: A systematic review and meta-analysis of global controlled trials were carried out to assess the effectiveness of home food production of vitamin A-rich foods on night-blindness, xeropthalmia, stunting, wasting, underweight, dietary diversity, mortality, cost and income generated from intervention. Cost-effectiveness analysis and a value of information analysis were carried out to investigate the likely cost-effectiveness and value of further research in home gardening/community farming of vitamin A biofortified cassava and maize (yellow cassava and orange maize) to prevent vitamin A deficiency in Nigerian children.

RESULTS: A total of 16 trials, GRADED as low-quality evidence show that home food production modestly improves stunting, wasting underweight and dietary diversity in children. The effect of home food production on serum retinol was inconclusive and no studies reported night blindness, xeropthalmia or mortality. Home gardening/community farming of yellow cassava and orange maize is likely to be highly cost-effective, however, more research on its cost and effect on serum retinol in children would be good value for money.

CONCLUSION: This thesis strongly suggests that home gardening/community farming has the potential to tackle vitamin A deficiency in young Nigerian children. Additional research, especially high-quality trials, including cost-analysis to assess the effect of home gardening/community farming of yellow cassava and orange maize on serum retinol would be worthwhile before deciding on its implementation. Until then, more funding and targeted implementation are needed to up-scale vitamin A supplementation and food fortification programmes to rural children.

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ABBREVIATIONS

CCT – Controlled Clinical Trial (allocation may or may not be randomised)

CEAC – Cost-Effectiveness Acceptability Curve

CGAP – Consultative Group to Assist the Poor

CGIAR – Consultative Group on International Agriculture Research

DALY – Disability-Adjusted Life Year

DEVTA – Deworming and Enhanced Vitamin A

ENGS – Expected Net Gain of Sampling

EVPI – Expected Value of Perfect Information

EVPPI - Expected Value of Perfect Parameter Information

EVSI – Expected Value of Sample Information

FAARM – Food and Agricultural Approaches to Reducing Malnutrition

FAO – Food Agriculture Organisation

FRAT – Fortification Rapid Assessment Tool

GAIN – Global Alliance for Improved Nutrition

GDP – Gross Domestic Product

HFP – Home Food Production

HIES – Household Income and Expenditure Survey

HIV – Human Immunodeficiency Virus

ICER – Incremental Cost-effectiveness Ratio

IITA – International Institute of Tropical Agriculture

IRR – Internal Rates of Return

LGA – Local Government Area

LMICs – Low and middle income countries

MDAST – Malaria Decision Analysis Support Tool

MI – Micronutrient Initiative

MRC – Medical Research Council

NGO – Non-Governmental Organisation

OFSP – Orange Fleshed Sweet Potato

PICO – Population, Intervention, Comparison, and Outcome

PPP – Purchasing Power Parity

PSA – Probabilistic Sensitivity Analysis

RAE – Retinol Activity Equivalent

RDA – Recommended Dietary Allowances

RDI – Recommended Dietary Intake

SANHANES – South African National Health and Nutrition Examination Survey

SSA – Sub-Saharan Africa

TP – Transition Probabilities

UNDP – United Nations Development Programme

UNICEF – United Nations International Children Emergency Fund

UNIDO – United Nations Industrial Development Organisation

VOI – Value of Information

WASH – Water, Sanitation and Hygiene

WHO – World Health Organisation

WTP – Willingness to Pay

YLD – Years Lived in Disability

YLL – Years of Life Lived

TO

JEHOVAH EBENEZER - MY HELPER

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WORD COUNT

Footnotes and bibliography included, but excludes appendices: 54,334 words

STATEMENT OF AUTHORSHIP

The work in this thesis is my original work and the publications were carried out in collaboration with other professionals.

CHAPTER ONE: Background. Written by Chizoba Esio-Bassey

CHAPTER TWO: Effectiveness of home food production in the prevention of vitamin A deficiency in children: systematic review and meta-analysis of controlled trials. Written by Chizoba Esio-Bassey.

Chizoba Esio-Bassey is the lead author and collaborated with other professionals in the published work:

Chizoba Bassey, Harriet Crooks, Katherine Paterson, Rachel Ball, Kristoffer Howell, Iona Humphries-Cuff, Kirsty Gaffigan, Nitya Rao, Jennifer A. Whitty & Lee Hooper (2020). Impact of home food production on nutritional blindness, stunting, wasting, underweight and mortality in children: a systematic review and meta-analysis of controlled trials, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2020.1848786

This work has been presented in conferences – School of Health Sciences Festival – 2019, Faculty of Medicine and Health Sciences Annual Conference 2020, African Women in STEM 2021.

CHAPTER THREE: Cost-effectiveness of home gardening of yellow cassava and orange maize in the prevention of vitamin A deficiency in children. Written by Chizoba Esio-Bassey.

CHAPTER FOUR: Value of information analysis on the home gardening of yellow cassava and orange maize in the prevention of vitamin A deficiency in children. Written by Chizoba Esio-Bassey.

Chapters three and four have been written up as manuscripts with Chizoba Esio-Bassey as lead author in collaboration with her supervisors and are about to be submitted for publication to Plos One journal.

Chizoba Esio-Bassey, MSc, Edward Wilson, PhD, Lee Hooper, PhD, Nitya Rao, PhD, Jennifer A. Whitty, PhD (2021). Home gardening of yellow cassava and orange maize for the prevention of nutritional blindness in children: An economic evaluation and value of information analysis. **About to be submitted to Plos One journal.**

Chapter three and four has been presented in conferences - Faculty of Medicine and Health Sciences Annual Conference 2021.

CHAPTER FIVE: Discussion. Written by Chizoba Esio-Bassey.

I was a part of a team that worked on a World Health Organisation scoping review to update dietary guidelines on Vitamin A, magnesium and iron in children aged 0 – 3 years.

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CHAPTER ONE

BACKGROUND

1.0 PREAMBLE

While practicing Optometry in Nigeria and engaging in eyecare outreach programmes in rural communities, I discovered that many children in rural Nigeria presented with subclinical signs and symptoms of vitamin A deficiency. This spurred my interest in vitamin A deficiency and I decided to take up this area in research. This thesis focuses on the potential of home food production to prevent vitamin A deficiency in children living in rural Nigeria.

There are five chapters in this thesis, with the methods and results included in each chapter. The first chapter presents a general background on vitamin A deficiency and establishes a gap in research and the rationale behind this work. Chapter one ends by specifying the research questions to be answered in this thesis. Chapter two is a systematic review of the effectiveness of home food production in the prevention of vitamin A deficiency, and blindness outcomes in children. Chapter three presents a cost-effectiveness analysis of home gardening/community farming of vitamin A biofortified cassava and maize (yellow cassava and orange maize) while chapter four focuses on a value of information analysis on home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children. The final chapter, chapter five, discusses findings, policy implications and recommendations of the research.

1.1 BURDEN OF VITAMIN A DEFICIENCY

Vitamin A deficiency is a public health concern in low-and-middle-income countries (LMICs). According to the World Health Organisation (WHO), 190 million preschool children are vitamin A deficient (WHO, 2021). Vitamin A deficiency remains one of the most prevalent micronutrient deficiencies globally, especially in LMICs (Bahreynian et al., 2017). Vitamin A deficiency accounts for 1.8% of the global disease burden measured in disability-adjusted life years (DALYs) and 0.8 million deaths worldwide (WHO, 2013). There is limited globally-collated data, a global survey –from over a decade ago on the prevalence of vitamin A deficiency in preschool children by the WHO reported that 33.3% of preschool children are vitamin A deficient (WHO, 2009). Preventable childhood blindness is caused primarily by vitamin A deficiency with 2.8 million preschool-age children at risk of blindness (WHO, 2009). As well as causing blindness in children, vitamin A deficiency impairs immunity and increases the risk of mortality from other childhood diseases such as diarrhoea and measles (UNICEF, 2018a).

Vitamin A is an essential micronutrient that is not manufactured in the body but is needed for good vision, a strong immune system, reproduction, growth and functioning of epithelial cells (Gilbert, 2013a). As vitamin A is not manufactured in the body, it has to be included in our diet for it to be available for use in the body. Vitamin A is of two types; preformed vitamin A and provitamin A. Preformed vitamin A, also known as retinol is found in animal foods such as eggs, milk, cheese, fish, liver and kidneys. Provitamin A is found in plant-based foods and the most common type is beta-carotene. Coloured plant food such as carrots, orange-fleshed sweet potato, dark green leafy vegetables (such as spinach), broccoli, pumpkin, yellow maize, papaya, mango, grapefruits are the richest sources of beta-carotene (National Institute of

Health, 2013). Vitamin A is a fat-soluble vitamin and any excess amount consumed is stored in the liver. Over time, an excess in the liver can lead to vitamin A toxicity which could be acute (drowsiness, abdominal pain, nausea etc) or chronic (mouth ulcers, swelling of bones and respiratory infections) (National Institute of Health, 2013). Prolonged intake of excess pro-vitamin A carotenoids do not lead to toxicity. The conversion of beta-carotene to vitamin A in the intestinal wall by dioxygenase is regulated by the amount of vitamin A present in the body. When the body has enough vitamin A, the conversion of beta-carotene reduces (Novotny et al., 2010). Vitamin A toxicity is usually derived from excessive intake of preformed vitamin A (Coates, 2010)

Nutritional blindness in children is caused by vitamin A deficiency and manifests as xeropthalmia which is an array of ocular signs and symptoms, caused by an insufficient intake of vitamin A-rich foods. Xeropthalmia presents as night blindness, bitot's spots, conjunctival xerosis, corneal xerosis, corneal ulcer, corneal scarring and keratomalacia (cornea ulcer covering up to 1/3rd of the cornea is known as keratomalacia). Xeropthalmia mainly affects children under five years of age (Gilbert, 2013a). Eye signs such as night blindness, conjunctival xerosis and bitot's spot indicate a long-standing vitamin A deficiency and are usually not blinding. Corneal xerosis, cornea ulcer and keratomalacia indicate an acute sudden onset of vitamin A deficiency, which can lead to permanent loss of vision and a high risk of death from vitamin A deficiency (Gilbert, 2013a). According to the WHO, blindness is defined as corrected visual acuity in the better eye presenting less than 3/60 in a Snellen's chart (WHO, 2007). A report written by Feroze and Kaufman (Feroze & Kaufman, 2018) demonstrated that approximately 2.8 million children worldwide are suffering from xeropthalmia with an incidence rate of 350,000 cases annually. Childhood blindness has a huge impact both socially and economically. Blind children will grow up to become blind adults and this loss in vision can hamper their quality of life, educational attainment, independence and social function (Gilbert & Muhit, 2008).

1.2 SOCIOECONOMIC DETERMINANTS OF VITAMIN A DEFICIENCY

One of the major causes of vitamin A deficiency is insufficient dietary intake of foods rich in vitamin A. Other causes are liver disorders (Gilbert, 2013b). Surveys have shown that vitamin A deficiency is more prevalent in children and women living in rural areas (Dole et al., 2009; Hanson et al., 2016; Schémann et al., 2007; Sherwin et al., 2012). A randomised cluster sampling design carried out in Congo by Samba et al. (2006) revealed that vitamin A-rich food was consumed more in urban areas than in rural areas. A survey by Arlappa et al. (2011) conducted in a rural area in India demonstrated that vitamin A deficiency was significantly more prevalent in children of lower socioeconomic status. Findings from this study showed a gross deficiency of vitamin A-rich food in rural areas. Results from a cross-sectional study by Yang et al. (2015) corroborates other findings by showing a strong correlation between vitamin A deficiency and poverty. This study established that vitamin A deficiency was significantly more prevalent among pregnant women in impoverished rural areas, illiterate people and low-income earners as these groups of people are unable to afford food rich in micronutrients. A secondary analysis of data on South African women who took part in the South African National Health and Nutrition Examination Survey (SANHANES – 1) reported that locality and household income were some overarching risk factors of vitamin A deficiency (Parker et al., 2017). This further supports that rurality and poverty are risk factors for vitamin A deficiency. The Nigerian Demographic Health Survey (2018) shows that in the vitamin A supplementation programme, children born to uneducated parents had a low coverage of vitamin A supplementation programme (29.4%) compared with children (6 – 59 months) born to parents educated above secondary school level (70.8%). Also, children in the lowest wealth quintile received a lower coverage (33.5%) of vitamin A supplementation programme compared with children born to parents in the highest wealth quintile (68.0%) (NPC & ICF, 2019)

1.3 INTERVENTION STRATEGIES FOR VITAMIN A DEFICIENCY

As far back as the 1980s, when there was a recognition of the importance of vitamin A in human health, concerted global efforts were made to eradicate vitamin A deficiency as a public health problem (Bruins & Kraemer, 2013). The challenge of eliminating vitamin A deficiency as a public health problem was included in the end-of-decade micronutrient goals sanctioned by the World Summit for Children (1990) (United Nations, 2021), the International Conference on Nutrition (1992) (WHO, 1992), and the World Health Assembly (1993) (World Health Assembly, 1993). In the face of these efforts to eliminate vitamin A deficiency over the past three decades, clinical and subclinical vitamin A deficiency are still prevalent worldwide (Stevens et al., 2015). Public health interventions used in combating vitamin A deficiency include vitamin A supplementation and food-based approaches such as food fortification, home food production of vitamin A-rich foods, biofortification, palm oil produce and point-of-use fortification with micronutrient powder (Faber and Jaarsveld, 2007).

1.3.1 VITAMIN A SUPPLEMENTATION

Undoubtedly, biannual supplementation with a high dose of Vitamin A capsule has played a vital role in the past. High dose vitamin A supplementation is being practised in 82 countries given to children aged 6 to 59 months twice yearly for the control of vitamin A deficiency (UNICEF, 2021; WHO, 2021). A systematic review and meta-analysis of randomised controlled trials by Imdad *et al.* (2017) demonstrated a reduction in the incidence of night blindness (risk ratio 0.32, 95%CI 0.21 to 0.50), bitot's spot (risk ratio 0.42, 95% CI 0.33 to 0.53), diarrhoea (risk ratio 0.85, 95% CI 0.82 to 0.87) and measles (risk ratio 0.50, 95% CI 0.37 to 0.67) in children below five years of age supplemented with biennial vitamin A compared to not being supplemented. Other systematic reviews have shown that vitamin A supplementation is effective in preventing vitamin A deficiency in children. It is important to state that VAS has been identified as one of the most effective public health interventions. It has an easy route of administration (oral administration of oil-based retinyl palmitate or retinyl acetate in liquid form) (WHO, 2011). It has a quicker mechanism of action, bioavailability and is likely to be more effective in controlling vitamin A deficiency in children compared with foods rich in beta-carotene that requires conversion to retinol in the blood (WHO, 2011).

Some authors have contested the effectiveness of vitamin A supplementation in controlling vitamin A deficiency and for all-cause mortality. In a randomised controlled trial of vitamin A supplementation programme administered every six months to 27,873 children aged 9 – 72 months by Herrera et al., 1992 in Sudan (Intervention children received 200,000 IU of vitamin A and 40 IU of vitamin E, or control children 40 IU of vitamin E as a placebo every 6 months for 18 months) showed no effect on mortality (relative risk 1.06, 95% CI 0.82 to 1.37) (Herrera et al., 1992). In line with the findings of Herrera and his colleagues, a randomized controlled trial by Fisker et al. (2014) in Guinea- Bissau, 7587 children aged 6 – 23 months were administered vitamin A supplementation once in six months (100,000 IU for 6 – 11-month-old and 200,000 IU for 12 – 23-month-old children) showed that vitamin A supplementation had no general effect on mortality (Mortality rate ratio: 0.91, 95% CI 0.59 to 1.41).

Vitamin A supplementation is cost-effective though the cost of vitamin A supplementation programmes vary considerably by country (Edejer et al., 2005). A review of literature on the cost-effectiveness of vitamin A supplementation globally by Neidecker-Gonzales et al., 2007 (Neidecker-Gonzales et al., 2007) showed an overall global estimate of US$1 per capsule delivered. They also demonstrated that the cost of administering vitamin A supplementation in rural areas is 3.7 times more than in urban areas (Neidecker-Gonzales et al., 2007). Additional workers, time and resources are needed to reach the rural population. This means that vitamin A supplementation programmes may not be suitable for targeting children in rural areas. Regardless of the benefits of vitamin A supplementation as a major child survival intervention, the issue of programme coverage lingers (Semba et al., 2008). In 2016, vitamin A supplementation programmes were able to reach 64% of children vulnerable to vitamin A deficiency, missing over 140 million other children in need of vitamin A supplementation (UNICEF, 2018b). In countries with the most vulnerable children, where there is a high death rate in children below the age of five, vitamin A supplementation coverage reduced by 50% between 2015 and 2016 (UNICEF, 2018b). In addition to missing children, the coverage gap is inequitable. Thapa in 2008, analysed data from the 2006 Nepal Demographic and Health Survey and reported that the Nepalese vitamin A supplementation programme bypassed the poorest of the poor, illiterate mothers and rural inhabitants (Thapa, 2010). Nguyen and colleagues in 2012 examined the association between vitamin A supplementation programme and socio-demographic factors from a cross-sectional demographic survey in Nepal. Ironically, they found out that children living in the rural areas who are more susceptible to vitamin A deficiency were less likely to receive vitamin A supplementation than children living in urban areas (Nguyen et al., 2012). Aghaji and colleagues analysed the 2013 Nigerian National Demographic Health Survey and illustrated that vitamin A supplementation was significantly higher in urban areas, reaching a higher number of children (53.5%, P > 0.001) than in rural areas (34.7%) (Aghaji et al., 2019). Furthermore, a study in the Philippines by Choi, Bishai and Hill. (2005) reported that vitamin A supplementation programmes did not succeed in reaching vulnerable children. While vitamin A supplementation is efficacious and cost-effective when delivered to those at risk, it is important to recognise that coverage eludes many of the most vulnerable due to geographical isolation. This does not invalidate the supplementation strategy, but it suggests that vitamin A supplementation should be part of an integrated approach sensitive to socioeconomic status, geared towards the elimination of vitamin A deficiency as a public health concern.

1.3.2 FOOD-BASED APPROACHES TO COMBAT VITAMIN A DEFICIENCY

According to Low et al. (2007), food-based approaches may have the potential for achieving sustainability in controlling vitamin A deficiency and can serve as a suitable complement to vitamin A supplementation. Food-based approaches include point-of-use fortification with micronutrient powders, home food production of vitamin A-rich crops and fortification at large scale processing facilities of staple foods such as oil, wheat flour, sugar amongst others with vitamin A (Chakravarty, 2000).

1.3.2.1 POINT-OF-USE FORTIFICATION WITH MICRONUTRIENT POWDER

Point-of-use fortification with micronutrient powder is achieved by adding a mixture of vitamins and minerals in powder form enclosed in a sachet to meals just before consumption. This fortification should not affect the taste or flavour, but increase the nutritional value of the meal (Suchdev et al., 2015). The impact of home fortification of food with multiple micronutrient powder on vitamin A deficiency was evaluated in 2017 by Silva et al. (2017) using a multi-centre controlled trial in Brazil. They enrolled 794 children, aged 6 – 14 months.

The intervention arm received micronutrient powder to be added to their complementary foods once a day for two months and the control arm received no intervention. The trial established that micronutrient powder was effective in abating vitamin A deficiency, with vitamin A deficiency present in 16.2% of the children in the control group at the end of the intervention, and in 7.5% of the intervention group children. This was a 55% reduction in vitamin A deficiency (Prevalence ratio 0.45, 95% CI 0.28 to 0.72). A similar study (also a controlled trial, set in health centres enrolling children aged under two years) by Oliveira et al. (2016) in Brazil also showed that micronutrient powder is effective in reducing vitamin A deficiency. Oliveira and colleagues enrolled 240 children finding that after receiving micronutrient powder, vitamin A deficiency was present in 4.75% compared to 18.6% in the control group. The Prevalence Ratio was 0.25 (95% CI 0.09 to 0.64). Semba et al. (2008) argued that point-of-use fortification with micronutrient powder is convenient, doesn't rely on changes in food habits and can be produced in bulk at a relatively low cost (US$ 0.02 per sachet). However, Nyhus Dhillon et al. (2017) pointed out that although point-of-use fortification with micronutrient powder is easy to use and efficacious in reducing vitamin A deficiency, achieving high coverage is difficult, relying both on good distribution and maternal/carer education and buy-in.

1.3.2.2 FOOD FORTIFICATION

Food fortification is an industrial process, intentionally increasing micronutrient content by adding vitamins and minerals (fortifiers) to foods (called vehicle foods e.g., wheat flour, sugar, margarine, biscuits, salt, cooking oil etc) during production. The aim is to improve the nutritional value of the food, providing health benefits with marginal risk (WHO, 2016a). Fortification is socially acceptable, cost-effective and has delivery systems in place already, but may require some modification of food habits (Lotfi et al., 1996; Nestel, 1993). In 2002 and 2008, the Copenhagen Consensus classed food fortification as one of the most cost-effective interventions (GAIN, 2022). Large-scale food fortification is a sustainable method of reaching large number of people with vital micronutrients including vitamin A. At least one cereal grain fortification is mandated in 83 countries and 30 countries legislate for the fortification of cooking oils, margarine and ghee (Global Nutrition Report, 2019) . Currently in Nigeria, five foods must be fortified with vitamin A – sugar, cooking oil, wheat, semolina and maize flour (Valerie, Friesen; Michael, Ojo; Mduduzi, 2021).

Sugar and cooking oil fortification with vitamin A increased by 200% and 28% respectively, and caused an additional 125.7 million children to have access to vitamin A fortified sugar and 13.8 million children to have access to cooking oil in Nigeria (TechnoServe, 2020). In the Philippines, fortification of wheat flour was found to have increased the vitamin A liver content of preschool children (Solon, 1997). Also, in a survey on the Guatemalan vitamin A sugar fortification programme, adding retinyl palmitate caused an increase in serum retinol in 76% of preschool children. The Guatemalan survey found that in children receiving the intervention, mean serum retinol increased from 16.2 ± 2.9 to 30.2 ± 9.7 µg/dL (P-value < 0.00001) (Arroyave, 1979). Very weak evidence from a systematic review has shown that food fortification may not improve serum retinol in children (Mean difference (MD) 0.03µmol/L, 95% CI -0.06 to 0.12; 3 studies, 1829 participants) (Hombali et al., 2019). Despite these benefits of food fortification, it may not be useful in resource-poor settings owing to the tendency of this group of people to make food choices based on price rather than quality (Levinson, 1972). (Dary & Mora, 2002).

1.3.2.3 HOME FOOD PRODUCTION OF VITAMIN A-RICH FOODS

Home food production (or home gardening) involves planting vitamin A-rich fruits and vegetables alongside nutrition and gardening education for poorer households and may involve the provision of tools and seeds or plants, and even animal husbandry (Helen Keller, 2013). Home food production may have the potential to make micronutrient-rich foods more accessible to infants and children in rural settings (Faber, 2001), but do require substantial labour and time. The paucity of dietary diversity is a concern inherent in poor-resource settings where meals are mainly starchy staple foods with limited amounts of additional nutritious foods such as fruits, vegetables or animal produce (World Bank, 2008). Three out of four persons reside in rural areas in LMICs and they depend on agriculture as their source of food (World Bank, 2008).

Home gardens are small plots of land near the home which are managed by members of the household with limited cost input. A home garden of 15m by 10m has the potential to supply adequate fruits and vegetables to meet vitamin A requirements for a family of six throughout the year (Faber and Jaarsveld, 2007). Though, the required size of a garden to meet household needs will vary between different contexts and depending on factors such as availability of land, water for irrigation, seedlings, time, childcare support amongst others. Home food production may have the potential to increase serum retinol in children (Afolami, et al., 2021). According to Talukder et al. (2010), home food production is likely to be cost-effective in improving dietary diversity and consumption of nutrient rich foods.. Faber and van Jaarsveld (2007) suggest that the benefits of home food production are potentially important. Fruits and vegetables can provide multiple macro and micronutrients concurrently and may strengthen food security amongst households in rural areas. More broadly, extra produce may be sold to raise additional income for the family. Home food production could be highly beneficial to communities not covered by vitamin A supplementation and food fortification.

A home food production project was implemented in the rural area of Ndunakazi, South Africa. Demonstration gardens within the village were set up and used for training. Nutrition education was given in addition to training on home gardening (Faber, 2001). After the project, the routine consumption of cereals was reduced and the intake of a variety of vegetables produced in the garden increased. At follow up (20 months after the intervention), 79% of children in the experimental village consumed more pumpkin than baseline (compared to 26% in the control village). Consequently, in children, serum retinol was higher in the experimental village (0.81 ± 0.22 umol/L, n = 110) than the control village (0.73 ± 0.19 mol/L, n = 111) (Faber, Venter, et al., 2002).

Home food production may have the potential to control vitamin A deficiency in children below the age of five. However, it needs further investigation in its effectiveness and cost-effectiveness. In assessing the potential of home food production to tackle vitamin A deficiency in children, its cost-effectiveness is crucial as health needs compete for scarce resources. For an intervention to be recommended for implementation, it must be a good use of limited resources. Understanding the cost-effectiveness of home food production will guide policymakers in deciding whether it is worth investing into tackle vitamin A deficiency in children. No one strategy is a panacea on its own, and evidence is needed to assess whether home food production would form part of an integrated approach towards the successful elimination of vitamin A deficiency.

There are disadvantages in the uptake of home food production. Financial constraints may mean that households may have limited access to seeds, tools and capital investment. Gender norms and power dynamics between men and women in households may affect productivity of home gardens. Pests and diseases, drought and limited access to training and supportive organisations may impede productivity from home gardens. Also, free roaming animals may spread infections and even destroy crops in home gardens. A cross-sectional formative study in Ethiopia evaluated risk factors for campylobacter infection in infants and illustrated that infected poultry faeces ($P < 0.001$; OR 1.34) and keeping animals inside the compound ($P = 0.027$; OR 3.5) were risk factors associated with campylobacter infection in infants (Budge et al., 2020). Other factors include lack of water supply, soil infertility and erosion, and competing time spent in home gardening and cultural acceptance of home gardens. There is the issue of sustainability of home gardening intervention where some households may not continue with the intervention after withdrawal of programme support. Households in urban and peri-urban settings may resort to contaminated soils (due to shortage of land) previously used in disposing waste water, solid urban and industrial waste which may expose these households to trace metals such as lead, cadmium, chromium and nickel (Nabulo et al., 2012). In addition, recurrent cost is needed to maintain and monitor traits in biofortified crops including high nutritional content, high yield, and drought and disease resistance (Bouis et al., 2013).

1.3.2.4 RED PALM OIL

Red palm oil has been shown as a rich source of carotenoids and has been able to reduce vitamin A deficiency in children. A study that evaluated the impact of red palm oil on vitamin A deficiency in Burkina Faso demonstrated a decrease in low serum retinol from 84.5 ± 6.4% to 66.9 ± 11.2% (Zagré et al., 2003). Also, the results of a meta-analysis of 446 children indicated that red palm oil reduced the risk of vitamin A deficiency ((RR) (95% confidence interval (CI)) = 0.55 (0.37, 0.82), p = 0.003) and increased serum retinol levels in children ($p < 0.00001$) (Dong et al., 2017).

1.3.3 STRATEGIES TO IMPROVE VITAMIN A STATUS THROUGH INCREASED DIETARY DIVERSITY

Diversifying children's diet with vitamin A rich foods is associated with improved vitamin A status in children (Fujita et al., 2012). If children are to obtain all essential nutrients, dietary diversity is a pertinent requirement (Fujita et al., 2012) (Karlsson et al., 2022). Dietary diversity is the process of measuring the variety in types of food consumed within a household quantitatively. It serves as a proxy for nutrient adequacy in an individual's diet (Fujita et al., 2012). Some authors have established the relationship between a diversified vitamin A-rich dietary consumption to improved vitamin A status and protection against xeropthalmia. There are several ways of improving vitamin A status in children through dietary diversity such as having a home garden, nutrition education, increased income and women's time use.

Some authors have investigated the association of dietary diversity with nutritional blindness in children. Gittlesohn et al. in 1997 explored infant feeding practices and the risk of xeropthalmia in Nepali children, using a case-control study design with 78 xeropthalmic and 78 non-xerophthalmic children between the ages of 1-6 years. The feeding of vitamin A-rich foods served as a protection against xeropthalmia in early childhood. Schaumberg et al. (1996) carried out a case control study in the republic of Kiribati, assessing 666 cases of xeropthalmic children and 816 controls. Results from this study showed that higher frequency of consumption of vitamin A-rich foods (OR 0.93, CI 0.80 – 0.96) and the presence of a garden (OR 0.70, CI 0.52 – 0.93) conferred a protective layer against xeropthalmia. Mele et al. (1991) conducted a case-control study in Indonesia that investigated the nutritional and household risk factors of xeropthalmia in children under the age of six. The study reported that the risk of xeropthalmia increased with a less frequent consumption of vitamin A-rich foods (OR 3.5). Shankar et al. (1996) conducted a case-control study in Nepal among 81 household with xeropthalmic children and 81 households with non-xeropthalmic children. The cases were less likely to consume vitamin A-rich fruits (OR 1.01) and vegetables (OR 2.15) in comparison to controls.

1.3.3.1 NUTRITION EDUCATION

Nutrition education is a fundamental strategy to various approaches of nutrition intervention such as dietary diversity. Evidence shows that nutritional intervention improves serum retinol status. In Sri Lanka, the effect of nutrition education was assessed on nutrition related knowledge, food consumption patterns and serum retinol levels in 229 adolescents between the ages of 15 and 19. Nutrition education was delivered as lecture discussions and interactive group discussions. After a ten-week period, nutrition education was associated with a significant increase in knowledge ($P < 0.001$) and consumption of local vitamin A-rich foods. The prevalence of vitamin A deficiency (<20 microg/dL) reduced from 17% to 4.8%. Nutrition education had a highly significant effect ($P < 0.001$) on subjects with baseline serum retinol concentration below 20 microg/L (Lanerolle & Atukorala, 2006). Another study in Uganda assessed the impact of nutrition education focused on the child-feeding practices of low-income rural caregivers to reduce anaemia and improve vitamin A food intake using a controlled intervention trial. Forty-six women enrolled in the intervention arm and completed nine sessions of lectures on nutrition while for the control arm, women (n = 43) were enrolled into sewing classes. The caregivers' child-feeding practices and children's nutritional status were assessed one month and one year after the intervention. The results showed that caregivers in the intervention arm reported an improvement in child snacking pattern, food selection practices, meal adequacy and food variety. There was an improvement in mean retinol-binding protein from 0.68 µmol/l (95% CI: 0.57-0.78) to 0.91 µmol/l (95% CI: 0.78-1.03) in the intervention group, but there was no change in the control group (Kabahenda et al., 2016).

1.3.3.2 SOCIO-ECONOMIC STATUS

Socioeconomic status is associated with healthy diet patterns, diet quality and diversity in high income countries as well as low-and-middle income countries. Dietary diversity may represent a proxy for household resources (Morseth et al., 2017). Evidence has shown that increased dietary diversity was associated with higher income levels and higher per capita energy availability in households (Hoddinott, 2014). A cross-sectional study in the Saharawi refugee camps, Algeria, assessed the association between dietary diversity and socioeconomic status using the WAMI index (sanitation, assets, education and income). The results showed that there is a positive association between dietary diversity and WAMI index ($P > 0.001$), suggesting that low dietary diversity is associated with low socioeconomic status (Avula et al., 2011). A cross-sectional survey in two districts of Illu Ababora Zone Oromis region of Ethiopia assessed the determinants of dietary diversity. Data were collected from 334 households and results showed that household income and wealth positively influenced dietary diversity (Huluka & Wondimagegnhu, 2019). Likewise, a survey in Bangladesh that included 188,835 households using a bi-monthly data collection method from 2003 – 2005 illustrated that dietary diversity was significantly associated with total household expenditures ($P < 0.0001$) (Thorne-Lyman et al., 2010).

1.4 EQUITY CONSIDERATIONS IN HOME GARDENS

1.4.1 GENDER NORMS

In most households, there are power dynamics in decision making pertaining to home gardens such as in the type of crops to grow, allocation of time spent in home gardening among others. Men are custodians of lands in many African countries as lands are passed from father to male heir, and they decide how the land is used (Obayelu, 2017). Traditionally, in many African countries, land ownership does not reside with women, and they only have access to lands through household membership. Though women sell home-grown foods, men take over the cultivation and sale of crops that provide significant amounts of income (Nguyen et al., 2017). Women have limited access to technology, capacity building and market information. This may be attributed to extension agents being mostly men, thereby having more interaction with men and engaging in male agricultural activities such as yam cultivation (Nguyen et al., 2017).

Female-headed households face particular challenges in growing a home garden as women have challenges engaging in activities habitually carried out by men. Female headed households may find it difficult to engage with local authorities, access training, loans, land, water supplies and financial services. While women undertake more than half of agricultural activities, they have limited access to financial support, technology, market intelligence and capacity-building opportunities (Nguyen et al., 2017).

1.4.2 LAND OWNERSHIP AND TENURE

Land is a critical agricultural production resource, and limited access to land impedes agricultural productivity. Equity issues surrounding land ownership impacts on agricultural production. In some African countries including Nigeria, land ownership is primarily through inheritance (Obayelu, 2017). Families that have limited access to lands and are financially constrained to lease lands will experience challenges in cultivating a home garden. A household that has leased a piece of land for one year may not cultivate a crop that spans over one year. A multi sampling technique carried out by Adamu in 2004 which included 120 farmers showed that the method of land acquisition was mainly through inheritance and the method of land acquisition affected the types of crop cultivated (Adamu, 2014).

1.4.3 CHILD LABOUR IN AGRICULTURE

Globally, 70% of child labour is in agricultural activities (FAO, 2017). Approximately 108 million children are involved in crop production, livestock, fisheries, forestry and aquaculture with protracted hours of work under hazardous conditions. Africa has the highest number of child labourer in agriculture with 72 million children involved in agricultural practices, followed by Asia with 62 million (FAO, 2017).Child labour poses a hindrance to the sustainability of home gardening. Children are likely to be affected more by the hazards and risks that adults face in agricultural practices, and they may suffer from permanent disabilities and poor health by engaging in agricultural activities. The root causes of child labour in agriculture such as poverty and lack of social protection must be tackled to end this inequity in home gardening (FAO, 2017).

1.4.4 NUTRITIONAL BENEFITS FOR DIFFERENT DEMOGRAPHIC GROUPS

A home garden that concentrates on vitamin A-rich foods may not be meeting the nutritional requirements of other members of the household. This introduces an imbalance and may affect the choice of crops planted in a home garden.

1.4.5 WOMEN'S TIME

Women are greatly involved in domestic activities including laundry, cooking, cleaning and caring for the children. As well as being involved in domestic activities, they are heavily involved in home gardening. In LMICs, women make up approximately 43% of agricultural activities. Women being heavily involved in domestic activities as well as agricultural activities is overburdening and may lead to unhealthy conditions (Oxfam International, 2021).

1.5 INTERVENTION STRATEGIES FOR VITAMIN A DEFICIENCY IN SUB-SAHARAN AFRICA

Geographically, Sub-Saharan Africa (SSA) is the region in the continent of Africa located south of the Sahara desert (United Nations Development Program, 2021), comprising 48 countries (World Bank, 2021). Forty-one percent of Sub-Saharan Africans live in extreme poverty with 47% surviving on less than $1.25 a day (CGAP, 2018; United Nations Development Program, 2021). While poverty levels seem to be improving, they represent the most extreme poverty in the world (CGAP, 2018). Given the strong association between poverty and vitamin A deficiency (Section 1.2), it is likely that SSA is highly susceptible to vitamin A deficiency.

Data from UNICEF confirms that SSA has the highest prevalence of vitamin A deficiency worldwide with 48% cases of vitamin A deficiency in SSA (UNICEF, 2018b). According to the study by Beal et al. (2017) in Sub-Saharan Africa, the prevalence of inadequate intake of vitamin A was reported to be high at approximately 76% (Beal et al., 2017). Aguayo and Baker showed from their analysis of national surveys in eleven SSA countries that 43.2 million children were at risk of vitamin A deficiency as a result of insufficient intake of vitamin A-rich foods (Aguayo & Baker, 2005). Ten years later, Stevens et al., 2015 (Stevens et al., 2015) corroborated the findings of Aguayo and Baker by reporting that 1.7% of all mortality in LMICs is linked to vitamin A deficiency and 95% of deaths attributable to vitamin A deficiency in LMICs occurred in SSA (Stevens et al., 2015). They assessed mortality attributable to vitamin A deficiency by pooling data on the prevalence of vitamin A deficiency, cause-specific deaths and relative risks. These results are truly disturbing and call for immediate action.

While vitamin A supplementation was a widely adopted approach for combating vitamin A deficiency in Africa, in 2016, the continent recorded the lowest coverage for vitamin A supplementation (2 dose coverage) globally, at 54% of under five year olds (UNICEF, 2018a). A cross-sectional study by Adamu and Muhammad, 2016 (Adamu & Muhammad, 2016) in the most populous country (Nigeria) in SSA reported that 61.6% of children received one dose of vitamin A supplementation and just 41.6% received two doses in 12 months. They found that parent's education and occupation were associated with low vitamin A supplementation uptake. Another Nigerian study by Aremu, Lawoko and Dalal (2010) found that parental occupation and household wealth status were significantly associated with vitamin A supplementation coverage, such that children of poorer families were most at risk of missing supplementation. Guinea reported vitamin A supplementation coverage of 58% (Bendech et al., 2007), and Ethiopia's Demographic and Health Survey suggested only 47% of preschool children received vitamin A supplementation (Semba et al., 2008). Vitamin A supplementation has been unable to control vitamin A deficiency in SSA countries.

The Fortification Rapid Assessment Tool (FRAT) was established in several countries in SSA to aid programme managers in planning and executing food fortification programmes at the national level. In 2013, Hess et al. (2013) surveyed FRAT in 12 SSA countries (Burkina Faso, Cameroon, Congo, Guinea, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Senegal, Uganda) by analysing consumption trends of wheat-flour, vegetable oil, sugar and bouillon cubes. This survey found that more of these food fortification vehicles were consumed in urban areas than in rural areas. Whilst food fortification should be targeted for the urban settings in SSA, this is less useful in rural settings where consumption of processed food is minimal. This underscores the need for approaches such as home food production which may be feasible and sustainable among the poor in rural settings. The need for sustainable approaches bespoke to rural areas in SSA countries is urgent, and the answers are unknown.

1.6 RESEARCH AIMS AND OBJECTIVES

1.6.1 AIM:

The overall aim of this thesis is to understand the potential role of home food production in the prevention of vitamin A deficiency and nutritional blindness in children.

1.6.2 OBJECTIVES:

1. To assess the effectiveness of interventions to promote home food production in the prevention of vitamin A deficiency in children globally.
2. To estimate the cost-effectiveness of home food production to prevent vitamin A deficiency in Nigerian children.
3. To evaluate the value of further research on home food production in preventing vitamin A deficiency in Nigerian children.

1.6.3 RESEARCH QUESTIONS

1. What is the effectiveness of interventions to promote home food production in preventing vitamin A deficiency and nutritional blindness in children globally?
2. what is the likely cost-effectiveness of an intervention to promote home gardening with yellow cassava and orange maize in the prevention of vitamin A deficiency and blindness in Nigerian children?
3. Should further research be conducted based on the level of uncertainty surrounding the cost-effectiveness of home gardening of yellow cassava and orange maize?
4. If further research is to be conducted on home gardening of yellow cassava and maize, what type of studies should be prioritized?

1.7 METHODOLOGICAL APPROACHES

A mixed-method approach was adopted for this work – a systematic review, cost-effectiveness analysis and a value of information analysis (VOI). The systematic review involved the synthesis of available evidence on the effectiveness of interventions that promoted home food production on nutritional blindness in children. It supported the need and provided data for an economic evaluation where the cost-effectiveness of home food production was assessed. A VOI analysis was carried out to investigate if additional research is worthwhile before deciding whether home food production can be implemented in tackling vitamin A deficiency in children.

The remaining chapters will present the various methods used in this thesis along with the results and discussion of those results - Chapters two, three and four will cover the methods, results and discussion of the systematic review, cost-effectiveness analysis and VOI analysis respectively. The last chapter will focus on discussion and summary of all findings, and recommendations flowing from this research.

CHAPTER TWO

THE EFFECTIVENESS OF HOME FOOD PRODUCTION IN PREVENTION OF NUTRITIONAL BLINDNESS IN CHILDREN: SYSTEMATIC REVIEW AND META-ANALYSIS OF CONTROLLED TRIALS

2.0 SUMMARY

The previous chapter set this thesis in context, by discussing the burden of vitamin A deficiency and the rationale for carrying out this thesis. In Chapter two, I carry out a systematic review and meta-analysis. I aim to systematically review trials assessing the effects of home food production (also called homestead food production and agricultural interventions) on xeropthalmia, night blindness, stunting, wasting, underweight, mortality, cost of intervention and income generated. Medline, Embase, Scopus, Cochrane CENTRAL and WHO trial registers were searched to February 2019. Inclusion of studies, data extraction and risk of bias were assessed independently in duplicate. Random-effects meta-analysis, sensitivity analyses and subgrouping were carried out and GRADE was used to assess the quality of evidence. Sixteen trials were included randomizing 2498 children, none reported data on xerophthalmia, night-blindness or mortality. The results showed that home food production may slightly reduce stunting (mean difference (MD) 0.13 (z-score), 95% CI 0.01 to 0.24), wasting (MD 0.05 (z-score), 95% CI -0.04 to 0.14) and underweight (MD 0.07 (z-score), 95% CI -0.01 to 0.15) in young children (all GRADE low-consistency evidence), and increase dietary diversity (standardized mean difference (SMD) 0.24, 95% CI 0.15 to 0.34). The effect of home food production on serum retinol was inconclusive. This systematic review has been published by Bassey et al., 2020 in Critical Reviews of Food Science (Bassey et al., 2020). The

results of this chapter lead to further investigation of home food production in a cost-effective analysis.

2.1 INTRODUCTION

A systematic review was carried out to assess the effectiveness of home food production in the prevention of vitamin A deficiency and nutritional blindness in children. Systematic review methodology was adopted because it utilises an orderly and reproducible technique in identifying, choosing, critically assessing, extracting and synthesizing data from all the relevant empirical studies with the lowest level of bias. Systematic reviews develop and address an explicitly formulated research question (Chandler et al., 2019). Along with the systematic process of locating all the relevant studies, assessing the potential bias within included trials, meta-analysis and systematic reporting, this reduces potential bias within the reviewing process. Risk of biases such as publication bias is minimised and selection bias, performance bias, detection bias, attrition bias and reporting bias are quantified using the Cochrane risk of bias. Assessment of inclusion, data extraction and risk of bias assessment is carried out independently in duplicate to minimise errors. A thorough assessment of risk of bias helps the reader of a systematic review to understand the quality of evidence (internal validity) produced by a review (Higgins et al., 2011)

2.2 DESCRIPTION OF INTERVENTION

Home food production interventions have been utilised in some South Asian and African countries as far back as 1990 (Meyer, 2016). Helen Keller International, a non-governmental organisation has been the major player in promoting home gardening interventions across Asia and Africa, and in many situations, national governments have also supported small-scale agriculture and home gardening to foster food security. They provide tools and train women from poor households in the skills to grow selected fruits and vegetables in home gardens and raise poultry on a small scale (Hellen Keller International, 2013). Fruits and vegetables are selected based on their nutritional composition as well as their capacity to thrive in a specific geographic location. Poultry is raised to augment essential nutrients lacking in plant produce. A vital component of this health intervention is nutrition education where women are equipped with valuable information on the benefits of eating well and the healthiest ways of feeding their children. The interventions also provide support and education in marketing strategies to assist women to sell their excess harvest and increase their household income (Hellen Keller International, 2013).

Helen Keller International is actively involved in the promotion of home food production. They advocate that home food production is beneficial to disadvantaged people owing to its cost-effectiveness, sustainability and multiple positive outcomes such as an increase in dietary diversity, food security and household income (Hellen Keller International, 2013). Since vitamin A supplementation and other food-based approaches such as food fortification and the use of micronutrient powder often miss out on disadvantaged children and women in rural areas, home food production might be used specifically to target this population (Faber and Jaarsveld, 2007).

Home food production programmes have supported women to produce foods rich in micronutrients such as iron, zinc and vitamin A by equipping women of deprived households with planting tools, seeds and training, with or without seedlings for planting, chicks for rearing, and technical assistance (Talukder et al., 2010).

In this systematic review, home food production programmes were those that supported women to grow food mostly for home consumption (though the surplus might be sold to raise income) through training in home gardening skills and/or provision of tools and planting materials. Interventions might also train women in marketing strategies to enable them to sell their surplus produce and/or cooking methods to preserve micronutrients. Animal husbandry might or might not be added to home gardening.

2.3 HOW MIGHT THE INTERVENTION WORK?

Home food production programmes aim to enable households to produce dark green vegetables, yellow and orange fruits, tubers, roots, grains and a range of other crops. This is hypothesised to lead to increased consumption of food rich in vitamin A and other micronutrients by the family's children (Galhena et al., 2013).

Animal husbandry such as raising poultry produces foods (such as eggs) containing preformed vitamin A. While plant produce contains bioavailable vitamin A, animal produce contains vitamin A with higher bioavailability than plants. For this reason, women may be encouraged to raise chickens in addition to planting fruits and vegetables to increase intake of preformed vitamin A (West Jr, 2002). Home food production bestows upon women the critical responsibility of producing micronutrient-rich foods for their families through informed choices and a sustainable approach (Ruel & Levin, 2001).

Home food production involves a complexity of factors that affects its success ranging from availability of land, childcare, availability of time for gardening, sale of surplus produce, marketing of produce, nutritional requirements of members of households, nutrition education amongst others (UK Aid, 2014).

Several mechanisms of action for training in home food production have been proposed. Training in home food production is thought to support women to acquire skills that enable them to maximise the quality and quantity of produce realised from their work. The provision of planting materials empowers women to engage in home gardening with the appropriate tools and materials (especially seedlings) needed to grow micronutrient-rich foods. The provision of tools and materials relieve disadvantaged women of the burden of sourcing funds to grow micronutrient-rich foods (Talukder et al., 2010). Nutrition education aims to provide women with knowledge of foods rich in vitamin A and other micronutrients, so they can make informed decisions on what plants to grow and what foods to feed their children (Low et al., 2007). Cooking sessions aim to empower women on the best cooking methods to ensure the preservation of essential micronutrients (such as frying orange sweet potato to aid rapid absorption in children) (Gelli et al., 2018). Marketing strategies aim to provide support for women to sell their surplus farm produce, which could lead to additional income, enabling other family needs (such as education and health) to be met (Low et al., 2007).

2.4 WHY IS IT IMPORTANT TO DO THIS REVIEW?

Vitamin A deficiency is still a public health issue despite decades of efforts towards its control. A more sustainable approach aimed at tackling the underlying cause of vitamin A deficiency (insufficient intake of vitamin A-rich foods) may be a useful solution for poorer and rural households (Faber and Jaarsveld, 2007). Home food production is currently promoted as a good strategy, however evidence of its efficacy in boosting vitamin A and preventing blindness in children is unclear. Therefore, a systematic review focusing on the impact of home food production on key outcomes of vitamin A deficiency such as blindness would be helpful. Existing systematic reviews (Girard et al., 2012; Masset et al., 2012) that have assessed effects on vitamin A deficiency are outdated and did not assess the impact of home food production on nutritional blindness. There is a need for an up-to-date and methodological rigorous systematic review in this crucial area.

2.5 RESEARCH QUESTION:

- What is the effectiveness of interventions to promote home food production in preventing vitamin A deficiency and nutritional blindness in children?

2.5.1 SUB-QUESTIONS:

- Does the effectiveness of home food production depend on the duration of intervention?
- Is home food production more effective in Africa or Asia?
- Does the effectiveness of home food production differ when the planting of fruits and vegetables is combined with animal husbandry?
- What is the effectiveness of home food production in preventing stunting, wasting and underweight in children?
- What is the effectiveness of home food production in improving dietary diversity in children and generating income for families?

2.6 METHODOLOGY

A protocol was developed, registered with PROSPERO (PROSPERO registration number: CRD42019126455) and used to ensure methodological rigour (See Appendix 1 for the PROSPERO registration).

The PICO framework (Population, Intervention, Comparison, and Outcome) relates to the elements of the question asked by the review. PICO served as a guide in formulating the inclusion criteria and search strategy.

- Population – interventions aimed at women of childbearing age and outcomes assessed in their children.
- Intervention – home food production (training or support for home gardening with or without rearing of domestic animals).
- Comparison – No intervention or any other intervention
- Outcomes
  - Vitamin A status, xeropthalmia, night blindness, stunting, wasting, underweight, mortality, dietary diversity of children aged less than five years.
  - income from the sale of surplus produce, and
  - Cost of intervention.
- Methods - Randomised controlled trials, controlled clinical trials and quasi-experimental designs.
- Duration - at least one year.

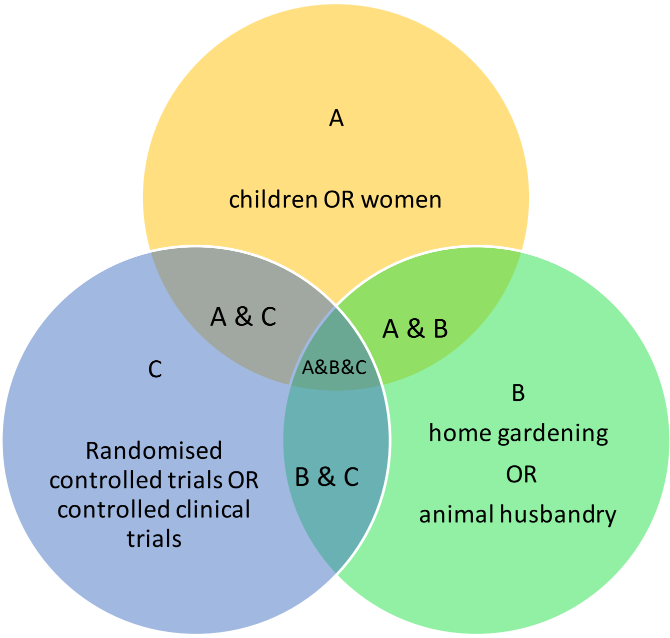
2.6.1 SOURCES OF DATA

Searches were developed for and conducted in Medline Ovid, Embase, Scopus, Cochrane Central Register of Controlled Trials and the World Health Organisation International Clinical Trial Registry Platform. Manual searching of reference lists of included papers and checking of reference list of previous systematic reviews (Girard et al., 2012; Masset et al., 2012) were carried out. Searches were conducted manually on Google Scholar to identify papers that were missed by the search of databases.

2.6.2 SEARCH STRATEGY

Medline Ovid, Embase Ovid, Scopus, CENTRAL and The World Health Organisation International Clinical Trial Registry Platform were searched from inception to the 1st of February 2019 using text words and index terms. The search strategy was organized into concepts using the PICO framework. The Boolean operators (AND, OR and NOT) were used to extend and narrow the search when necessary, and truncation was used to identify all how text words may appear (Lefebvre et al., 2019). Independent searches on population, intervention and study type were developed using the PICO as a guide. Afterwards, the independent searches were combined using Boolean operators. The final search is a subset of the three components ((children OR women) AND (home gardening OR animal husbandry) AND (randomised controlled trial OR controlled clinical trial)) (Figure 2.1). The Medline search was translated for each of the databases. The full search strategy for each database is shown in Appendices 2 – 6.

Figure 2.1: Venn diagram showing search strategy concept



2.6.3 INCLUSION CRITERIA

TYPES OF STUDIES

We included controlled clinical trials (studies that had control and an intervention arm) and randomized controlled trials. Included studies had an intervention duration of at least one year.

TYPES OF PARTICIPANTS

Women of childbearing age.

TYPES OF INTERVENTIONS

We considered home food production interventions, whether or not they explicitly aimed to improve the consumption of vitamin A-rich foods, using training in home food production, distribution of seedlings and/or behavioural interventions. The following interventions were included:

- Provision of seedlings and/or training in home gardening – provision of seedlings and training in the planting of vitamin A-rich foods on a piece of land attached to the home or near home primarily for household consumption.
- Training in and/or distribution of chicks for home rearing and consumption

Studies that explored home food production in combination with behavioural change interventions were considered. Studies that compared home food production to the non-intervention group were considered. However, studies without a comparator and before/after studies were excluded.

2.6.4 TYPES OF OUTCOMES

PRIMARY OUTCOMES

The following outcomes were assessed in children aged below 5 years.

- Night blindness
- Xeropthalmia
- All-cause mortality
- Stunting – measured as mean z-scores or risk ratio
- Wasting – measured as mean z-scores or risk ratio
- Underweight – measured as mean z-scores or risk ratio

Z scores, also known as standard scores, are numerical measurements that show the relationship of a value to the mean of a set of numerical values. They are measured in terms of standard deviations from the mean (WHO, 2006). According to the World Health Organisation, z scores are widely accepted as the appropriate method of measuring anthropometric data. Z scores are calculated thus: Z-score (or SD-score) = (observed value -

median value of the reference population) / standard deviation value of reference population (WHO, 2006).

Risk ratio, also known as relative risk, can be defined as “the ratio of the risk of an event occurring in two groups” (Deeks et al., 2019). It is calculated by dividing the cumulative incidence in the exposed group by the cumulative incidence in the unexposed group (Deeks et al., 2019)

SECONDARY OUTCOMES

- Income of the family
- Dietary diversity in children – using any food variety score.
- Serum retinol level in children - measured as mean z-score
- Cost of intervention

2.6.5 EXCLUSION CRITERIA

- Studies with a duration of less than a year
- Before/after studies and studies without a control
- Studies that didn’t measure at least one primary or secondary outcome of interest
- Studies that didn’t explore home food production
- Studies that assessed commercial farming or school farming
- Studies not published in the English language

2.6.6 SCREENING OF TITLES AND ABSTRACTS

Covidence, an online software designed to manage systematic review data was used in screening titles, abstracts, and full texts (Covidence, 2021). Two independent reviewers screened the titles and abstracts in duplicate. Screening of titles and abstracts as well as full texts was carried out using the inclusion and exclusion criteria

2.6.7 FULL-TEXT SCREENING

Full-text articles of titles and abstracts that were unclear or appeared potentially relevant were collected for a more complete assessment. A total of 115 papers were collected in full text for full-text screening by two independent reviewers in duplicate. Conflicts were settled through discussion.

2.6.8 DATA EXTRACTION

A data extraction form bespoke to the research questions of this review was developed, tested and used in data extraction (See Appendix 7 for the data extraction form used). Data were extracted by two independent reviewers in duplicate and conflicts were resolved by a third reviewer. The following data were retrieved for each included study:

- Study characteristics: study design, period of study, study location, sample size, number of study centres, study location, setting, mode of data collection, and bibliographic details of study reports.
- Characteristics of participants: total number of participants, socioeconomic status, mean age, age range.

- Interventions: type of intervention, duration, comparison, and any supporting behavioural intervention.
- Outcome variables: effect sizes and measure of uncertainty for primary and secondary outcomes.

2.6.9 RISK OF BIAS ASSESSMENT

The Cochrane risk of bias tool (Higgins et al., 2011) was used in assessing the risk of bias for all included studies in this review (Appendix 8). The studies were assessed for selection bias, performance bias, detection bias, attrition bias and reporting bias. The assessment of risk of bias was carried out in duplicate by two independent reviewers in Covidence, and differences were settled through discussion. Each study was assessed separately for risk of bias. Summary of risk of bias was assessed outcome by outcome based on the recommendations from Cochrane (Higgins et al., 2011). An outcome was judged to be at low risk of bias if the studies for that outcome are at low risk of bias for all domains. An outcome was judged to be at high risk of bias if the studies that reported that outcome were assessed as at a high risk of bias or unclear for at least one domain (Deeks et al., 2019).

2.6.10 DATA SYNTHESIS

This systematic review used both statistical synthesis and narrative synthesis. Meta-analysis is the statistical merging of results from two or more separate studies to obtain an absolute effect in a systematic review (Deeks et al., 2019). Meta-analysis was carried out simultaneously with narrative synthesis in this review as a meta-analysis gives the summary of findings in a review quantitatively and augments a narrative synthesis. Review Manager

5.3 (Cochrane Collaboration, 2014) software was used in this review and the random-effects model was chosen as it considers that the included studies have related intervention effects and are similar enough to pool but display slightly different true effect estimates (Deeks et al., 2019).

2.6.11 HETEROGENEITY ANALYSIS

This review considered clinical heterogeneity by carefully examining the population receiving the intervention, the population in which outcomes were measured, units of measurement and assessed whether the comparison and control groups differed significantly among included studies. This was to ensure that they were similar enough to be pooled (Deeks et al., 2019). In this review statistical heterogeneity was examined using the statistic for heterogeneity automatically generated by Review Manager in meta-analysis. The I^2 statistic was used as it quantifies the extent of heterogeneity between studies. The I^2 statistic is on a scale of 0% to 100% and the higher the value, the higher the level of heterogeneity I^2 0% to 40% represents unimportant heterogeneity. I^2 30% to 60% represents moderate heterogeneity while I^2 75% to 100% represents high heterogeneity (Deeks et al., 2019)

2.6.12 SENSITIVITY ANALYSIS

Sensitivity analyses were run to assess whether making different assumptions would alter the results of the meta-analysis. Sensitivity analyses undertook meta-analysis using the fixed-effect model to understand how the findings would differ from the main analysis which used the random-effects model (Deeks et al., 2019).

2.6.13 SUBGROUP ANALYSIS

Data were grouped according to their statistical analysis – unadjusted data, data adjusted for clustering, data adjusted for clustering and other factors. This review reported data adjusted for clustering and other factors as its main results because possible confounding factors that can impact the results have been adjusted for in the analysis. The following subgroups were analysed, to address the sub-questions of the review:

- Planting of fruits, vegetables and rearing of chickens versus only planting of fruits and vegetables.
- Duration of assessment of 12 ≤ 24 months versus > 24 months from the beginning of the intervention.
- Studies conducted in Africa versus studies conducted in Asia.

Undertaking subgroup analysis in this review allowed me to assess whether effective home food production depended on continent, duration of intervention or type of intervention.

2.6.14 ASSESSING QUALITY OF EVIDENCE ACROSS STUDIES

The quality and certainty of the findings in this review were assessed and reported using the GRADE approach (Grading of Recommendations, Assessment, Development and Evaluation) on GRADEpro GDT software. When assessing the GRADE certainty of findings, I assessed the following for each primary outcome (Gradepro, 2021; Guyatt et al., 2008).

- Risk of bias: methodological validity of included studies for that outcome. The Cochrane recommendations for reaching an overall risk-of-bias judgment for outcomes was used as stated in the section of risk of bias assessment (Section 2.6.9).

- Inconsistency: disparity in effects sizes across studies (level of heterogeneity in meta-analysis, an I^2 above 60% was considered as serious and above 75% was considered very serious).
- Indirectness: difference in population, intervention and outcome in the included studies
- Imprecision: imprecision is determined by the 95% confidence interval of the effect estimate. (Confidence interval of included studies in meta-analysis).

Each feature above was judged as ‘not serious’, ‘serious’, or ‘very serious’. As evidence was based on Randomised controlled trials, the quality of evidence started at “high” and was downgraded as follows: any judgement of ‘serious’ risk downgraded the quality of the outcome. The quality of evidence for each outcome was rated through the GRADE process as high (no downgrades - ⊕⊕⊕⊕), moderate (one downgrade - ⊕⊕⊕ ◯), low (two downgrades - ⊕⊕⊕ ◯◯) or very low (three or more downgrades - ◯◯◯⊕).

2.7 RESULTS

In total, 7021 titles and abstracts were retrieved and uploaded to Covidence, 1623 papers were eliminated as duplicates, and 5398 titles and abstracts were screened using the inclusion and exclusion criteria. Titles and abstracts were screened separately and in duplicate by two reviewers - Chizoba Esio-Bassey and Harriet Crooks. After the titles and abstracts were screened by the two reviewers, conflicts were resolved through discussion and 115 papers were collected in full text for full-text screening. The full-text papers were retrieved and uploaded to Covidence for full-text assessment done independently and in duplicate. At the end of the screening process, 92 papers were eliminated. Twenty-three papers were found eligible for data extraction. Of these 23, seven papers were merged into studies, so that 16 studies were included in this systematic review (Figure 2.2, the PRISMA flowchart). Seven further studies were found eligible but are still ongoing.

The on-going studies were conducted in Bangladesh (n = 1), Kenya (n = 4), Tanzania (n = 1), Ethiopia (n = 1), and Nepal (n = 1). They will be used in updating this systematic review in future (See Table 2.1 for a list of the on-going studies).

Table 2.1: Eligible On-going studies

Title	**Primary Investigator**	**Type of Intervention**	**Year of Completion**
Food and Agricultural Approaches to Reducing Malnutrition (FAARM). NCT02505711	Sabine Gabrysch Collaborators: • Helen Keller International • BRAC University • University of Giessen	Reducing young child undernutrition through an integrated agricultural project with women's groups	December 2019.

	• German Federal Ministry of Education and Research • Department for International Development, UK		
Multi-Sectoral Agricultural Intervention to Improve Nutrition, Health, And Developmental Outcomes Of HIV-Infected Children in Western Kenya NCT03170986	Lisa Butler, University of Connecticut	Multi-sectoral agriculture and microfinance Intervention	March 2021
Homestead Agriculture and Nutrition Project in Rufiji District, Tanzania. NCT03311698	Fawzi, Harvard School of Public Health	Nutrition-sensitive intervention using behaviour change communication on home gardening, diet, nutrition, WASH, and women's empowerment.	December 2019
Evaluation of Orange Fleshed Sweet Potato Promotion and The Healthy Baby Toolkit in Southern Ethiopia: A Cluster Randomized Controlled Trial. NCT03423472	Amy Webb Girard, Emory University	Improve diet quality, primarily of women and young children, through the promotion of vitamin A-rich orange flesh sweet potato (OFSP) production and nutrition education	November 2019
Effectiveness of An Integrated Programme to Reduce Maternal and Child	Fabian Rohner	Integrated programme by introducing nutrition-sensitive (improved water,	July 2020

Malnutrition in Kenya: Cluster-randomized, Parallel-group, Prospective, Follow-up Effectiveness Study in Children 6-35 Months of Age. NCT03448484		sanitation and hygiene (WASH): e.g. soap or handwashing) and nutrition-specific (e.g micronutrient supplements) components	
Community Development and Nutrition Education in Banke District, Nepal: Effect on Child Health and Growth. NCT03516396	Laurie Miller, Md, Tufts University	Training plus enhanced community development activities	December 2020.
Effectiveness Of An Integrated Programme to Reduce Maternal and Child Malnutrition in Kenya: Cluster randomized Controlled Trial in Pregnant Women and Their Offspring. NCT03558464	Fabian Rohner	Comparing an agricultural intervention alone to a combined agricultural, nutrition and wash intervention	April 2021.

Figure 2.2: PRISMA Flow Diagram

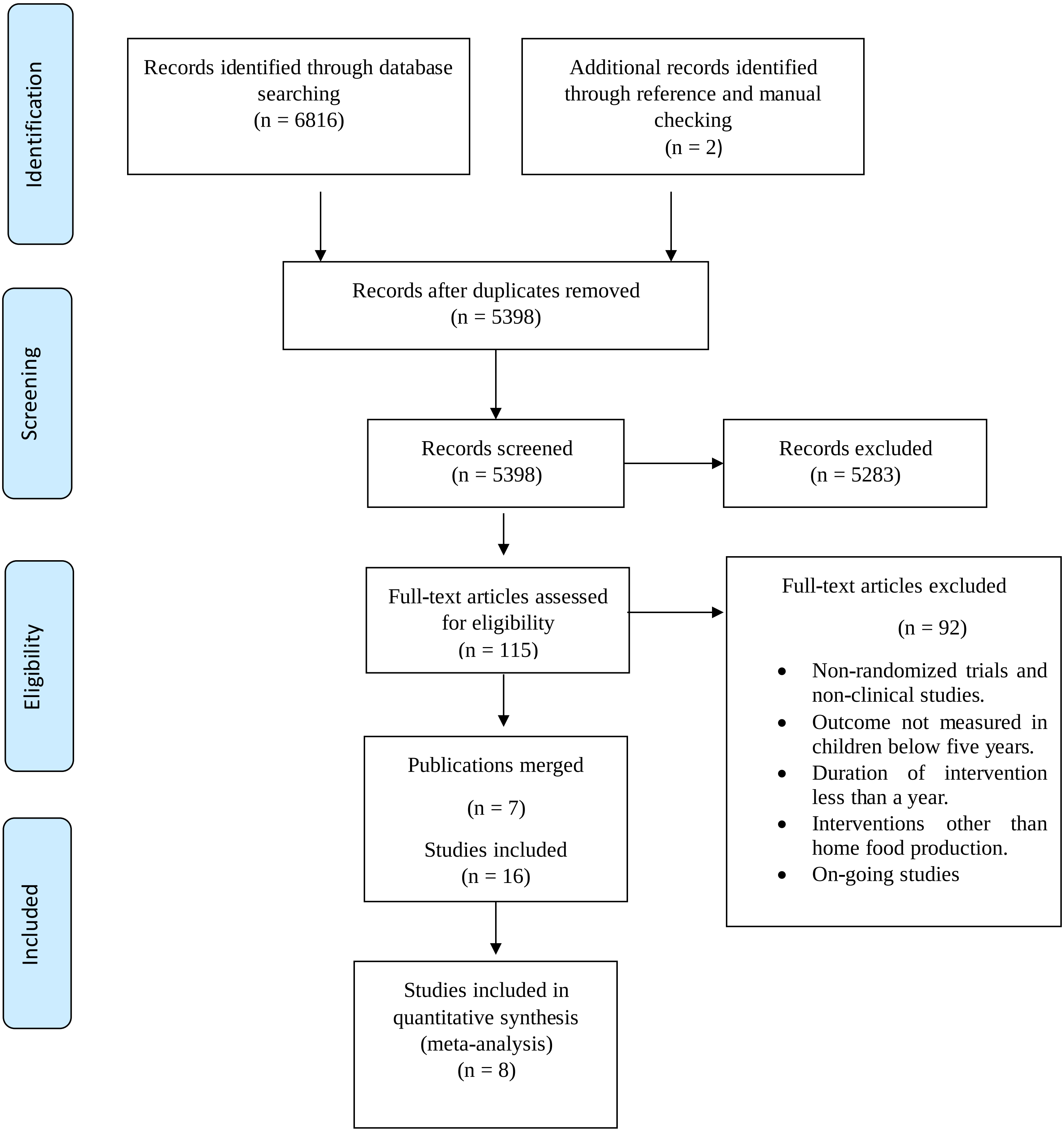


Table 2.2: characteristics of included studies

Study	Country	Period of study	Setting	Study design	No of clusters	Unit of randomisation		Age of children	Age of women	Type of intervention
Faber 2002 (Faber, Phungula, et al., 2002)	South Africa	2 years	Rural	Controlled clinical trial	2 villages	2 villages, 1 for control and 1 for intervention		2 – 5 years	NR	Training in home gardens and nutrition education. The control arm received no intervention.
Gelli 2018 (Gelli et al., 2018)	Malawi	1 year	Rural	Cluster randomised controlled trial	20	60 communities, 20 clusters		6 – 72 months	>14	Training in agricultural practices and distribution of chicks and seedlings. Loans granted to households, cooking sessions, nutrition education. The Control group was

										exposed to child nutrition education
Hotz 2012 Mozambique (Hotz et al., 2012a)	Mozambique	3 years	Rural	Cluster randomised controlled trial	72 clusters	36 clusters across 3 districts each for intervention and control arm		6 – 35 months	Mean age 28.9	Distribution of orange sweet potato vines and nutrition education, demand creation. Control was exposed to no intervention
Hotz 2012 Uganda (Hotz et al., 2012b)	Uganda	2 years	Rural	Cluster randomised controlled trial	84	84 clusters, 3 districts		6 – 35 months. 3 – 5 years	Mean age of 34.0	Distribution of orange sweet potato vines and nutrition education, demand creation. The Control group had no intervention
Khamhoung 2000	LAO	2 years	Rural	Controlled clinical trial				Preschool children	15 – 45 years	Training on setting up home gardens and animal rearing. The

(Khamhoung et al., 2000)										Control group received no intervention
Kidala 2000 (Kidala et al., 2000)	Tanzania	2 years	Rural	Quasi-experimental	5 villages	5 villages each for control and intervention and 125 households each for intervention and control arm		6 – 71 months	NR	Training and distribution of seedlings, nutrition education, cooking sessions. The control arm received no intervention
Kuchenbecker 2017 (Kuchenbecker et al., 2017)	Malawi	3 years	Rural	Cluster randomised controlled trial	24 clusters	12 clusters each for intervention and control		6 – 23 months	Mean age 27.2	Distribution of farming items, livestock and training in farming. Nutrition education and cooking sessions. The control arm received only agricultural practices

										with no nutrition education
Lakzadeh 2016 (Lakzadeh, 2016)	Cambodia	22 months	Rural	Cluster randomised controlled trial	60 clusters	900 households		<5 years	NR	Training and distribution of seedlings for home gardening. Creation of fishponds. 3 arms – HFP plus fishpond, HFP and control with no intervention
Low 2007 (Low et al., 2007)	Mozambique	2 years	Rural	Quasi-experimental	3 districts	827 households in 3 districts		< 39 months	NR	Training and distribution of orange sweet potato vines, demand creation, nutrition education. The Control group was not exposed to the interventions

Marquis 2017 (Atuobi-Yeboah et al., 2016; Marquis et al., 2017)	Ghana	1 year	Rural	Cluster randomised controlled trial	16 clusters	3 districts		0 – 32 months	NR	Training, distribution of seedlings, chicks and orange sweet potato vines, cooking sessions, nutrition education. The Control group received no intervention
Olney 2009 (Olney et al., 2009)	Cambodia	19 months	Rural	Randomised controlled trial	NR	300 households for intervention and 200 households for control arm		>5 years	NR	Training and distribution of seedlings and chicks, nutrition education. The control arm received no intervention
Olney 2015	Burkina Faso	2 years	Rural	Cluster randomised	NR	55 villages, 25 for control and 30 villages for		3 – 12.9 months	NR	Training in home garden, distributions of seedlings and chicks, nutrition

(Olney et al., 2013; Olney et al., 2015)				controlled trial		intervention group				education. The control arm received no intervention. Nutrition education was carried out by two groups of women – the health committee and the older women group.
Osei 2015 (Osei et al., 2017; Osei et al., 2015; Pries et al., 2013)	Nepal	4 years	Rural	Cluster randomised controlled trial	63	12 sub-districts or Ilakas		0 – 23 months	NR	Training in home gardening, and poultry. Nutrition education. Three arms were used- HFP, HFP plus micronutrient powder and the control group that received no intervention.

Raneri 2017 (Raneri et al., 2017)	Vietnam	1 year	Rural	Cluster randomised controlled trial	NR	NR		12 – 24 months	NR	Training in home garden, nutrition education and cooking demonstrations. The Control group had no intervention.
Reinbott 2016 (Reinbott et al., 2018; Reinbott et al., 2016)	Cambodia	2 years	Rural	Cluster randomised controlled trial	NR	10 communes for intervention and 5 communes for control		0 – 23 months	NR	Training in home gardening, nutrition education and giving out vouchers. The control arm received agricultural practices with no nutrition education
Schreinemacher 2016 (Schreinemachers et al., 2016)	Bangladesh	3 years	Rural	Quasi experimental	NR	408 participants in the intervention arm and 238		Entire household	NR	Training in home gardening, distribution of seedlings and orange sweet potato vines. The control arm

						participants in the control arm				received no intervention

HFP – Home food production

2.7.1 CHARACTERISTICS OF INCLUDED STUDIES

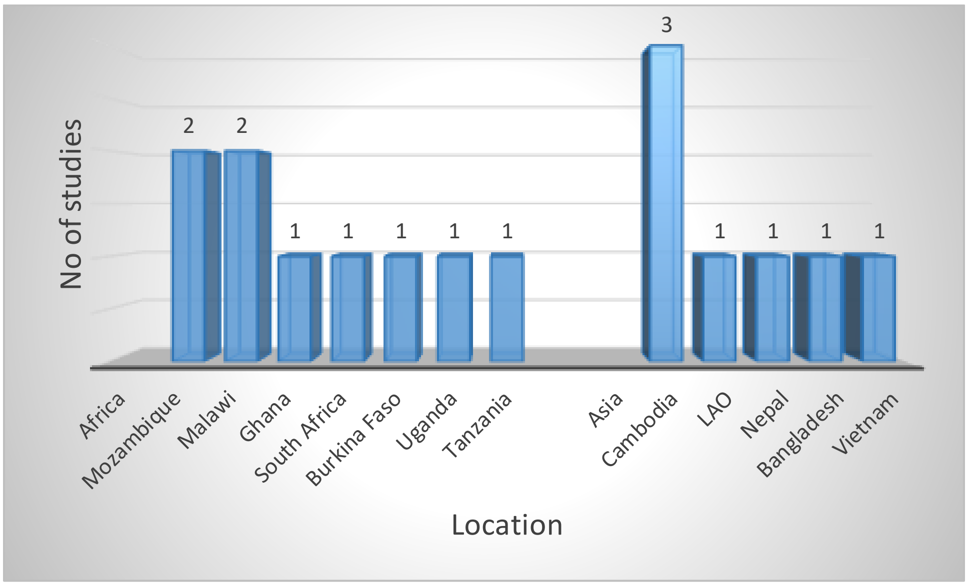
The characteristics of the included studies are briefly described in Table 2.2

2.7.1.1 STUDY LOCATION

All the included studies in this review were conducted in LMICs, in Africa and Asia. Nine studies were conducted in Africa - two in Mozambique (Hotz et al., 2012a; Low et al., 2007), two in Malawi (Gelli et al., 2018; Kuchenbecker et al., 2017), one in Burkina Faso (Olney et al., 2015), one in South Africa (Faber et al., 2002), one in Uganda (Hotz et al., 2012b) and one in Tanzania (Kidala et al., 2000) Seven studies were conducted in Asia - three in Cambodia (Lakzadeh, 2016; Olney et al., 2009; Reinbott et al., 2016), one each in Laos (Khamhoung et al., 2000), Bangladesh (Schreinemachers et al., 2016), Nepal (Osei et al., 2015) and Vietnam (Raneri et al., 2017). All the studies were conducted in rural settings (See Figure 2.3).

Some studies grouped participants by district (Low et al., 2007; Osei et al., 2015) or community (Gelli et al., 2018; Marquis et al., 2017; Raneri et al., 2017; Reinbott et al., 2016) while some studies grouped participants by village (Faber, et al., 2002; Hotz, et al., 2012a; Khamhoung et al., 2000; Kidala et al., 2000; Lakzadeh, 2016; Olney et al., 2015; Schreinemachers et al., 2016). Studies included from 10 (Gelli et al., 2018) to 84 clusters (Hotz et al., 2012), three (Low et al., 2007) to 12 districts (Osei et al., 2015), four (Raneri et al., 2017) to 60 communities (Gelli et al., 2018) and two (Faber et al., 2002) to 144 villages (Hotz et al., 2012b).

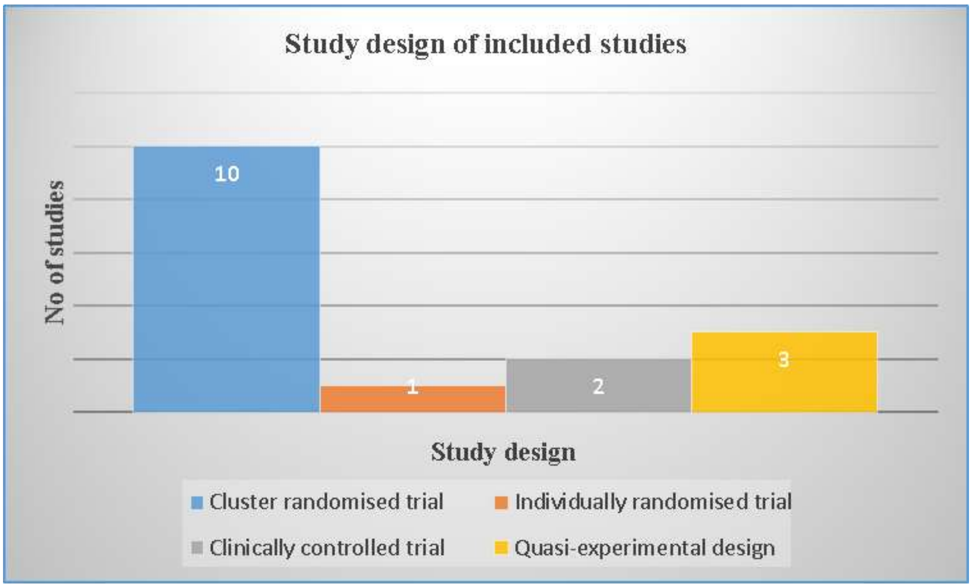
Figure 2.3: location of included studies



2.7.1.2 STUDY DESIGN

The studies included were cluster randomised trials, an individually randomised controlled trial, quasi-experimental designs and controlled clinical trials (see Figure 2.4). Ten studies (Gelli et al., 2018; Hotz et al., 2012a; Hotz et al., 2012b; Kuchenbecker et al., 2017; Lakzadeh, 2016; Marquis et al., 2018; Osei et al., 2015; Raneri et al., 2017; Reinbott et al., 2016; Olney et al., 2015) were cluster randomised controlled trials, one study (Olney et al., 2009) was an individually randomised controlled trial. Three studies (Kidala et al., 2000; Low et al., 2007; Schreinemachers et al., 2016) used a quasi-experimental design. Low et al. (2007) used a controlled and longitudinal trial. Two studies (Faber et al., 2002; Khamhoung et al., 2000) were controlled clinical trials.

Figure 2.4: study designs of included studies



2.7.1.2 DURATION OF STUDY

The duration (exposure to intervention) of included studies ranged from 12 months to ≤ 24 months (Faber et al., 2002; Gelli & Roschnik, 2017; Hotz et al., 2012b; Khamhoung et al., 2000; Kidala et al., 2000; Low et al., 2007; Marquis et al., 2017; Olney et al., 2009, 2015; Raneri et al., 2017; Reinbott et al., 2016) to > 24 months (Hotz et al., 2012a; Kuchenbecker et al., 2017; Lakzadeh, 2016; Osei et al., 2015; Schreinemachers et al., 2016). Osei et al. (2015) had the longest duration of 4 years.

2.7.1.3 TYPES OF INTERVENTION

All studies trained women using demonstration gardens in agricultural practices such as seedbed preparation, compost preparation and use, fencing, insect and pest control, and/or vine conservation (preserving vines for the next planting season). Low et al. (2007), Hotz et al. (2012a) and Hotz et al. (2012b) provided support in selling orange sweet potato. Twelve studies (Gelli et al., 2018; Hotz et al., 2012a; Hotz et al., 2012b; Kidala et al., 2000; Kuchenbecker et al., 2017; Lakzadeh, 2016; Low et al., 2007; Olney et al., 2009, 2015; Osei et al., 2015; Schreinemachers et al., 2016; Olney et al., 2015) trained women using demonstration gardens and also distributed seedlings and vines. Five studies (Gelli et al., 2018; Kuchenbecker et al., 2017; Marquis et al., 2017; Olney et al., 2015; Osei et al., 2015) distributed chicks in addition to seedlings. Lakzadeh (2016) included a fish pond in the home gardens. Khamhoung et al. (2000) and Faber et al. (2002) only trained women without distribution of seedlings or chicks. Five trials (Gelli et al., 2018; Kidala et al., 2000; Kuchenbecker et al., 2017; Marquis et al., 2017; Raneri et al., 2017) included cooking demonstrations as part of the training. Olney et al. (2015) used two groups of women to deliver nutrition education - Health Committee (HCO – female health personnel from the local health centre and the Older Women Leaders (OWL - elderly women in the community) and the effects of both groups were tested. Hotz et al. (2012a) and Hotz et al. (2012b) had two models of interventions – model one had training in nutrition and agricultural practice for only one year while model two had training in nutrition and agricultural practices for three years (Table 2.3).

Table 2.3: Types of intervention in included studies

Study	Training using demonstration gardens	Distribution of seedlings	Distribution of chicks	Cooking demonstration	Fishpond	Loan and voucher	Support for selling surplus produce
Faber 2002 (Faber et al., 2002)	√						
Gelli 2018 (Gelli et al., 2018)	√	√	√	√		√ Loan	
Hotz 2012 Mozambique (Hotz et al., 2012a)	√	√					√
Hotz 2012 Uganda (Hotz et al., 2012b)	√	√					√
Khamhoung 2000 (Khamhoung et al., 2000)	√						
Kidala 2000 (Kidala et al., 2000)	√	√		√			
Kuchenbecker 2017 (Kuchenbecker et al., 2017)	√	√	√	√			
Lakzadeh 2017 (Lakzadeh, 2016; Talukder et al.,	√	√			√		

2017; Verbowski et al., 2018)							
Low 2007 (Low et al., 2007)	✓	✓					✓
Marquis 2017 (Atuobi-Yeboah et al., 2016; Marquis et al., 2017)	✓	✓	✓	✓			
Olney 2009 (Olney et al., 2009)	✓	✓					
Olney 2015 (Olney et al., 2013; Olney et al., 2015)	✓	✓	✓				
Osei 2015 (Osei et al., 2017; Osei et al., 2015; Pries et al., 2013)	✓	✓	✓				
Raneri 2017 (Raneri et al., 2017)	✓			✓			
Reinbott 2016 (Reinbott et al., 2016)	✓					✓ Voucher	
Schreinemacher 2016 (Schreinemachers et al., 2016)	✓	✓					

2.7.2 RISK OF BIAS ASSESSMENT

Risk of bias as assessed for each outcome is displayed in figures 2.5 and 2.6.

Figure 2.5: Risk of bias graph

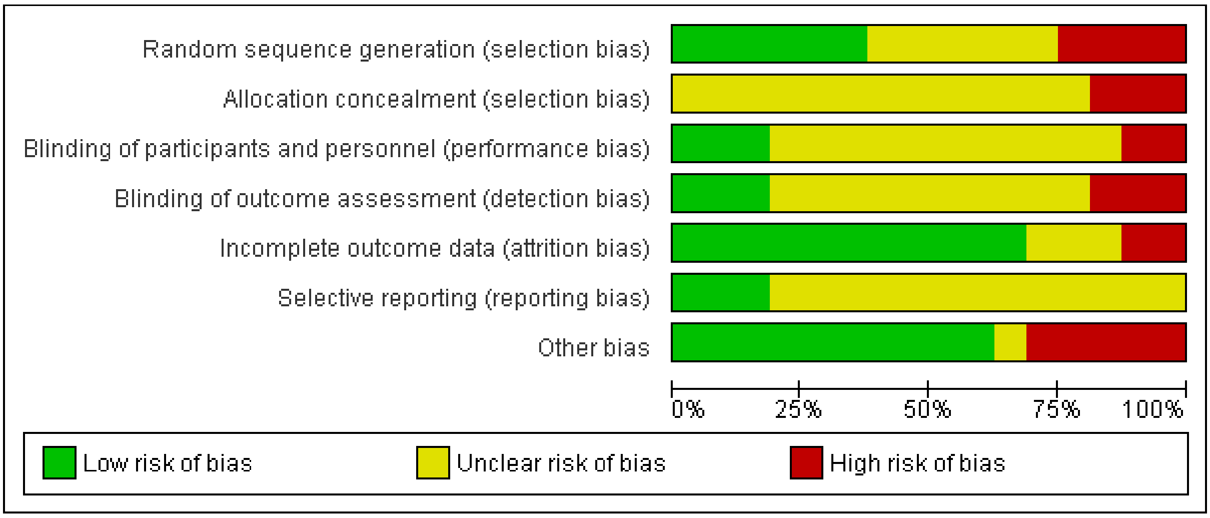
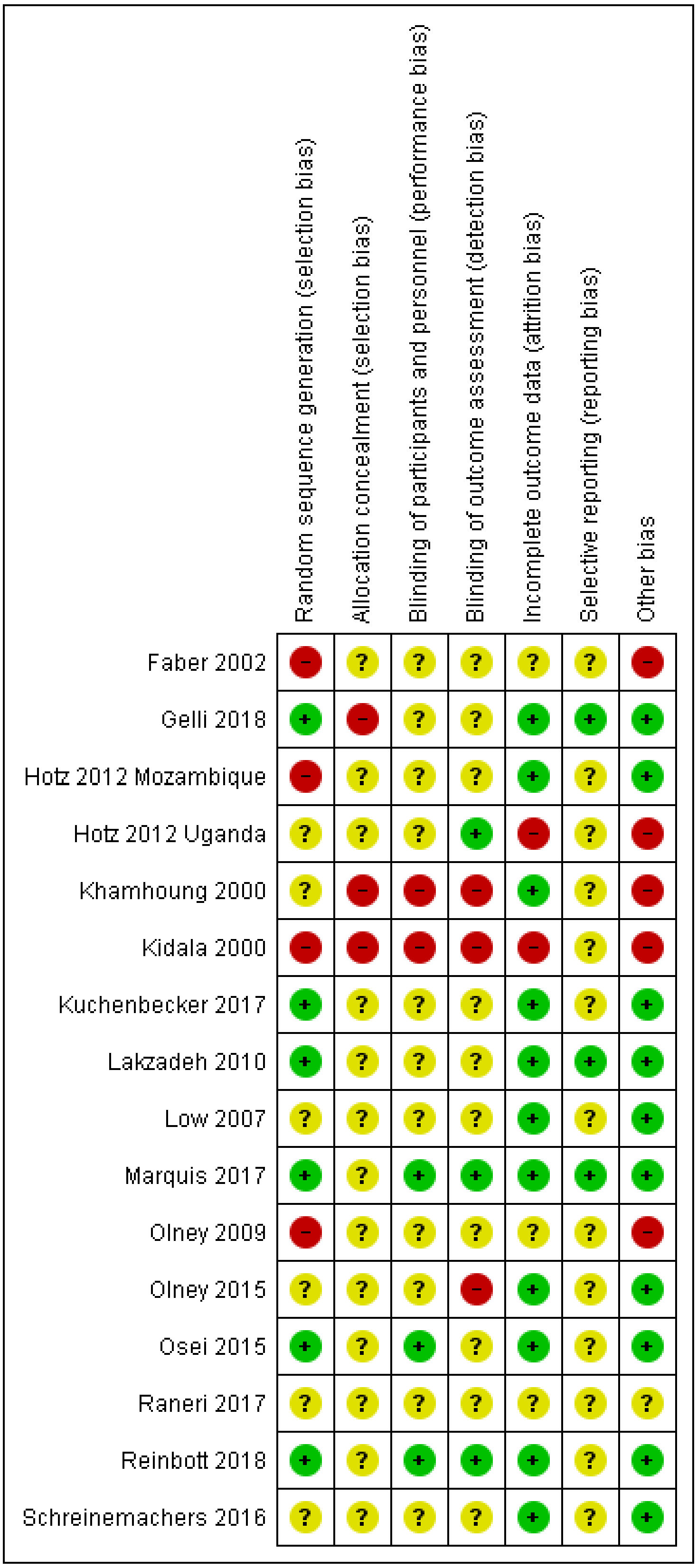


Figure 2.6: Risk of bias summary



- represents a high risk of bias, ? represents an unclear risk of bias, + represents a low risk of bias

2.7.2.1 RANDOM SEQUENCE GENERATION (SELECTION BIAS)

Six studies described how randomization was carried out, through the use of software like R and use of random numbers (Gelli et al., 2018; Kuchenbecker et al., 2017; Marquis et al., 2017; Osei et al., 2015; Reinbott et al., 2018), these were, therefore, judged to be at low risk of bias for random sequence generation. Six studies (Hotz et al., 2012a; Khamhoung et al., 2000; Low et al., 2007; Olney et al., 2015; Raneri et al., 2017; Schreinemachers et al., 2016) mentioned that randomization was carried out but did not describe exactly how. These were judged to be unclear. Four studies (Faber et al., 2002; Hotz et al., 2012b; Kidala et al., 2000; Olney et al., 2009) did not randomise and were considered to be at high risk of bias for this domain.

2.7.2.2 ALLOCATION CONCEALMENT (SELECTION BIAS)

Thirteen studies did not provide information on whether or how allocation concealment was carried out, so were considered to be at unclear risk of bias for allocation concealment. Three studies (Gelli et al., 2018; Khamhoung et al., 2000; Kidala et al., 2000) did not carry out allocation concealment and were judged to be at high risk of bias

2.7.2.3 BLINDING OF PARTICIPANTS AND PERSONNEL (PERFORMANCE BIAS)

Eleven studies (Faber et al., 2002; Gelli et al., 2018; Hotz et al., 2012a; Hotz et al., 2012b; Kuchenbecker et al., 2017; Lakzadeh, 2016; Low et al., 2007; Olney et al., 2009, 2015; Raneri et al., 2017; Schreinemachers et al., 2016) did not give sufficient information on any blinding of participants and personnel. These studies were judged as having an unclear risk of performance bias. Three studies (Marquis et al., 2017; Osei et al., 2015; Reinbott et al., 2018) were judged to be at low risk of performance bias as they described an adequate method of blinding participants and personnel. These studies used different personnel for the intervention and survey data collection, participants were convened at a central meeting point for data collection and clusters that were geographically distant were used. Two studies (Khamhoung et al., 2000; Kidala et al., 2000) were judged to be at high risk of bias for this domain.

2.7.2.4 BLINDING OF OUTCOME ASSESSMENT (DETECTION BIAS)

Ten studies (Faber et al., 2002; Gelli et al., 2018; Hotz et al., 2012a; Kuchenbecker et al., 2017; Lakzadeh, 2016; Low et al., 2007; Olney et al., 2009; Osei et al., 2015; Raneri et al., 2017; Schreinemachers et al., 2016) did not provide sufficient information on the blinding of outcome assessment, so were judged unclear for detection bias. Three studies (Hotz et al., 2012b; Marquis et al., 2017; Reinbott et al., 2018) were considered to be at low risk of bias while three studies (Khamhoung et al., 2000; Kidala et al., 2000; Kuchenbecker et al., 2017; Olney et al., 2015) were judged to be at high risk of detection bias.

2.7.2.5 INCOMPLETE OUTCOME DATA (ATTRITION BIAS)

Eleven studies (Gelli et al., 2018; Hotz et al., 2012a; Khamhoung et al., 2000; Kuchenbecker et al., 2017; Lakzadeh, 2016; Low et al., 2007; Marquis et al., 2018; Olney et al., 2015; Osei et al., 2015; Reinbott et al., 2018; Schreinemachers et al., 2016) were judged to be at low risk of attrition bias as these studies reported amount and reasons for attrition and there was negligible difference in attrition rates between the treatment and control groups. Two studies (Faber et al., 2002; Olney et al., 2009) provided insufficient information for this domain and were considered to be at unclear risk of attrition bias. Two studies (Hotz et al., 2012b; Kidala et al., 2000)were judged to be at high risk for this domain.

2.7.2.6 SELECTIVE REPORTING (REPORTING BIAS)

No protocol or trials registry entry could be found for thirteen studies, so these studies were therefore judged to be at unclear risk of attrition bias. Three studies (Gelli et al., 2018; Lakzadeh, 2016; Marquis et al., 2017) were judged to be at low risk of attrition bias as their protocols were retrieved and all outcomes planned in the protocol were reported in publications.

2.7.2.7 OTHER SOURCES OF BIAS

Eight studies (Gelli et al., 2018; Hotz et al., 2012a; Kuchenbecker et al., 2017; Lakzadeh, 2016; Low et al., 2007; Marquis et al., 2017; Olney et al., 2015; Osei et al., 2015) were judged to have no other sources of bias. Raneri et al. (2017) was considered to be at unclear risk of additional bias as only a conference abstract was available. Five studies (Faber et al., 2002; Hotz et al., 2012b; Khamhoung et al., 2000; Kidala et al., 2000; Olney et al., 2009) were considered to be at high risk for other sources of bias. Faber et al. (2002) conducted a follow-up assessment when orange-fleshed sweet potato and butternut squash were out of season. This may have affected the results of the study. There were other interventions in place such as vitamin A supplementation and food fortification at the same time Hotz et al. (2012b) carried out their study in Uganda. This might have impacted their results. Khamhoung et al. (2000) had large differences in baseline data between control and intervention arms as did

Olney et al. (2009). No baseline data were presented for the study carried out by Kidala, Greiner and Gebre-Medhin (2000).

2.7.3 PRIMARY OUTCOMES

The results of this systematic review are reported based on the outcomes stated in the methods section and review registration. Eight studies were included in the meta-analysis, eight studies could not be combined in meta-analysis and reported income, cost of intervention and dietary diversity. Results are shown study by study in table 2.4.

2.7.3.1 EFFECT OF HOME FOOD PRODUCTION ON XEROPTHALMIA IN CHILDREN LESS THAN FIVE YEARS OLD

This review found no evidence on xeropthalmia in any included studies.

2.7.3.2 EFFECT OF HOME FOOD PRODUCTION ON NIGHT BLINDNESS IN CHILDREN LESS THAN FIVE YEARS OF AGE

There was no evidence on night blindness from included studies.

2.7.3.3 EFFECT OF HOME FOOD PRODUCTION ON MORTALITY IN CHILDREN LESS THAN FIVE YEARS OF AGE

There was no evidence on mortality found in this review.

2.7.3.4 EFFECT OF HOME FOOD PRODUCTION ON STUNTING (HEIGHT-FOR-AGE) IN CHILDREN LESS THAN FIVE YEARS OF AGE

A total of eight studies (Gelli et al., 2018; Khamhoung et al., 2000; Kuchenbecker et al., 2017; Marquis et al., 2017; Olney et al., 2009, 2015; Osei et al., 2015; Reinbott et al., 2016) reported on stunting and were all included in the meta-analysis. Gelli et al., (2018) collected data by grouping children into 6 – 24 months and 36 – 72 months of age and results were reported separately for them. Home food production increased height-for-age in children compared to control arm in the highest quality data - adjusted for clustering and other factors (Mean difference MD 0.13 (z score), 95% CI 0.01 to 0.24, six studies, 5469 participants, I^2 = 84%, low-certainty evidence, Figure 2.7). The evidence was assessed as low-certainty, downgraded once each for risk of bias and inconsistency (Table 2.4a). Data adjusted for clustering showed an improvement in height-for-age in children (MD 0.24 (z score), 95% CI 0.00 to 0.48, I^2 41%) while unadjusted data showed no difference between intervention and control arm (MD 0.03 (z score), 95% CI -0.05 to 0.12, I^2 0%).

HETEROGENEITY

The highest quality of data showed high heterogeneity (I^2 84%), moderate (data adjusted for clustering I^2 41%) to no heterogeneity (unadjusted data I^2 0%) was detected in other subgroups of data.

SUBGROUP ANALYSIS

The studies were sub-grouped by continent, duration of intervention and type of intervention (Appendix 9). Effect sizes did not differ by duration (P = 0.63) or continent (P = 0.77). In the subgroup of type of interventions, a positive effect (difference in p-value between subgroups P =0.02) was seen in studies that combined home gardening and poultry (MD 0.17 (z score), 95% CI -0.03 to 0.32, I^2 86%) while a smaller effect (MD 0.06 (z score), 95% CI -0.20 to 0.80, I^2 NA) was seen in studies that practised only home gardening.

SENSITIVITY ANALYSIS

The fixed-effects model was the sensitivity analysis. The results of the fixed effect model differed from the random-effects model (data adjusted for clustering and other factors - MD 0.00 (z score), 95% CI -0.01 to 0.01, I^2 84%). This means that if we assume that all the included studies have an identical true effect size, home food production would not affect height-to-age in children (Borenstein et al., 2011).

Figure 2.7: Effects of home food production on stunting in children (z-score): Meta-analysis assessing mean difference using the random-effects model

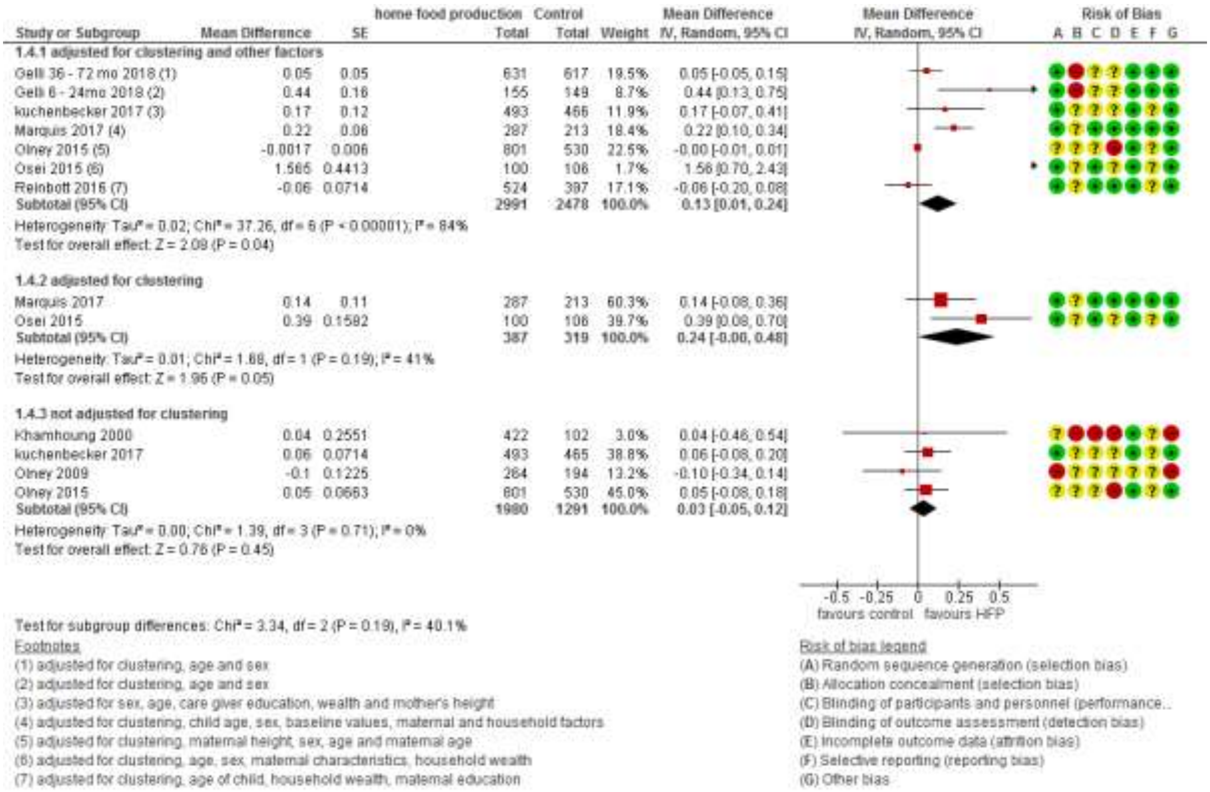


Table 2.4A: Table showing major results for primary outcomes in this review

Study	**Primary outcomes, in children ≤ 5 years**					
	Xer-opthalmia	**Night Blind-ness**	**All-cause Mortality**	**Stunting (z-score)**	**Wasting (z-score)**	**Underweight (z-score)**
Faber 2002 (Faber et al., 2002)	NR	NR	NR	NR	NR	NR
Gelli 2018 (Gelli et al., 2018)	NR	NR	NR	(DID impact/SE) 36 – 72 months old: 0.05 ± 0.05 6 – 24 month old: 0.44 ± 0.16	(DID impact/SE) 36 – 72 month old: -0.04 ± 0.07 6 – 24 month old: -0.13 ± 0.15	(DID impact/SE) 36 – 72 month old: 0.05 ± 0.05 6 – 24 month old: -0.02 ± 0.14
Hotz 2012 Mozambique (Hotz et al., 2012a)	NR	NR	NR	NR	NR	NR
Hotz 2012 Uganda (Hotz et al., 2012b)	NR	NR	NR	NR	NR	NR
Khamhoung 2000	NR	NR	NR	(Median, 95% CI) HFP -1.92 (- 2.1 to 1.87), (50.2% of stunted children). Control -1.92	(Median, 95% CI). HFP -0.50	(Median, 95% CI). HFP – 1.45

(Khamhoung et al., 2000)				(-2.52 to -1.53), (47.1% of stunted children).	(-0.59 to -0.44), (3.2% of wasted children). Control -0.57 (-0.77 to -0.46), (4.9% of wasted children)	(-2.1 to -1.89) (27.6% of underweight children). Control -1.56 (1.77 to 1.41), (33.3% of underweight children).
Kidala 2000 (Kidala et al., 2000)	NR	NR	NR	NR	NR	NR
Kuchenbecker 2017 (Kuchenbecker et al., 2017)	NR	NR	NR	(mean reduction/SD). HFP -1.79 ± 1.15. Control – 1.85 ± 1.10.	(mean reduction/SD). HFP 0.32 ± 1.00. Control 0.27 ± 0.96.	(mean reduction/SD). HFP -0.69 ± 1.07. Control -0.76 ± 1.05.
Lakzadeh 2016 (Lakzadeh, 2016)	NR	NR	NR	NR	NR	NR
Low 2007 (Low et al., 2007)	NR	NR	NR	NR	NR	NR
Marquis 2017 (Atuobi-Yeboah et al., 2016; Marquis et al., 2017; Marquis et al., 2018)	NR	NR	NR	(beta-coefficient/SE) Impact 0.22 ± 0.06 95% CI 0.09 to 0.34	(beta-coefficient/SE) Impact 0.07 ± 0.08	(beta-coefficient/SE) Impact 0.15 ± 0.07 95% CI 0.00 to 0.30
Olney 2009 ((Olney et al., 2009)	NR	NR	NR	(mean reduction/SD) HFP -1.7 ± 1.3, 40.5%. Control -1.6 ± 1.3, 42.3%	(mean reduction/SD) HFP -1.0 ± 1.0, 14.8%. Control -0.9 ± 1.0, 11.4%	(mean reduction/SD) HFP -1.6 ± 1.1, 36.1%. Control -1.6 ± 1.0, 34.4%

Olney 2015 (Olney et al., 2015)	NR	NR	NR	(mean/SD) HFP -0.07 ± 0.17 (OWL). -0.07 ± 0.14 (HC).	(mean/SD) HFP 0.02 ± 0.19 (OWL). 0.17 ± 0.15 (HC).	(mean/SD) HFP -0.05±0.14 (OWL). Control -0.16 ±0.12 (HC).
Osei 2015 (Osei et al., 2015)	NR	NR	NR	(mean/SE) HFP -2.01 ± 0.10 (48%). Control -2.40 ±0.12 (55.7%)	(mean/SE) HFP -0.71 ± 0.11(11.9%). Control -0.80± 0.10 (13.2%)	(mean/SE) HFP -1.57 ± 0.09 (32%). Control 1.84 ± 0.11 (39.6%)
Raneri 2017 (Raneri et al., 2017)	NR	NR	NR	NR	NR	NR
Reinbott 2016 (Reinbott et al., 2016)	NR	NR	NR	(mean/SD) HFP -1.27 ± 1.09. Control -1.33 ± 1.09	(mean/SD) HFP -0.63 ± 0.98. Control -0.63 ± 0.99	(mean/SD) HFP -1.13 ± 0.97. Control -1.15 ±0.99
Schreinemachers 2016 (Schreinemachers et al., 2016)	NR	NR	NR	NR	NR	NR

CI – Confidence Interval
HC – Health Committee
HFP – Home Food Production
IP – Intensive Programme
NR – Not Reported
OWL – Older Women Leader
RP – Reduced Programme

RAE – Retinol Activity Equivalent

SE – Standard Error

SD – Standard deviation

USD – US Dollars

DID – Difference in difference

Table 2.4B: Table showing major results for secondary outcomes in this review

Study	**Secondary outcomes**			
	Serum retinol/ vitamin A RAE	**Dietary diversity**	**Income**	**Cost of intervention**
Faber 2002 (Faber et al., 2002)	(Mean improvement/SD) HFP 0.81 ± 0.22µmol/l, control 0.73 ± 0.19 µmol/l,	NR	NR	NR
Gelli 2018 (Gelli et al., 2018)	NR	NR	NR	NR
Hotz 2012 Mozambique (Hotz et al., 2012a)	(Mean improvement/SE) Model one 56.1 ± 10.3, model two 47.1 ± 9.1, control 11.2 ± 5.3	NR	NR	NR
Hotz 2012 Uganda (Hotz et al., 2012b)	Vitamin A RAE 6 – 35 months (mean improvement/SE) IP – control 297 ± 51 RP – control 229 ± 52 IP – RP 68 ± 43 3 – 5 years IP – control 206 ± 37 RP – control 370 ± 74 IP – RP	NR	NR	NR

	164 ± 78			
Khamhoung 2000 (Khamhoung et al., 2000)	NR	NR	NR	NR
Kidala 2000 (Kidala et al., 2000)	Not infected with helminth – HFP 21.2µg/Dl, control 25.2 µg/dL. Infected with helminth HFP 11.7µg/Dl, control 13.3µg/Dl	NR		
Kuchenbecker 2017 (Kuchenbecker et al., 2017)	Consumption of vitamin A-rich vegetable and fruits HFP 77.3%, control 70.2%. vitamin A-rich roots and tubers HFP 13.2%, control 12.1%	HFP 71.1% increase in dietary diversity, control 55.5%. Impact 12.70% (p =0.01)	NR	NR
Lakzadeh 2016 (Lakzadeh, 2016)	Vitamin A RAE (mean improvement/ 95% CI) HFP - 373 (282 to 463) Control 271 (219 to 322) HFP plus fish pond 331 (253 to 410)	NR	(Mean) HFP – 1.77 (P < 0 05) HFP plus fish pond 1.58 (P < 0.001)	220 USD for 22 months
Low 2007 (Low et al., 2007)	Vitamin A RAE HFP 426µg, control 56µg. Consumption of vitamin A-rich roots and tuber, HFP 35%, control 5%. Consumption of vitamin A-rich fruits and vegetables, HFP 56%, control 31%.	HFP 32% in dietary diversity, control 9%.	Mean revenue from HFP (from orange sweet potato sale) US$ 3.17 ± 2.91	NR
Marquis 2017 (Atuobi-Yeboah et al., 2016; Marquis et al., 2017; Marquis et al., 2018)	Unadjusted prevalence of egg consumption HFP 31.5%, control 22.6% P<0.005	Odds ratio 1.65 (95% CI 1.02 to 2.69)	NR	NR

Olney 2009 (Olney et al., 2009)	NR	(Mean improvement/SD) HFP 4.3 (1.1) Control 3.8 (1.3)	Income increased in HFP 49.7% (P<0.05), control 35.5% (P<0.05)	NR
Olney 2015 (Olney et al., 2015)	NR	NR	NR	NR
Osei 2015 (Osei et al., 2015)	NR	NR	NR	NR
Raneri 2017 (Raneri et al., 2017)	Impact 0.4 (p<0.01). Vitamin A vegetables and fruits increased by 26g and 3g (p<0.001, p<0.01)	NR	NR	NR
Reinbott 2016 (Reinbott et al., 2016)	Consumption of vitamin A-rich vegetables, fruits, root and tuber (%) for HFP – 46.2, 7.1, 38.2. Control – 37.5, 6.3, 20.4	(Mean improvement/%) HFP 3.9 (64.9%) Control 3.6 (55.9%)	NR	NR
Schreinemachers 2016 (Schreinemachers et al., 2016)	NR	NR	Mean -1.4 p-value = 0.798	23.2 USD per year

CI – Confidence Interval
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OWL – Older Women Leader
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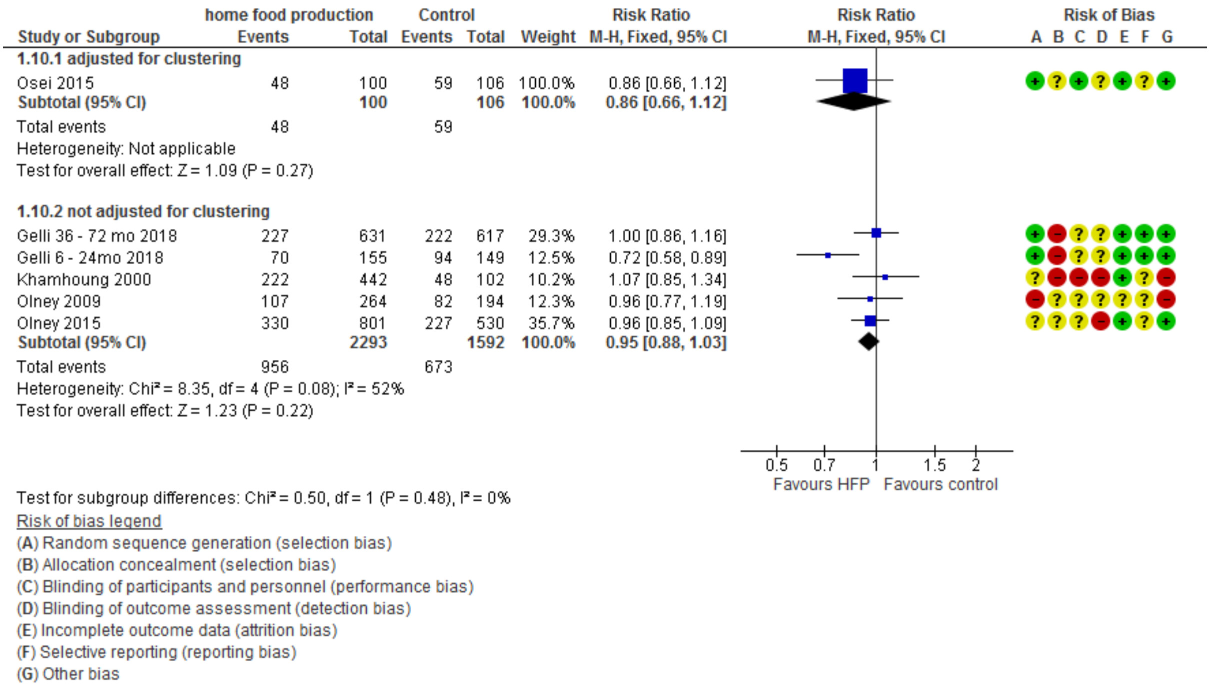
SE – Standard Error
SD – Standard deviation
USD – US Dollars

PREVALENCE OF STUNTING

Home food production reduced the prevalence of stunting in children (adjusted data for clustering – risk ratio 0.86, 95% CI 0.66 to 1.12, 206 participants, one study, I^2 NA, Unadjusted data – risk ratio 0.95, 95% CI 0.88 to 1.03, 3885 participants, four studies, I^2 52%, figure 2.8). The fixed-effects model showed a similar result to the random-effects model.

In summary, evidence of low certainty showed that home food production improved height-for-age in children.

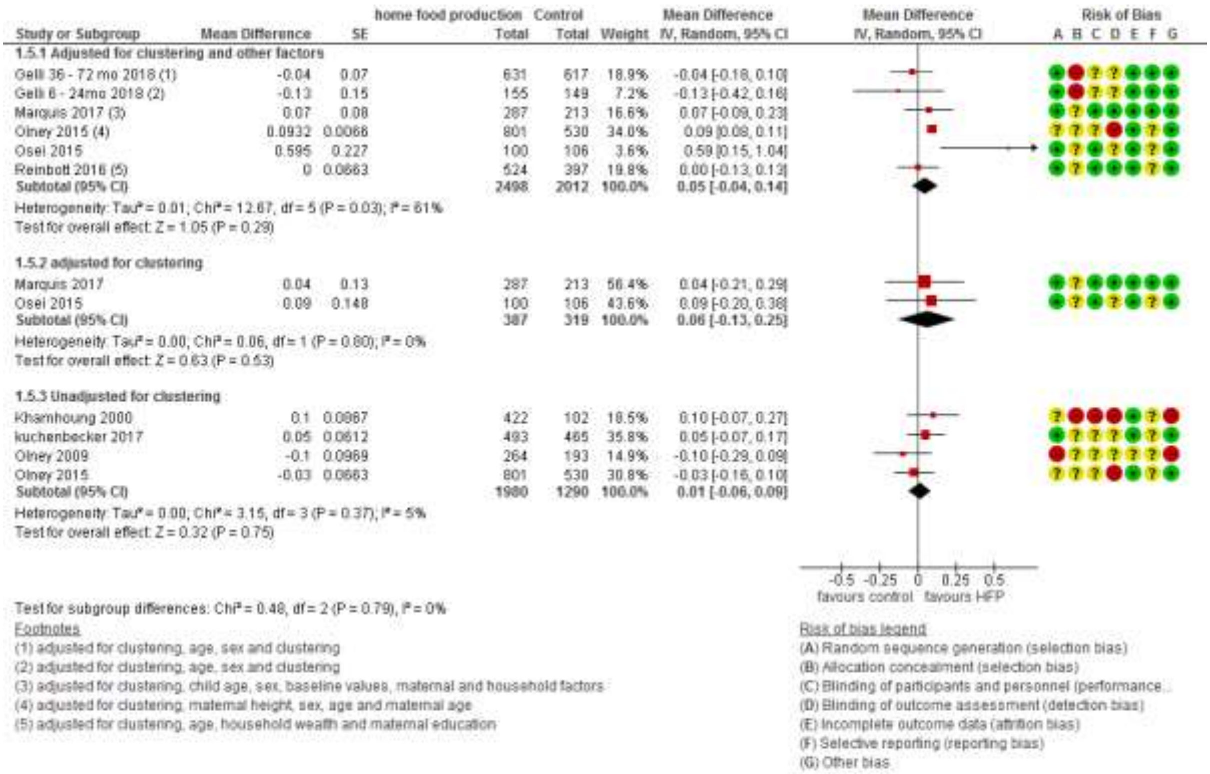
Figure 2.8: Effects of home food production on the prevalence of stunting in children (risk ratio): Meta-analysis assessing risk ratio using the random-effects model



2.7.3.5 EFFECT OF HOME FOOD PRODUCTION ON WASTING (WEIGHT-FOR-HEIGHT) IN CHILDREN LESS THAN 5 YEARS OF AGE

All the eight studies (Gelli et al., 2018; Khamhoung et al., 2000; Kuchenbecker et al., 2017; Marquis et al., 2017; Olney et al., 2009, 2015; Osei et al., 2015; Reinbott et al., 2016) that reported wasting as an outcome were included in the meta-analysis. (Figure 2.9). The evidence which was of low certainty (Table 2.4a) and downgraded for risk of bias and imprecision showed that home food production slightly improved height-for-weight in children compared to the control arm (adjusted data for clustering and other factors - MD 0.05 (z score), 95% CI -0.04 to 0.14, I^2 61%, five studies, 4510 participants, moderate certainty evidence). The same result was observed for other subgroups of data. See Appendix 10 for all analyses on wasting

Figure 2.9: Effects of home food production on wasting in children (z-score): Meta-analysis assessing mean difference using the random-effects model



HETEROGENEITY ANALYSIS

Heterogeneity was moderate (I^2 61%) across the studies in the category of data adjusted for clustering and other factors. Heterogeneity was low in the category of unadjusted data (I^2 5%) and absent for data adjusted for clustering (I^2 0%).

SUBGROUP ANALYSIS

We found no important differences between subgroups when subgrouping by duration (P = 0.22) or intervention (P = 0.49). Subgrouping by continent, an important difference was found (P = 0.021) between Asia (MD 0.59 z score, 95% CI 0.15 to 1.04, I^2 48%) and Africa (MD 0.04 z score, 95% CI -0.03 to 0.11), with interventions in Asia appearing effective at reducing wasting, but not interventions in Africa.

SENSITIVITY ANALYSIS

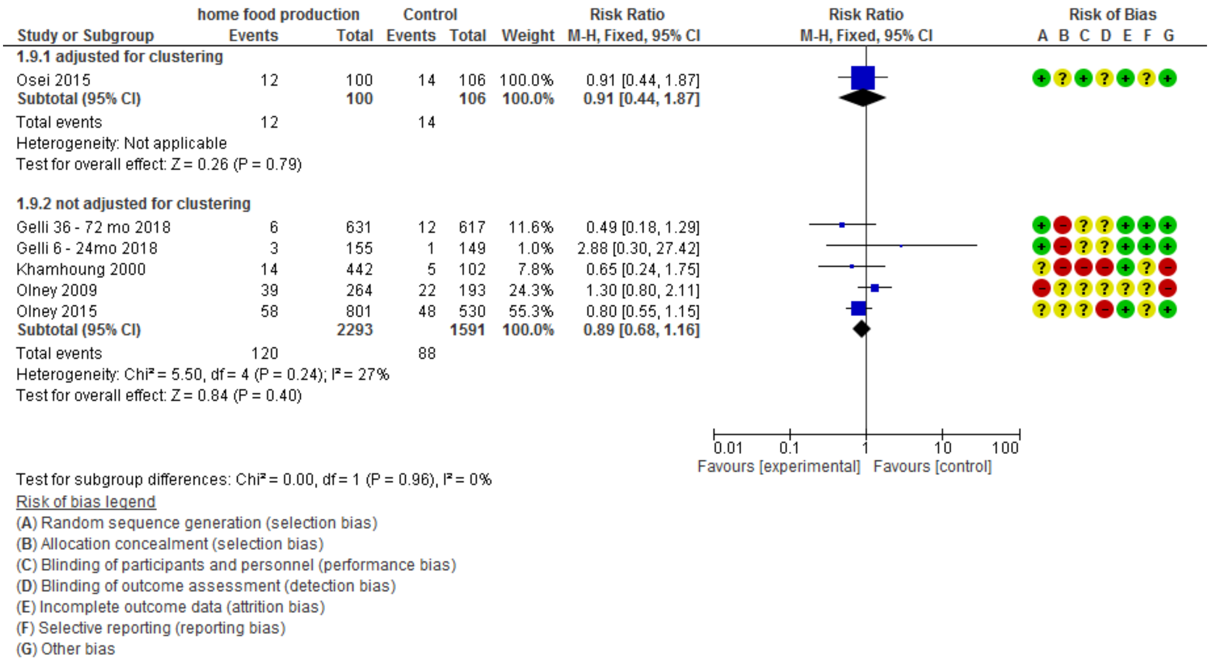
The fixed-effects model was used as a sensitivity analysis. The results differed with a mean difference of 0.04 from the random-effects model (data adjusted for clustering and other factors - MD 0.09 z score, 95% CI 0.08 to 0.10) also suggesting that home food production slightly improved wasting in children. Heterogeneity was the same as in the random-effects model.

PREVALENCE OF WASTING

In the random-effects meta-analysis, the impact of home food production reduced the prevalence of wasting in children (adjusted data for clustering – risk ratio 0.91, 95% CI 0.44 to 1.87, 206 participants, one study, I^2 NA). Unadjusted data for clustering showed no improvement in wasting in children. Using a fixed-effects model to analyse the prevalence of wasting, a similar result to the random-effects model was shown. See figure 2.10

In summary, evidence of low certainty showed that home food production slightly improved weight-for-height in children.

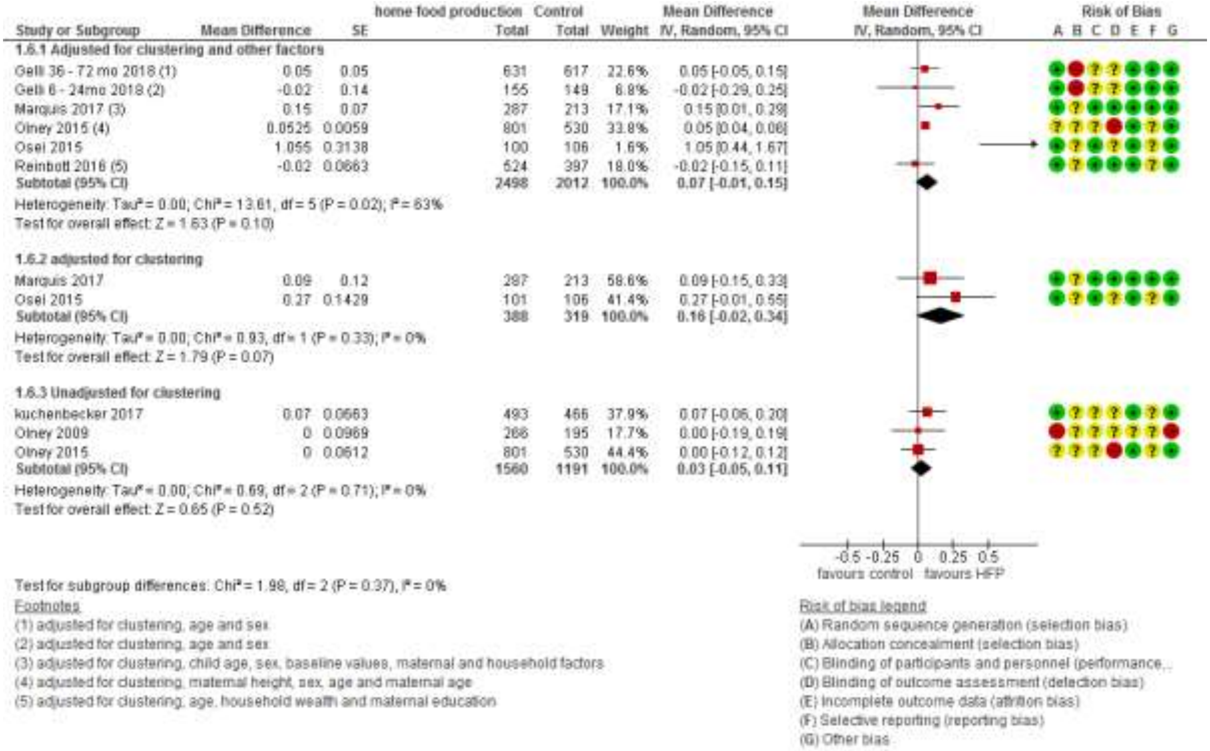
Figure 2.10: Effects of home food production on the prevalence of wasting in children (risk ratio): Meta-analysis assessing risk ratio using the random-effects model



2.7.3.6 EFFECT OF HOME FOOD PRODUCTION ON UNDERWEIGHT (WEIGHT-FOR-AGE) IN CHILDREN LESS THAN 5 YEARS OF AGE

Seven studies (Gelli et al., 2018; Kuchenbecker et al., 2017; Marquis et al., 2017; Olney et al., 2009, 2015; Osei et al., 2015; Reinbott et al., 2016) assessed as moderate certainty evidence, downgraded for risk of bias (Figure 2.11) showed that home food production slightly improved weight-for-age in children compared to the control arm (data adjusted for clustering and other factors - MD 0.07 z score, 95% CI -0.01 to 0.15, five studies, 4510 participants, I^2 53%). Unadjusted data showed a similar result, however, data adjusted for only clustering showed a positive impact (MD 0.16 z score, 95% CI -0.02 to 0.34, two studies, 707 participants, I^2 0%). Appendix 11 shows all the analyses for underweight.

Figure 2.11: Effects of home food production on underweight in children (z-score): Meta-analysis assessing mean difference using the random-effects model



HETEROGENEITY ANALYSIS

Heterogeneity was absent in the categories of data unadjusted for clustering (I^2 0%,) and adjusted for clustering (I^2 0%). The category of data adjusted for clustering and other factors showed moderate heterogeneity (I^2 63%)

SUBGROUP ANALYSIS

There was no important difference between subgroups when subgrouping by duration (P = 0.77), type of intervention (P = 0.18) or continent (P = 0.43, see Appendix 12).

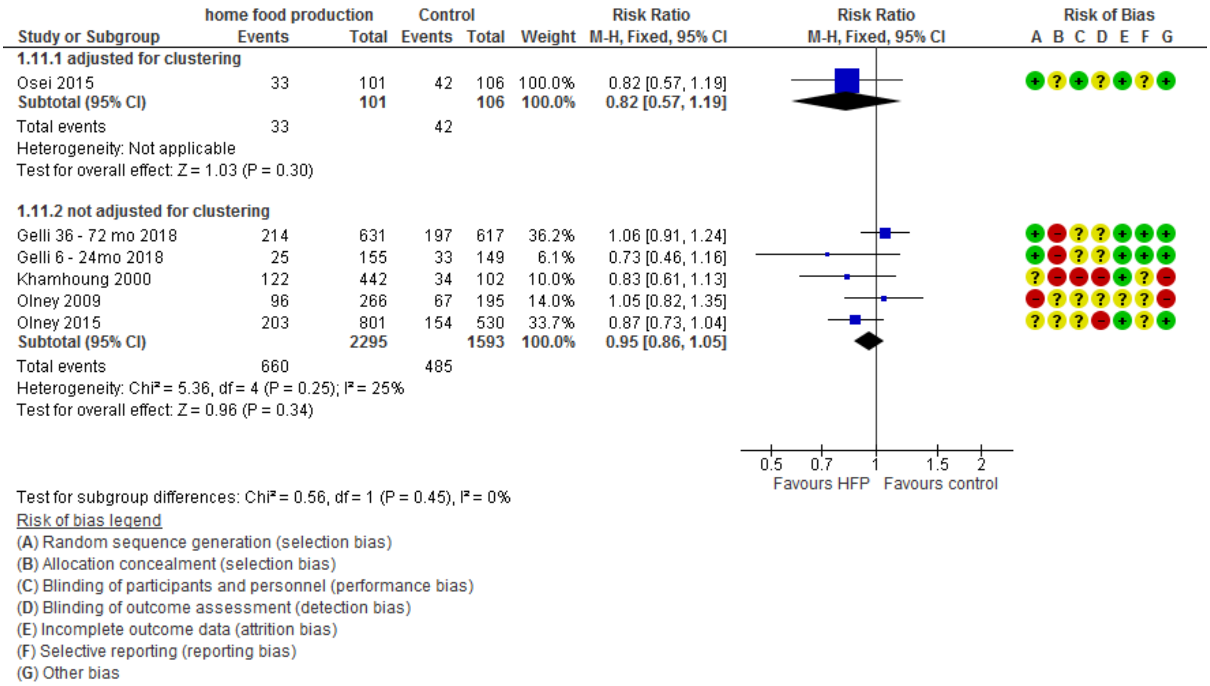
SENSITIVITY ANALYSIS

The fixed-effects model was used as a sensitivity analysis. A similar result to the random effect model was found (MD 0.05 z score, 95% CI 0.04 to 0.06, I^2 63%).

PREVALENCE OF UNDERWEIGHT

Home food production reduced the prevalence of underweight in the intervention arm (adjusted data for clustering – risk ratio 0.82, 95% CI 0.57 to 1.19, one study, 206 participants). Unadjusted data for clustering showed similar results to adjusted data. The fixed-effect model was used for sensitivity analysis and the same result to the random-effects model was obtained (Figure 2.12). In summary, evidence of low-certainty showed that home food production slightly reduced underweight in children.

Figure 2.12: Effects of home food production on the prevalence of underweight in children (risk ratio): Meta-analysis assessing risk ratio using the random-effects model

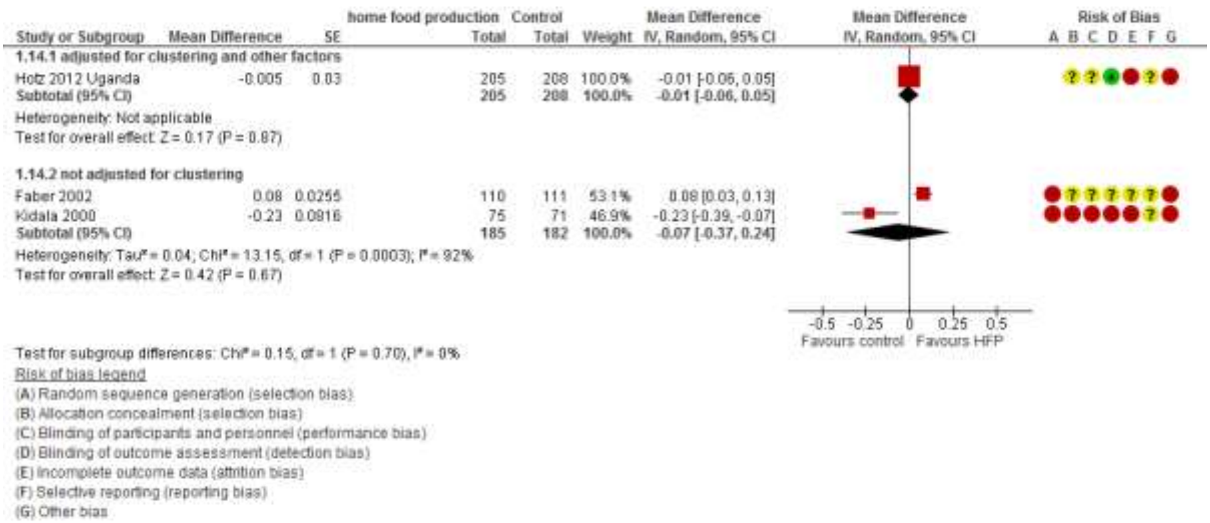


2.7.4 SECONDARY OUTCOMES

2.7.4.1 EFFECTS OF HOME FOOD PRODUCTION ON SERUM RETINOL IN CHILDREN AGED LESS THAN FIVE YEARS OLD

Only three studies, all at high risk of bias (Faber et al., 2002; Hotz et al., 2012b; Kidala et al., 2000) reported serum retinol as an outcome. All three studies were included in the meta-analysis. Home food production did not affect serum retinol (Figure 2.13, data adjusted for clustering and other factors MD -0.01umol/l, 95% CI -0.06 to 0.05, one study, 413 participants, I^2 NA). Unadjusted data showed a similar result to the adjusted data. The fixed-effects model (MD -0.01umol/l, 95% CI -0.06 to 0.05) showed that home food production did not affect serum retinol in children in the intervention arm compared to the control arm where no intervention was received. Appendix 12 shows all analyses for serum retinol in children below 5 years.

Figure 2.13: Forest plot showing serum retinol (umol/l) in children using random-effects meta-analysis



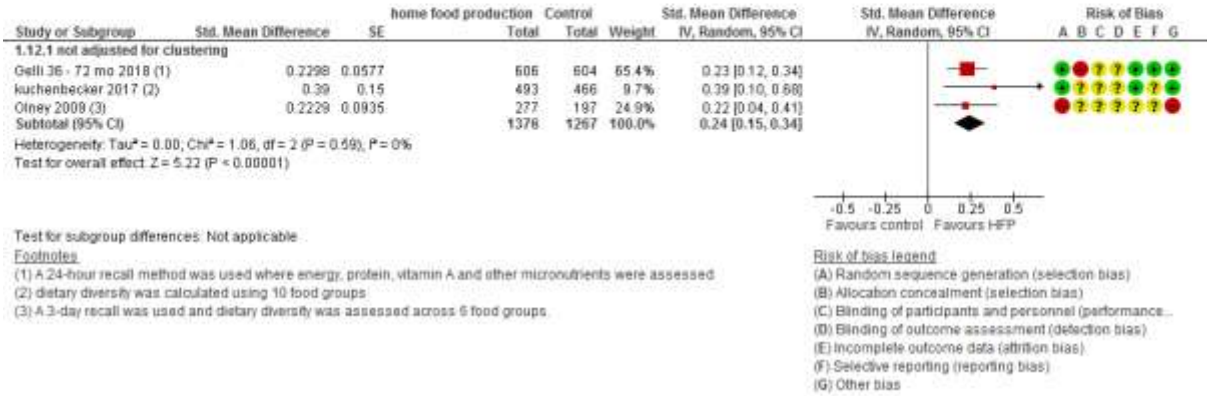
HETEROGENEITY ANALYSIS

One study was adjusted for clustering and other factors, so heterogeneity was not applicable. Unadjusted data for clustering had an I^2 = 92% which is a high level of heterogeneity.

2.7.4.2 EFFECT OF HOME FOOD PRODUCTION ON DIETARY DIVERSITY IN CHILDREN LESS THAN FIVE YEARS OF AGE

A total of six studies (Gelli et al., 2018; Kuchenbecker et al., 2017; Low et al., 2007; Marquis et al., 2017; Raneri et al., 2017; Reinbott et al., 2016), all high risk of bias reported dietary diversity. Three studies (Gelli et al., 2018; Kuchenbecker et al., 2017; Olney et al., 2009) were found eligible to be included in the meta-analysis as they were reported in a format that could be pooled statistically (Figure 2.14). Meta-analysis showed that home food production increased dietary diversity in children compared to the control arm (standardised mean difference 0.24, 95% CI 0.15 to 0.34, three studies, 2643 participants). The results showed no heterogeneity (I^2 0%). The fixed-effects model produced the same result as the random-effects model. Appendix 13 shows all analyses on dietary diversity.

Figure 2.14: Effects of home food production on dietary diversity in children (z-score): Meta-analysis assessing mean difference using the random-effects model



The studies that could not be included in the meta-analysis were (Marquis et al., 2017; Raneri et al., 2017; Reinbott et al., 2016). For all the dietary diversity scores, the higher the score, the higher the dietary diversity. Raneri et al. (2017) showed an 18% increase in minimum dietary diversity score in children in the intervention arm compared to the control arm. Reinbott et al. (2016) used the child dietary diversity score and reported a mean (SD) of 3.9 ± 1.5 for the intervention arm and 3.7 ± 1.5 for the control arm. Marquis et al. (2017) reported minimum dietary diversity of 80.2% in the intervention arm and 69.5% in the control arm.

Eight studies at high risk of bias (Marquis et al., 2017; Hotz et al., 2012a; Hotz et al., 2012b; Kuchenbecker et al., 2017; Lakzadeh, 2016; Low et al., 2007; Raneri et al., 2017; Reinbott et al., 2016) showed that home food production increased the consumption of vitamin A-rich foods (Table 2.4b). However, consumption of vitamin A-rich foods was not a prespecified outcome for this review, and they did not measure serum retinol levels in children.

In summary, evidence of a high risk of bias from the meta-analysis showed that home food production improved dietary diversity in children. Other studies not included in the meta-analysis also reported an increase in dietary diversity in children.

2.7.4.3 EFFECT OF HOME FOOD PRODUCTION ON FAMILY INCOME

A total of four studies all at high risk of bias (Lakzadeh, 2016; Low et al., 2007; Olney et al., 2009; Schreinemachers et al., 2016) reported on income generated by home food production through the sale of surplus produce. However, they could not be pooled statistically as they lacked useable variance data. These studies all suggested that home food production can generate additional income for the household. Marquis et al. (2017) reported a mean revenue from home food production of US$ 3.17 ± 2.91 from orange sweet potato sales during the intervention. Olney et al. (2009) showed that income increased in home food production by 14.2% compared to the control arm at the end of the intervention (See table 2.4b).

2.7.4.4 COST OF INTERVENTION

The cost of setting up a home garden was reported by two studies (Lakzadeh, 2016; Schreinemachers et al., 2016). Schreinemachers et al. (2016) reported that the cost of setting up a home garden with tools and planting materials per annum is USD 23.2 per garden while Lakzadeh 2016 reported a cost of USD 220 for 22 months per garden (Table 2.4b).

Table 2.5: Quality of evidence using GRADEpro GDT

Question: Home food production compared to control for home food production

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	home food production	control	Relative (95% CI)	Absolute (95% CI)		
Xeropthalmia												
0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	Critical
Night blindness												
0	NR	NR	NR	NR	NR	NR	NR	NR	-NR	NR	NR	Critical
Mortality												
0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	Critical
Stunting, z-score, GIV - adjusted for clustering and other factors												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	home food production	control	Relative (95% CI)	Absolute (95% CI)		
7	Randomised controlled trial	serious [c]	serious [d]	not serious	not serious	none	2991	2478	-	MD 0.13 higher (0.01 higher to 0.24 higher)	⨁⨁◯◯ LOW	IMPORTANT
Wasting GIV - Adjusted for clustering and other factors												
6	Randomised controlled trial	serious [c]	not serious	not serious	Serious	none	2498	2012	-	MD 0.05 higher (0.04 lower to 0.14 higher)	⨁⨁◯◯ LOW	IMPORTANT
Underweight GIV - Adjusted for clustering and other factors												

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	home food production	control	Relative (95% CI)	Absolute (95% CI)		
6	Randomised controlled trial	serious [c]	not serious	not serious	Serious	none	2498	2012	-	MD 0.07 higher (0.01 lower to 0.15 higher)	⨁⨁◯◯ LOW	IMPORTANT

CI: Confidence interval; MD: Mean difference; SMD: Standardized mean difference; RR: Risk ratio

Explanations

a. All the 3 studies were at high risk of bias for almost all the domains

b. Heterogeneity was high at 90%

c. All the studies had a high risk of bias for at least one domain

d. High heterogeneity at 85%

2.8 DISCUSSION

2.8.1 SUMMARY OF MAIN FINDINGS

This systematic review aimed to examine the effectiveness of home food production in the prevention of vitamin A deficiency and nutritional blindness in children below the age of five. It also sought to examine the effectiveness of home food production on anthropometric measures in children. In total, ten outcomes were assessed – xeropthalmia, night blindness, serum retinol level, dietary diversity, mortality, stunting, wasting, underweight, income and cost of intervention. No studies assessed xeropthalmia, night blindness and mortality, but some evidence was found for each of the remaining outcomes.

A total of 16 studies were included in this systematic review, assessing effects on 2498 children. Meta-analysis was carried out to assess the effects of home gardening on stunting, wasting, underweight, dietary diversity and serum retinol. The remaining outcomes were reported narratively.

Evidence of low-certainty showed that home food production was effective in reducing stunting (mean difference MD 0.13 (z score), 95% CI 0.01 to 0.24, six studies, 5469 participants, I^2 84%, low-certainty evidence, downgraded for high risk of bias and inconsistency, Figure 2.7). Heterogeneity between studies was high and this could be as a result of different local conditions and dietary habits or poor study designs. This will be taken up as a future research topic as heterogeneity was not reduced in the subgroup analyses. The clinical impact of improved height-for-age (reduction in stunting) suggests that for a 24-month-old boy, to move from a height-to-age z-score of -2 to -1, 3.1cm in height is achieved. For a girl of similar age, to move from a height-to-age z-score of -2 to -1, 3.2cm in height is achieved (WHO, 2006). A systematic review by Roberts and Stein (2017) assessed the impact of nutritional interventions on stunting in children two years of age and above, searched Medline and Embase and assessed risk of bias using the Jadad score. They found that vitamin A supplementation increased linear growth in children (standardised mean difference 0.05, 95% CI 0.01 to 0.09, I^2 52%). However, food-based interventions did not have the same effect.

Low-certainty evidence showed that home food production reduced wasting MD 0.05 (z score), 95% CI -0.04 to 0.14, I^2 61%, five studies, 4510 participants, low certainty evidence downgraded for high risk of bias and imprecision) and underweight (data adjusted for clustering and other factors - MD 0.07 z score, 95% CI -0.01 to 0.15, five studies, 4510 participants, I^2 53%, low certainty evidence downgraded for high risk of bias and imprecision) in children. Home food production improved dietary diversity in children (standardised mean difference 0.24, 95% CI 0.15 to 0.34, three studies, 2643 participants). Limited evidence showed that home food production was able to bring in more income to households. The effectiveness of home food production did not differ based on the duration of intervention or type of intervention (home garden alone versus home garden and animal husbandry). The effectiveness of home food production differed by continent. An improvement in wasting was observed in Asians compared to African children. Sensitivity analysis was carried out by using the fixed effects model in the meta-analysis. Different results were obtained from the fixed and random-effects models. However, this systematic review focuses on the results of the random-effects model as the between-study variability is large and statistically significant. This makes the fixed effects model inappropriate to use for the main analysis (Borenstein et al., 2011).

2.8.2 OVERALL COMPLETENESS AND APPLICABILITY OF EVIDENCE

Little evidence was found on the effect of home food production on children's serum retinol level, concurring with previous systematic reviews (Masset et al., 2012). Only three included studies measured serum retinol in children. Eight studies (Low et al., 2007; Hotz et al., 2012a; Hotz et al., 2012b; Lakzadeh, 2016; Reinbott et al., 2016; Kuchenbecker et al., 2017; Marquis et al., 2017; Raneri et al.,

2017) showed that home food production can lead to increased consumption of vitamin A-rich foods but did not measure the level of vitamin A in the blood.

One factor that inhibits the absorption of vitamin A is helminth infestation. Only one included study considered helminth infestation in children (mean serum retinol in experimental group: 13.7 µg dl−1, n = 75; control group: 19.3 µg dl−1, n = 71). There was a higher number of helminth infested children in the experimental group (79%) compared with the control group (49%) (P > 0.001). (Kidala et al., 2000), and the results showed that children with helminth infestation had lower mean serum retinol than non-infected children (12.3 ± 5 vs. 24 ± 10 µg dl−1; P = 0.001). However, the difference in serum retinol level between the intervention and control group was not statistically significant after adjustments were made for helminth infection. Countries where vitamin A deficiency is endemic are co-endemic for soil-transmitted helminthiasis (Strunz et al., 2016). About 75% of countries with moderate to high prevalence of vitamin A deficiency have preschool children at risk of soil-transmitted helminthiasis and in need of recurring collective treatment referred to as preventive chemotherapy (Strunz et al., 2016). Soil-transmitted helminthiasis disrupts the circulation of serum retinol and hampers the true levels of serum retinol. Suchdev et al., 2015 carried out a cross-sectional study in Kenya that investigated the impact of soil-transmitted helminth infection on the nutritional status of children (Suchdev et al., 2015). This study showed that soil-transmitted helminth infection was associated with vitamin A deficiency in preschool children (prevalence ratio 2.2, 95% CI 1.1 to 4.6). Also, a meta-analysis of observational studies by De Gier et al. (2014) assessed the impact of helminth infestation on the micronutrient status of school-age children, using both observational studies and randomised controlled trials. They searched Embase, Medline and the Cochrane library, and assessed risk of bias using the Verhagen et al. (1998) and Newcastle-Ottawa scales. They found a negative association between soil transmitted helminth infections and serum retinol, but, meta-analysis of randomised controlled studies on anti-helminthic treatment showed a negative impact of treatment on serum retinol.

The absence of dietary fat can lead to low serum retinol levels among children consuming vitamin A-rich food. Findings have suggested that dietary fat aids in the absorption of beta-carotene in the body. A randomised controlled trial by Jalal et al. (1998) demonstrated that feeding children with beta-carotene in addition to dietary fat and deworming caused a further rise in serum retinol levels of pre-school children. Another randomised controlled trial by Ribaya-Mercado et al. (2007) that evaluated strategies for improving serum retinol levels in vulnerable populations supports the findings of Jalal et al. (1998) in that consumption of vitamin A-rich fruits and vegetables alongside dietary fat increases serum retinol levels.

Evidence gathered from this systematic review in my thesis showed that home food production caused a modest increase in the mean z scores of stunting and slightly improved wasting and underweight in children. Although agricultural practices may have the potential to tackle the issue of malnutrition in children, the problem of tackling malnutrition is complex as other important factors can determine the nutritional status of a child. These factors must be addressed when intervening to reduce malnutrition in children. One of these factors is the opportunity cost of women engaging in agricultural work. Time spent in the practice of home food production by women competes with time for quality childcare and appropriate food preparation and could go on to have unplanned harmful consequences on a child's nutritional status. A systematic review by Johnston et al. (2015) explored the relationship between agricultural practices, time use and nutritional outcome through the role of gender, using both quantitative and qualitative studies. Databases searched include Econlit, Proquest, web of science and Scopus. Quality of studies on time use was assessed using a checklist created by the authors, qualitative studies were assessed based on whether the paper was peer-reviewed or not and quantitative data (randomised controlled trial) were assessed using the international initiative for impact evaluation score. This review posited that women are the major players in agricultural practices, and this is reflected in the time spent in it. A systematic review by Rao et al. (2019) assessed the impact of women's work in agriculture on maternal and child nutritional outcomes using qualitative and quantitative studies. They searched PubMed, Scopus, Web of science, IFPRI and ELDI. This review demonstrated that when women in South Asia engaged in agriculture practices this impacted negatively on their children's dietary intake. Rao et al. (2019) further suggested that a contextualised approach is important in understanding women's time use in agriculture and its correlation to the nutritional status of their children. Socioeconomic factors play a role in determining whether time spent in agricultural practice affects the nutritional status of children positively or negatively. Integrating adequate childcare support into interventions and providing favourable conditions for child minding activities is crucial for the success of home food production intervention. Revising gender norms so that men are more involved in agricultural practices could avail women more time to ensure proper food preparation and feeding practices, thus, improving nutritional outcomes for young children.

Poor hygiene and sanitation are important factors that could sabotage the impact of home food production on anthropometric measures. All the studies described within this systematic review were conducted amongst vulnerable households in rural areas and lack of potable drinking water, poor sanitation and non-ideal hygiene practices may have been problematic in many of these settings. A systematic review by Gera, Shah and Sachdev (2018) examined the impact of water, sanitation and hygiene on growth, non-diarrhoeal morbidity and mortality in children using Randomised controlled trials, non-randomised controlled trials and controlled before/after studies. Gera and colleagues searched Medline, web of science, Cochrane Controlled Trials Register, EMBASE, LILACS, Popline and Gray source. Risk of bias was assessed using the Cochrane risk of bias tool. The review suggested that clean water, good sanitation and hygiene practices reduced the risk of stunting (relative risk 0.77; 95% CI 0.68 to 0.86), wasting (relative risk 0.12; 95% CI 0.02 to 0.85) and underweight (relative risk 0.81; 95% CI 0.69 to 0.96). However, the included studies in this review were of low quality.

Seasonal variation can influence the outcome of home food production trials. Faber et al. (2002) mentioned that at the time of outcome assessment, orange sweet potato and butternut squash were both out of season, and a greater response could have been obtained if the outcomes had been assessed during the season that these crops were being consumed. Olney et al. (2009) also suggested that seasonal variation may influence findings, buttressing the observations of Faber et al. (2002)

The results of this systematic review have shown that home food production can improve household income as it allows women to have surplus farm produce that can be sold to raise money. This can also have other unintended positive consequences by strengthening their decision-making power within the family. A cross-sectional survey by Sultana (2011) in Bangladesh assessed factors that influence women's decision-making power in households and reported that generating income (regression co-efficient 0.60, $P < 0.05$) in the family was associated with enhanced decision-making by women in rural households. Corroborating the findings of Sultana (2011), Bushamuka et al. (2005) carried out a controlled clinical trial (CCT) that assessed added benefits of a home garden in Bangladesh and found that women who engaged in home gardening were able to generate more income (64% of intervention group generated 343 taka from gardening while 25% of control group generated 200 taka, $P < 0.001$, US$1 = 51 taka) for their families and consequently had a stronger decision-making power within their families

A systematic review by Masset et al. (2012) included 23 CCT and assessed the effectiveness of agricultural interventions on the nutritional status of children in low and middle income countries. They searched ten databases (Econlit, IBSS, PubMed, and Web of Science) and unpublished literature (Agris, Eldis, IDEAS, IFPRI, Jolis, and World Bank) from July to September 2010 and included Randomised controlled trials and controlled clinical trials. Quality of studies was assessed using four dimensions (statistical analysis, sample size and power calculation, examination of intermediate outcomes and subgroups). They found little evidence that home gardening interventions had strong positive effects on serum retinol levels of children (MD 2.4 µg/dL, 95% CI 1.67 to 3.16). Nineteen studies in the review reported that home gardening improved dietary diversity, however, they could not summarise across studies as the included studies measured dietary diversity in different ways. Also, the review found limited evidence that home gardening interventions increased household incomes but did not provide details on the extent of the increase.

Masset and colleagues did not investigate blindness-related outcomes. A similar systematic review by Girard et al. (2012) assessed the effectiveness of agricultural interventions on nutritional outcomes in children and women. They included 36 studies of which 32 reported on nutritional outcomes for children, all were quasi-experimental studies with one randomised controlled trial and did not conduct a meta-analysis. They assessed the quality of included studies using Child Health Epidemiology Reference Group adaptation of GRADE and reported that some (but not all) included studies showed an impressive impact on anthropometric measures, however, the results were not consistent. This systematic review also found an inconsistent result for vitamin A status. My results are in line with the results of Masset et al. (2012) but differ slightly in anthropometric measures with Girard et al. (2012). This could be attributed to the inclusion of only one randomised controlled trial and all quasi-experimental studies by Girard et al. (2012). Neither Girard et al. (2012) or Masset et al. (2012) reported blindness-related outcomes in children. To the best of my knowledge, my systematic review is the first to investigate the impact of home food production on nutritional blindness and blindness-related outcomes in children. Currently, it is a stand-alone in this regard. This also highlights the importance of more research in this area to fully understand the effectiveness of home food production in the prevention of nutritional blindness in children.

2.8.3 RELATIONSHIP BETWEEN CONSUMPTION OF VITAMIN A-RICH FOODS AND NUTRITIONAL BLINDNESS IN CHILDREN

The findings from this systematic review suggest that home food production was positively associated with increased consumption of vitamin A-rich foods. Some authors have investigated the association of consumption of vitamin A-rich foods in children with nutritional blindness. Gittelsohn et al. (1997) explored infant feeding practices and the risk of xeropthalmia in Nepali children, using a case-control study design with 78 xeropthalmic and 78 non-xeropthalmic children between the ages of 1-6 years. This study showed that feeding of vitamin A-rich foods was associated with protection against xeropthalmia in early childhood. Schaumberg, O'Connor and Semba (1996) carried out a case-control study in the republic of Kiribati, assessing 666 cases of xeropthalmic children and 816 controls. Results from this study showed that a higher frequency of consumption of vitamin A-rich foods (OR 0.93, CI 0.80 to 0.96) and the presence of a garden (OR 0.70, CI 0.52 to 0.93) were associated with lower odds of developing xeropthalmia. Mele et al. (1991) conducted a case-control study in Indonesia that investigated the nutritional and household risk factors of xeropthalmia in children under the age of six. The study reported that the risk of xeropthalmia was associated with less frequent consumption of dark green vegetables (OR 6.4, 95% CI 3.4 to 12.2) and eggs (OR 2.7, 95% CI 1.7 to 4.3). Shankar et al. (1996) rolled out a case-control study in Nepal among 81 households with xeropthalmic children and 81 households with non-xeropthalmic children. The cases were less likely to consume vitamin A-rich fruits and vegetables, especially in October to December (OR 2.07, 95% CI 1.00 to 4.30) in comparison to controls.

2.8.4 IMPACT OF HOME FOOD PRODUCTION ON NUTRITIONAL BLINDNESS IN CHILDREN

Low serum retinol is associated with nutritional blindness in children (Asrat et al., 2002; Rosen et al., 1996; Tafesse et al., 1996; Uzoechina & Okoro, 1994; Wolde-Gebriel et al., 1991). A Cochrane systematic review by Mayo-Wilson et al. (2011) that assessed effects of vitamin A supplementation with mortality and morbidity in children aged six months to five years included 43 randomised controlled trials and showed that vitamin A supplementation reduced the prevalence of night blindness (rate ratio 0.32, 95% CI 0.21 to 0.50) and xeropthalmia (Rate ratio 0.31, 95% CI 0.22 to 0.45). During the process of carrying out this systematic review in my thesis, I noted some interventional studies that assessed the effectiveness of home food production on nutritional blindness but were not included in the review as they were not Randomised controlled trials or controlled clinical trials.

Campbell et al. (2011) carried out a cross-sectional study (not a CCT or randomised controlled trial) in Bangladesh that assessed the relationship of a homestead garden with night-blindness in children below the age of five. A population-based sample of six rural divisions of Bangladesh assessed in the Bangladesh nutrition surveillance project held from 2001 – 2005 was used. 158, 898 children aged 12 – 59 months were included in the study. The findings of this study illustrated that among pre-school children who were missed by vitamin A deficiency programme, lack of a home garden was associated with an increased odds of night blindness (OR = 3·16, 95 % CI 1·76 to 5·68; P = 0·0001). The All India Institute of Hygiene and Public Health implemented a pilot study on the effectiveness of home gardening and nutrition education to tackle vitamin A deficiency with the support of the Food Agriculture Organisation (FAO) in six villages of Purulia district, West Bengal, India (Chakravarty and Canet, 1996). After the project, they launched a similar project primarily to reduce the prevalence of vitamin A deficiency through the production and consumption of foods rich in carotene. The intervention reached 1500 households in three local governments (Balarampur, Hura and Barabazar) in

Purulia district. Beneficiaries were provided with seeds, fertilizer, gardening equipment, handbooks on home gardening, audio and video cassettes on the importance of vitamin A-rich foods and gardening techniques, and training on home gardening skills. This before/after study showed a reduction in clinical symptoms of vitamin A – conjunctival xerosis reduced from 6.4% to 3.5%, bitot's spots from 2.8% to 0.85%, night blindness from 15.3% to 4.7%.

The National Institute of Nutrition carried out a 3-year home gardening intervention in 20 villages in South-Indian states (Vijayaraghavan et al., 1997). The intervention included the distribution of seeds and seedlings of vitamin A-rich foods, plus nutrition education. Consumption of vitamin A-rich food increased by 50%, and the prevalence of bitot's spot decreased though not statistically significant ($P > 0.05$).

Talukder et al. (2014) evaluated the impact of the Helen Keller homestead food production programme on the prevalence of night blindness in children aged 12 – 59 months. Secondary data derived from the 1999 national vitamin A survey in Bangladesh was used. The evaluation showed that in children aged 12 – 59 months who had not received vitamin A capsule in the last 6 months before the survey, night blindness was significantly less prevalent in houses with a home garden and poultry than houses without a home garden and poultry (Talukder et al., 2014).

These excluded studies had a greater risk of bias than the included studies in this systematic review as they were surveys or before/after studies and lacked a comparison group or control arm. This systematic review included only studies with a control arm to be able to establish a cause-and-effect relationship between home food production and nutritional blindness in children. A control group reduces the possibility that an improvement or risks that occur during a trial are a result of other factors outside the intervention (Noordzij et al., 2009). The excluded studies are likely to have more biased results as they lacked control groups.

2.8.5 QUALITY OF EVIDENCE

This review included only randomised controlled trials and controlled clinical trials. Despite this, all the studies were assessed as being of poor methodological quality. The evidence was mostly downgraded due to the high risk of bias of the studies and the wide confidence intervals of the results (high levels of imprecision). Most of the studies were unclear on allocation methodology, so we were unable to assess whether allocation concealment was adequate, which throws the studies open to selection bias (Appendix 14). Most studies were unclear on whether or how participants, personnel and outcome assessors were blinded. Overall, the evidence in this review is of low quality. Only the evidence on dietary diversity was found to be of moderate quality. We identified seven ongoing trials that will add to existing evidence and may change the findings of this review. Their publications have not been found and the corresponding authors have been contacted to know the status of these trials. Due to the high heterogeneity in the meta-analyses, a consensus standard and protocol are needed in conducting high methodological quality research (such as large scale randomised controlled trials) for reliable conclusions to be drawn in this area.

2.8.6 POTENTIAL BIASES IN THE REVIEW PROCESS

This systematic review attempted to limit bias and adhered strictly to Cochrane methods of conducting systematic reviews. From the screening of titles to data extraction, two independent reviewers were involved, and conflicts were all resolved meticulously through discussions. Protocols could not be found for most of the studies, so it was impossible to assess reporting bias. There is also a possibility that relevant studies may be published in languages besides the English language and so were missed from inclusion.

2.8.7 AUTHORS' CONCLUSION

2.8.7.1 *IMPLICATION FOR PRACTICE*

This systematic review shows that home food production may modestly reduce stunting and slightly reduce wasting and underweight in children. No study reported effects on xeropthalmia, night blindness or mortality in children, and effects on serum retinol were unclear. Hence, it cannot be said that home food production can effectively reduce nutritional blindness in children. It would not be best practice to recommend home food production in preventing nutritional blindness in children. Other interventions that have enough evidence can be adopted in preventing nutritional blindness until sufficient evidence on home food production in preventing nutritional blindness is produced. However, the introduction of home food production to improve nutritional stunting, wasting and underweight may be appropriate in areas where these are prevalent and more intensive nutritional support is not available. The author suggests that implementation of home food production in areas without nutritional stunting, wasting or underweight should only be implemented as a complementary intervention.

2.8.7.2 *IMPLICATION FOR RESEARCH*

Due to the poor methodological quality of the included studies, the evidence of this review could not confidently answer the research questions of this systematic review. We need to plan large-scale high-quality trials with measures in place to minimise selection bias, performance and detection bias. One of the ways to reduce performance and detection bias might be to use a common centre for the collection of data rather than carrying out data collection at the houses of participants. Large sample sizes should be used to enable the detection of small but clinically relevant effects on eye health and serum retinol. Researchers should consider other factors that might affect the impact of home food production on nutritional status such as deworming, proper environmental sanitation and potable water. These factors should be appropriately included in study design as they can have important impacts on children's health. A factorial design could integrate and assess the effects of these factors in conjunction with home food production on nutritional blindness in children. Choosing the right crops for the intervention and collection of data at the most appropriate time of year also need to be thought through. Interventions used in trials need to be culturally specific in addressing barriers and supporting facilitators to home gardening, rallying community support, ensuring water supplies, training in foods high in vitamin A, cooking lessons for these foods and ensuring these are locally enjoyed and accepted. Finally, large-scale high-quality trials specifically aiming to assess the impact of home food production on nutritional blindness in children are urgently needed as there is a wide knowledge gap in this area. Studies focusing on the potential negative as well as positive outcomes, cost-effectiveness of home food production, and barriers and facilitators to implementation should be prioritized too.

No Randomised controlled trials or controlled clinical trials reported on xeropthalmia, night blindness or mortality in children. Other systematic reviews have looked at the effectiveness of vitamin A supplementation on nutritional blindness in children. But this systematic review has identified a lack of controlled studies that assessed the effectiveness of home food production on nutritional blindness in children. This review has shown that home food production improves dietary diversity, modestly improves stunting and slightly reduces wasting and underweight in children and leads to higher consumption of vitamin-A rich foods. However, high consumption of vitamin A-rich foods does not directly translate to a high serum retinol level as other factors such as soil-transmitted helminth infestation and environmental factors can sabotage this. Vitamin A deficiency leads to nutritional blindness in children and is caused by an insufficient intake of vitamin A-rich food. Our systematic review has established that home food production can lead to increased consumption of vitamin A-rich foods, but high-quality randomised trials focusing on the impact of home food production on blindness-related outcomes are needed. Evidence from excluded studies is supportive enough of the positive effects of home gardening on children's health to encourage further trials on the effectiveness of home food production in the prevention of nutritional blindness in children. This thesis draws upon these findings to further explore the cost-effectiveness, barriers and facilitators of home food production.

2.8.7.3 NEXT STEPS

Chapter two has used systematic review methodology to assess the effect of home food production on nutritional blindness in children below five years of age. As part of my searching, I screened for health economics studies, but no studies have evaluated the cost-effectiveness of home gardening of vitamin A-rich foods using a decision-analytic model in Nigeria. The next chapter will predict the cost-effectiveness of home gardening of vitamin A cassava and maize (yellow cassava and orange maize) in preventing vitamin A deficiency in Nigerian children with the available evidence. Chapter four will investigate whether additional information would be worthwhile before deciding whether to implement home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children.

CHAPTER THREE

HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE IN THE PREVENTION OF VITAMIN A DEFICIENCY IN CHILDREN: A COST-EFFECTIVENESS ANALYSIS

3.0 SUMMARY

This chapter presents an economic evaluation of home food production in the prevention of vitamin A deficiency in children, informed by the findings of chapter two. I carried out a cost-effectiveness analysis to assess if home gardening of yellow cassava and orange maize is cost-effective in the prevention of vitamin A deficiency in children. I developed a Markov model in Microsoft Excel and a probabilistic sensitivity analysis was carried out. Costing was from two perspectives – societal and funder's perspectives. Community farming was also investigated as a strategy for making vitamin A-rich foods accessible to children. The results from the societal perspective showed the ICER for home garden - $367.37 per DALY averted with 78.80% likelihood of cost-effectiveness. Community farm - $379.37 per DALY averted with 76.50% likelihood of cost-effectiveness. From the funder's perspective, the results showed the ICER for home garden as $364.99 per DALY averted with 82.70% likelihood of cost-effectiveness. Community farm - $369.18 per DALY averted with74.90% likelihood of cost-effectiveness. The results have demonstrated that home gardening of yellow cassava and orange maize is likely to be highly cost-effective in the prevention of vitamin A deficiency in children but with a probability of not being cost-effective ranging from 17.30% - 25.10%, implying that the results may be misleading.

The first section of this chapter discusses health economics and its importance. The second section explains all the methods used in the cost-effectiveness study. The third section presents the results and the final section focuses on the discussion of results, strengths and limitations of the study.

3.1 INTRODUCTION

3.1.1 WHAT IS HEALTH ECONOMICS?

Economics as a discipline is centred on the assumption that resources are finite (Guinness & Wiseman , 2011). Economics can be defined as the study of how society makes decisions on what, how and for whom to produce (Guinness & Wiseman V, 2011). On the other hand, health economics is when individuals, health care providers and government apply economic theories, models and experiential techniques to the health and health care of the society (Drummond et al., 2015). In the world's economy, resources are never sufficient to meet all the desires of humans at any given time, people are faced with the decision of choosing what needs and wants must be met from scarce resources. In the same vein, the health care system faces a scarcity of resources to meet all the health needs of people, therefore health care providers have to make the hard choices of which needs are met and which are forgone (Drummond et al., 2015)

In everyday life, making choices means making trade-offs (Edlin et al., 2015). The implication of this is that to have a good or service, you have to forgo another good or service. Opportunity cost which is also known as the economic cost of a good or service is the satisfaction or benefit lost in the inability to use the same resources to have another service or good which will equally bring benefits that are desirable and satisfying (McPake et al., 2020; C. Phillips, 2005; Rice & Unruh, 1998).

Clinical trials investigate the efficacy or effectiveness of health interventions by assessing health outcomes (Drummond et al., 2015). In a world of unlimited resources, health care outcomes of interventions would be the only information needed to decide which intervention to implement in healthcare. Nevertheless, because a world of unlimited resources does not exist and resources are always limited, an intervention being effective is not enough reason for it to be adopted in the healthcare setting (Phillips, 2005). It becomes imperative to know whether the intervention represents good value for the cost of implementing it. That is to say, is it cost-effective?

Economic evaluation is the method of assessing cost-effectiveness with the best available evidence of costs and outcomes (Drummond et al., 2015). It is the process of identifying, measuring and valuing inputs (costs) and outputs (benefits) of two (or more) alternative interventions/strategies systematically for a comparative analysis (Drummond et al., 2015). There are different types of economic evaluation – cost consequences analysis, cost-effectiveness analysis, cost-benefit analysis and cost-utility analysis (Drummond et al., 2015). A cost-utility analysis will be carried out for this study as it expresses health outcomes as utilities such as disability-adjusted life years (DALYs) and quality-adjusted life-years (QALY) which capture both quality and quantity of life.

3.1.2 BIOFORTIFICATION OF CASSAVA AND MAIZE

Biofortification is the act of improving or enhancing the nutritional content of staple crops through conventional breeding, biotechnology, agronomics and mineral fertilization (HarvestPlus, 2020). The primary objective of biofortification is to increase the micronutrient content of staple foods readily available to poor people in rural areas who have limited access to commercially fortified foods due to their low purchasing power and where supplementation programmes are problematic due to geographical location (WHO, 2020). Contrary to food fortification where fortified foods have to be purchased, Biofortification targets rural areas where the growing and consumption of staple crops are predominantly carried out at home (HarvestPlus, 2020). Biofortification stands apart from commercial fortification in that biofortification enhances the nutrient quality of crops during plant growth while commercial fortification enhances the nutrient content of foods by processing the crops (after plants are grown and harvested) into finished products such as sugar, salt, oil and cereals amongst others (WHO, 2020a). Repeat purchases of biofortified varieties are not necessary as the biofortification strategy is self-sustaining. Farmers can take seeds and tubers from harvested produce and store them for the next planting season (IITA, 2011). Seeds and tubers of biofortified varieties can be stored and reused for the next planting season and can be distributed to other farmers. After the initial breeding and distribution of biofortified plant species, reproducing most biofortified crops (such as sweet potato, cassava and maize) is cost-saving (HarvestPlus, 2020).

3.1.2.1 YELLOW CASSAVA

Cassava, also known as Manihot esculenta, manioc and yuca, is a major staple crop in Nigeria, consumed by over 70 million Nigerians daily. Worldwide, Nigeria is the largest producer of cassava, producing about 54 million metric tons produced annually, with nearly 95% consumed in the country. Cassava contributes greatly to food security and income generation in the country (FAO, 1999). In Nigeria, the average consumption of cassava per person per day is about 700g on a fresh-weight basis(Onuegbu et al., 2017). Cassava can be processed into garri, fufu, cassava porridge, cassava flour for baking, and abacha. Garri is a coarse granular flour made from frying fermented cassava with or without palm oil. Fufu is made from cooking and pounding fermented cassava dough. Abacha is dried cassava chips (IITA, 2020). Cassava provides about 37% of dietary energy and is rich in carbohydrates (IITA, 2011). Generally, cassava has a white colour, however, the biofortified varieties are yellow (also known as yellow cassava). Similar to white cassava (Figure 3.1), yellow cassava can be processed into garri, fufu, abacha and flour (IITA, 2011). The yellow varieties of cassava are also high yielding and resistant to major diseases and pests. Cassava is highly compliant to problematic planting conditions such as impoverished soils, drought. It is easy to prepare for planting and is not time consuming (IITA, 2011). Children can consume yellow cassava in the form of cakes, pies, pudding, porridge, pancakes, fufu and garri. Yellow cassava has the potential to provide 100% of vitamin A daily requirement in children (Harvestplus, 2020)

Figure 3.1: Yellow cassava contrasting with white cassava

Source: (FoodsNg, 2015)

3.1.2.2 ORANGE MAIZE

Globally, maize (Zea mays L. or corn) is the most commonly produced cereal (IITA, 2021). In Africa, Nigeria produces the largest quantity of maize annually with above 33 million tons of maize production (IITA, 2021). A survey of 6480 households in Nigeria in 2003 showed that maize is more widely (by 20.1% of the population) consumed than any other staple in Nigeria, followed by cassava (16.5%) (Maziya-Dixon et al., 2004). The average consumption of maize per person per day in Nigeria is about 300g (Onuegbu et al., 2017). The pro-vitamin A hybrids of maize (Figure 3.2) released in Nigeria have a yielding capacity of 6 -9 tons of maize per hectare of land (IITA, 2012) and they usually come in deep orange colour, distinct from the white or yellow regular maize. Orange maize can be given to children in form of cereal (pap), pudding, corn-meal, boiled or roasted corn.

Figure 3.2: Orange maize contrasting with yellow maize

Source: (Chicamod, 2014)

3.1.3 ECONOMIC EVALUATION OF INTERVENTIONS FOR VITAMIN A DEFICIENCY: A LITERATURE REVIEW

Economic evaluation is an invaluable tool widely used in the health sector to support the allocation of scarce health resources (Gray & Wilkinson, 2016). Economic evaluation has been used to assess the cost-effectiveness of different interventions for tackling vitamin A deficiency. An economic evaluation of interventions geared towards reducing vitamin A deficiency are summarised here. Seven relevant studies (Chow et al., 2010; Fiedler et al., 2000; Fiedler & Afidra, 2010; Fiedler & Macdonald, 2009; Lakzadeh, 2016; Loevinsohn et al., 1997; M. Phillips et al., 1996) were identified that carried out an economic evaluation on vitamin A supplementation, food fortification with vitamin A or home food production. Six studies (Chow et al., 2010; Fiedler et al., 2000; Fiedler & Afidra, 2010; Fiedler & Macdonald, 2009; Loevinsohn et al., 1997; M. Phillips et al., 1996) conducted a cost-effective analysis using DALYs as an outcome measure. Only one study carried out a cost-benefit analysis (Lakzadeh, 2016). All studies were done in LMICs. The study by Fiedler and Macdonald (2009) assessed the feasibility, costs and cost-effectiveness of food fortification programmes in 48 countries prioritized for high prevalence of vitamin A deficiency, anaemia, stunting and under-five mortality. Other studies assessed costs and cost-effectiveness in single countries.

3.1.3.1 DETAIL OF STUDIES

A cost-effectiveness analysis was carried out by Fiedler and Afidra (2010) in Uganda. This study compared the feasibility, cost, coverage and cost-effectiveness of fortifying cooking oil and sugar with vitamin A. Uganda, a country in Sub-Saharan Africa has a vitamin A deficiency prevalence of 28% for children between 6 to 59 months (Ugandan Demographic Health Survey, 2000). The objective of the study was to find out whether sugar should be adopted as a food vehicle for fortification with vitamin A. The 2005/2006 Ugandan household budget was used to estimate the level of consumption of fortified sugar and vegetable oil, and the cost per DALY averted was calculated. The annual incremental private sector cost of fortifying cooking oil with retinol palmitate one million IU/g fortificant was US$555,668, and US$2,644,765 for sugar. The cost per DALY averted for sugar is US$82 and US$18 for cooking oil (the study didn't state if costs were measured per annum). Also, the study found that the private sector cost of fortifying sugar is 4.8 times more than the private sector cost of fortifying cooking oil. Analysis from this study showed that sugar is consumed in Uganda than cooking oil by 17% more people. Therefore, adopting vitamin A fortification of sugar in Uganda would lead to more people having access to vitamin A fortified food. Fiedler and Afidra, 2010 (Fiedler & Afidra, 2010) were able to give a transparent costing method but they made some assumptions on effects data. Sensitivity analysis was not used to understand how the uncertainty of these missing data might have affected the results obtained. Discounting of costs and consequences was not taken into consideration which can lead to an economic evaluation giving misleading results (Torgerson & Raftery, 1999).

Fiedler and Macdonald (2009) assessed the feasibility, cost and cost-effectiveness of fortifying vegetable oil and sugar with vitamin A and fortifying wheat and maize flour with two other multiple micronutrient formulations for 48 high priority countries. These countries were termed high priority based on their high prevalence of vitamin A deficiency, anaemia, stunting and under-five mortalities. One hundred and twenty interventions were assessed. The interventions assessed include the fortification of vegetable oil (fortified with vitamin A), sugar (fortified with vitamin A), wheat flour (fortified with iron, folic acid, vitamin A, zinc, vitamin B1, B2, B3, B6, B12 for the expanded package and iron, folic acid and vitamin B12 for the reduced package) and maize flour (fortified with iron, folic acid, vitamin A, zinc, vitamin B1, B2, B3, B6, B12 and iron, folic acid and B12 for the reduced package). Household Income and Expenditure Survey (HIES) data were used to calculate the proportion of the population that consumed fortified foods. This study adopted a societal perspective and estimated both public and private sector costs. Costs data were retrieved from the United National Industrial Development Organisation Database (UNIDO), Flour Fortification Initiative (2007), World Grain Report, International Sugar Organisation's 2006 Yearbook, Global Alliance for Improved Nutrition (GAIN), Micronutrient Initiative (MI), the US Agency for International Development Micronutrient Agency. Costs were determined using the algorithm-based spreadsheet tool also known as production function to estimate the average plant cost and the national cost of the fortification programme. Both public and private sector costs of fortification were determined. The cost per DALYs averted by each of the interventions was calculated. The impact of the interventions on zinc, iron and vitamin A deficiencies were assessed in this study. The impact of the fortification programme was determined by calculating the difference in DALYs lost due to micronutrient deficiencies before and after the fortification programme. The 60 most cost-effective fortification programmes in the 48 high priority countries showed a 10-year incremental cost per DALY saved ranging from US$1 to US$134 and a 10-year incremental cost of US$1billion. Fiedler and Macdonald (2009) failed to make allowance for uncertainty in their analysis and estimated costs were not discounted.

Chow, Klein and Laxminarayan (2010) carried out a cost-effectiveness analysis of golden-mustard for treating vitamin A deficiency in India. Costs and benefits of genetically modified mustard seed which is consumed in the form of oil were compared to the industrial fortification of mustard seed during processing and high dose vitamin A supplementation. The number of DALYs and deaths averted by each intervention were estimated and incremental cost-effectiveness ratio was calculated for cost per DALY and death averted. The effects of the interventions were estimated over 20 years. Data were obtained from the literature. Costs were discounted at an annual rate of 3%. DALYs were assigned monetary values to calculate internal rates of return (IRR). The genetically modified mustard seed was still being developed at the time of this study. Thus, costs and effects were estimated based on inferences about health services, agriculture, food production and delivery system in India. Over 20 years, genetically modified fortification averted between 18 million and 34 million DALYs compared to high dose vitamin A supplementation which averted 12 million to 28 million DALYs. The incremental cost of genetically modified fortification was found to be US$403 (95% CI 389 to 418) to US$ 450 (95% CI 438 to 461) per DALY averted, while the incremental cost of high dose vitamin A supplementation was found to be US$23 (95% CI 22 to 24) to US$50 (95% CI 46 to 54) per DALY averted. The Monte Carlo sampling method was carried out to assess the robustness of the findings in this study. The cost-effectiveness ratio of ensuring that vitamin A supplementation is delivered with universal coverage gave an internal rate of return of 68% – 104%, which is greater than the internal rate of return for genetically modified fortification (21% - 42%) and industrial fortification (6% - 22%).

Phillips et al. (1996) carried out a cost-effectiveness study of sugar fortification with vitamin A, high dose vitamin A supplementation and promotion of home gardening with nutrition education in Guatemala. Data on cost were obtained from literature, donors, and implementing and collaborating agencies. This study focused on people at high risk of vitamin A deficiency (children under the age of 6 and women of childbearing age). Costs were discounted at a 10% rate. This study found that the annual cost of the sugar fortification programme (US$2,379,278) is 30 times higher than the cost of vitamin A supplementation (US$71,556) and home food production (US$85,284). The cost per high-risk person was US$0.98 for fortification, US$1.68 – 1.86 for vitamin A supplementation, and US$3.10 – US$4.16 for food fortification. A sensitivity analysis was carried out to check the uncertainty in the results.

A cost-effectiveness analysis was carried out in the Philippines by Loevinsohn, Sutter and Otelia Costales (1997) to determine whether a vitamin A supplementation capsule should be given to all children between 6 and 59 months old (universal approach), to children suffering from mild to severe underweight (broad approach) or preschool children suffering from moderate to severe malnutrition (narrow approach). A Department of Health perspective was used in this study. Data on costs were obtained from the Department of Health, UNICEF and Helen Keller International. Effects/benefits were calculated from data of 1993 National Immunization days, meta-analysis of published trials, national nutrition surveys and household surveys. Cost per death averted was US$67.21 for a universal approach compared to US$144.12 for mild to severely malnourished children and US$257.20 for preschool mild to severely malnourished children. The incremental cost for a broad approach was shown to be higher (US$1, 034, 510), compared to the universal approach (US$992, 894) and the narrow approach (US$888, 659). The number of deaths averted was higher for the universal approach (14, 773) compared to the broad approach (7, 178) and narrow approach (3, 455). Sensitivity analysis was carried out to assess the robustness of the findings.

A cost-effectiveness analysis of vitamin A supplementation and vitamin A fortification of wheat flour was carried out in the Philippines by Fiedler et al. (2000). This study measured vitamin A intake as an indirect proxy for vitamin A status. A private Filipino survey research firm known as TRENDS MBL conducted a 24-hour recall food consumption survey to measure vitamin A intake in this study. Data on costs of programmes were obtained from agencies, programme records, the Department of Health, interviews with suppliers and workers directly involved with food fortification and vitamin A supplementation programmes. The effectiveness of wheat flour fortification was calculated as the increase in the number of children with the recommended vitamin A intake as a result of the fortification programme. Effectiveness data for vitamin A supplementation was obtained from field reports of local health employees and department of health surveys. Effectiveness data on vitamin A flour fortification was derived from the increase in the number of children with the required vitamin A intake obtained from the fortified flour. The incremental cost-effectiveness ratio (ICER) was calculated. Findings from this study indicated that fortification of hard wheat flour had a lower ICER (104) compared to the vitamin A supplementation programme (646). The results showed that a universal vitamin A programme is more cost-effective compared to food fortification.

Lakzadeh (2016) conducted a cost-benefit analysis of a home food production intervention in Cambodia alongside a randomized controlled trial. Costs of food production were estimated using a micro-costing analysis. Costs were not discounted and benefits were projected over 12 months. The benefits of home food production were monetized using local village market values and calculated for both the intervention and the control group. A project perspective was adopted. The monetary benefit of having a fish pond with a home garden was found to be US$ 398 compared to a home garden (US$346) and the control arm (US$133). Also, the results showed that establishing a fish pond with a home garden is more costly (US$591) compared to setting up a home garden alone (US$239).

Schreinemachers et al. (2016) conducted a cost-effectiveness study in Bangladesh as a part of a quasi-experimental study on the training of women in home gardening and nutrition education. The cost of the intervention was calculated from the project’s financial report, project work plan and information from the main people directly involved in the project. The DALYs saved as a result of the intervention were estimated and used in determining the cost-effectiveness of home gardening compared to the control group that received no intervention. This study assumed that if 50% of the Bangladesh population is affected by vitamin A, iron and zinc deficiency (about 16.5 million households), it would cost US$375.1 million to reach these households with a home gardening intervention, or US$3, 059 per DALY saved.

3.2 IMPLICATION FOR THESIS

Existing literature has demonstrated that there is a dearth of knowledge on the cost-effectiveness of agricultural interventions to tackle nutritional deficiencies (Waage et al., 2013). A systematic review by Masset et al. (2012) and Lakzadeh (2016) both identified a gap in the literature in this area. Most of the studies reviewed above are outdated suggesting that a more recent economic evaluation of interventions targeting vitamin A deficiency is needed. None of these studies focused on Nigeria where vitamin A deficiency is a concern. Aghaji, Duke and Aghaji (2019) assessed the coverage of vitamin A supplementation programme in Nigeria using the Nigeria Demographic Health Survey (2013) data and literature published on population-based childhood blindness survey in Nigeria. This study reported 53.5% coverage in vitamin A supplementation programme in urban areas and a 34.7% coverage in rural areas. Children in the highest wealth quintile were more likely to receive vitamin A supplementation (odds ratio 2.81, P<0.001), as were children born to educated mothers (odds ratio 3.27, P<0.001) and children from the south-south region (odds ratio 2.38, p<0.001). This demonstrates that more children in urban areas than in rural areas are not covered by vitamin A supplementation programmes. Investigating the cost-effectiveness of an intervention that may be beneficial in tackling vitamin A deficiency in rural Nigeria is crucial.

These studies reviewed in section 3.3 have not provided an analytic framework that pulls together a full range of evidence relevant to assessing the cost-effectiveness of vitamin A deficiency interventions. A structure that shows the possible health states of vitamin A deficiency and how the interventions being assessed may influence health states over time is lacking. A means of linking intermediate and final outcomes of vitamin A deficiency is important in evaluating the cost-effectiveness of its various interventions (Drummond et al., 2015). Assessing the cost-effectiveness of interventions over a lifetime horizon is important. Also, a structure for decision-making under conditions of uncertainty is needed. A decision-analytic model can address these gaps (Drummond et al., 2015). Hence, it is sensible for a decision-analytic model to be used in evaluating the cost-effectiveness of different interventions for vitamin A deficiency.

Within this thesis, home gardening of vitamin A biofortified crops (yellow cassava and orange maize) will be compared against no home gardening intervention in the prevention of vitamin A deficiency in children below five years of age. Community farming will also be assessed as an alternative strategy to provide vitamin A-rich foods to children in rural Nigeria and will be compared to baseline in the prevention of vitamin A deficiency. Investigating community farming will inform policy-makers about whether there are other cost-effective strategies of making vitamin A-rich foods accessible to children besides home gardening. Valuation of resources will be carried out from two costing perspectives – societal perspective and funder's perspective. The societal perspective is the broadest costing perspective which accounts for direct and indirect costs in an economic evaluation. The societal perspective will include the cost of intervention, equipment, consumables and loss of productivity. The funder's perspective accounts only for direct costs (Drummond et al., 2015). The funder's perspective will include costs of intervention, equipment and consumables. These two perspectives will be considered to understand the impact of different costing perspectives on the cost-effectiveness of home gardening and community in the prevention of vitamin A deficiency in children.

Maize is one of the crops inter-planted with cassava in Nigeria. This cost-effectiveness study will therefore assess home gardening/community farming of co-planting yellow cassava and orange maize for household consumption. In addition, the impact of nutrition education, cooking session and distribution of posters and recipe books will be assessed alongside home gardening/community farming of yellow cassava and orange maize. This is because the systematic reviews in chapter two (Bassey et al., 2020) assessed multicomponent interventions made up of home gardening, nutrition education, cooking sessions and distribution of relevant materials.

Authors have examined the cost-effectiveness of various interventions to combat vitamin A interventions in children such as food fortification and vitamin A supplementation programmes. One of the studies discussed above in section 3.3 Schreinemachers et al. (2016), conducted a cost-effectiveness analysis on home gardening, but a decision-analytic model was not used. To the best of the author's knowledge, no study has examined the cost-effectiveness of home gardening of yellow cassava and orange maize using a decision-analytic model. For this reason, this chapter will focus on carrying out an economic evaluation using a decision-analytic model (Markov model) to predict the cost-effectiveness of vitamin A-rich foods in preventing vitamin A deficiency in children. The best available evidence was selected through a systematic literature search to inform the parameters of the model. Only two crops have been included in this study rather than a more general garden approach so that costing can be achieved. Narrowing the home garden concept to specific crops makes it easier to achieve costing.

3.3 AIMS

This study aims to assess the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children below the age of five in rural Nigeria.

3.3.1 RESEARCH QUESTION

- What is the likely cost-effectiveness of an intervention to promote home gardening with yellow maize and cassava compared to no intervention in the prevention of vitamin A deficiency and nutritional blindness in children below five years of age in rural Nigeria?

- How effective would an intervention to promote home gardening with yellow maize and cassava need to be in improving serum retinol in children for it to be cost-effective?

3.3.1.1 SUB-QUESTIONS

- Is home gardening/community farming of yellow cassava and orange maize likely to be cost-effective in preventing vitamin A deficiency in pre-school children compared to a no home gardening intervention alternative from a societal perspective?
- Is home gardening/community farming of yellow cassava and orange maize likely to be cost-effective in preventing vitamin A deficiency in pre-school children compared to a no home gardening intervention alternative from a funder's perspective?

3.4 METHODS

3.4.1 DECISION-ANALYTIC MODELLING

Decision analysis is the art of using a well-ordered and coherent approach to decide conditions of uncertainties (Briggs et al., 2006). A decision-analytic model creates a mathematical relationship to compare costs and consequences between two alternatives by using evidence from different sources such as clinical trials, observational studies, systematic reviews, surveys and expert consultation (Edlin et al., 2015). Decision analytic models are useful in the following ways – first, they create a structure that shows the progression of diseases to the end stage or death and it shows how alternative interventions impact the different stages of progression with costs and consequences being ascribed to these stages of progression. Second, decision-analytic models provide a framework that assembles all evidence relevant to a specific decision problem and includes them in the evaluation towards solving the problem. Third, an extensive examination of uncertainties around the evidence used in the model can be explored and the value of future research and areas of concentration can be investigated (Drummond et al., 2015). There are two main types of decision-analytic models used in economic evaluation - Markov models and decision trees. Decision trees have some important limitations in modelling chronic diseases. They become complex when using them to model chronic diseases and they do not account for the progress of time in the model (Drummond et al., 2015).

Due to the limitations of a decision tree, a cohort Markov model was developed in this study to predict the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize compared with a no home gardening intervention alternative. This is mainly because a Markov model is most suitable for the decision problem investigated in this study. Cohort Markov models are based on a series of health states that a cohort of patients can be in at one time. Individuals move from one health state to another based on transition probabilities (Figure 3.3). Effects and costs are estimated for each health state for the two interventions being compared (Briggs et al., 2006). Markov model provides an adequate structure for decisions on economic evaluation to be made based on uncertainties, and a lifetime horizon can be adopted. It can show the progression of vitamin A deficiency from onset to death as well as show the costs and consequences through the progression. It is structured in a way that shows the possible health states and how the interventions being assessed may influence the movement of the cohort between these health states and the costs and consequences of being in each health state over time. Table 1 summarises the methods for the model. The methods are explained in more detail in the sections below.

Figure 3.3: Visual conceptualization of the model

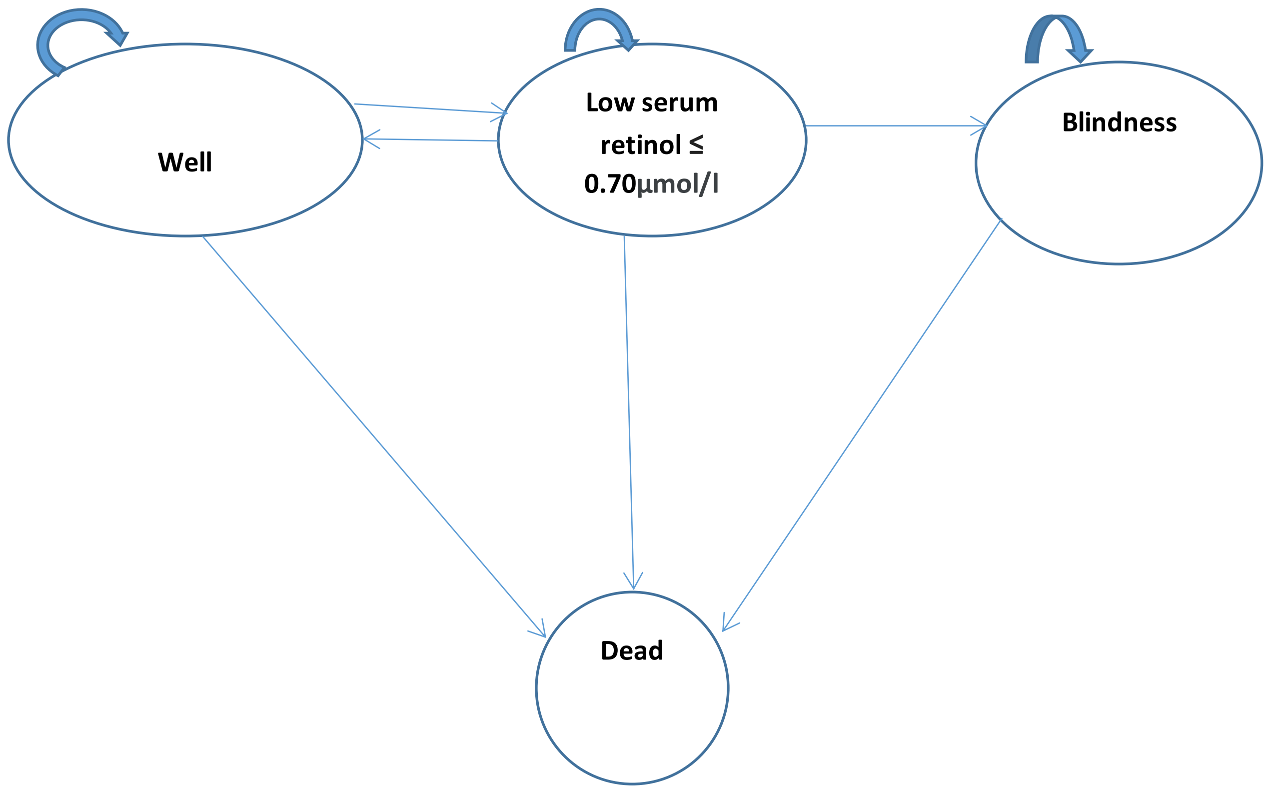


Table 3.1: Summary of methods for the Markov model to predict the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children

Methods	Description
Population	• Location – Ovia north-east local government, Edo state, Nigeria • Age group – children below the age of five • Population size – 834 households with children below the age of five years • Setting – rural
Intervention	• Intervention - Home gardening/community farming of yellow cassava and orange maize • Cost data – Expert consultation • Cost perspective: Funder and societal perspective (funder - A charity organisation such as Sight savers). • Currency - Cost was converted using purchasing power parity (PPP) to 2020 International dollars • Discount rate – 3.50%
Comparison	No home gardening intervention as the alternative
Outcome	• Disability-adjusted life years (DALYs) • Disability weights: Global burden of disease study 2019 • Length of cycle: one year. A lifetime horizon was used • Discount rate – 3.50% (WHO recommendation)
Transition probabilities	• Imdad et al., 2017, Mayo-Wilson et al., 2011 (Imdad et al., 2017; Mayo-Wilson et al., 2011) • Awasthi et al., 2013 (Awasthi et al., 2013) • *Life tables by WHO* (WHO, 2016b)
Effect	• Talsma et al., 2016
software	Microsoft Excel version 2019

Analysis	• Calculated mean costs and mean effects, incremental cost, incremental effect with 95% credible intervals, and ICER • Ran model twice, once for each alternative • Sensitivity analysis: One-way threshold analysis, probabilistic sensitivity analysis (PSA). • Threshold ($2,880) as recommended by (Woods et al., 2016)

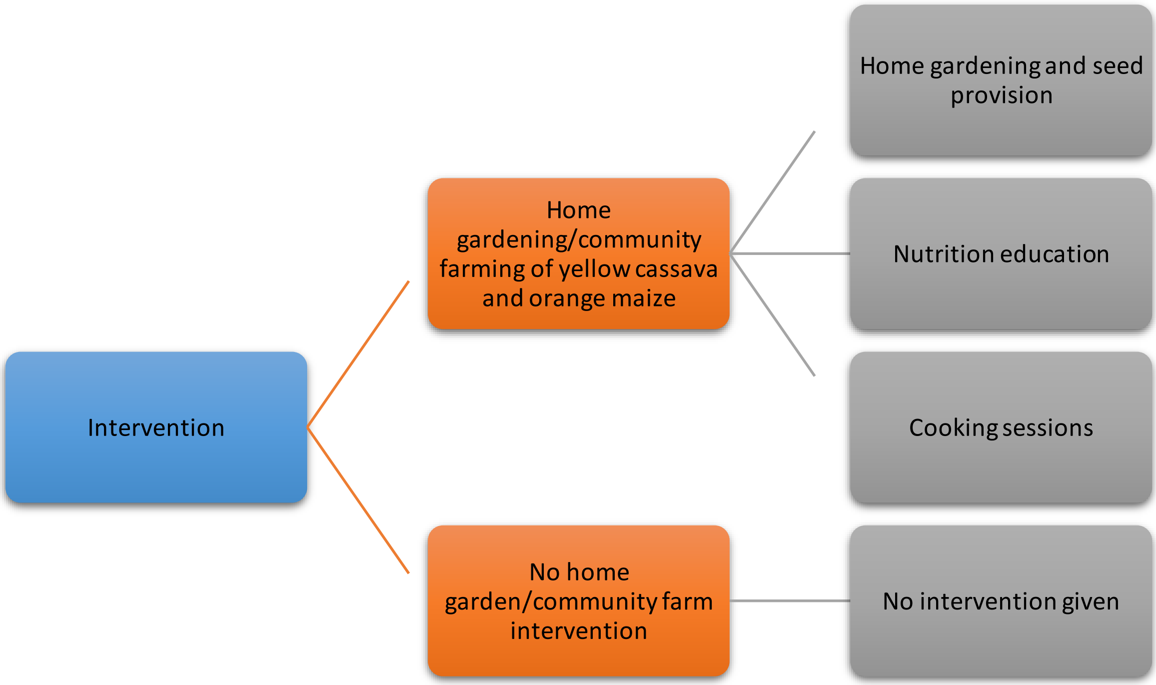
3.4.2 MODEL DESIGN AND STRUCTURE

A cohort Markov model made up of four health states (well, low serum retinol, blind and death) was programmed in Microsoft Excel. This model was conceptualised based on the epidemiology of vitamin A deficiency in children. According to the WHO (2009), vitamin A deficiency is defined as low serum retinol ≤0.70micromoles per litre. The low serum retinol health state was set at ≤0.70 µmol/l based on the WHO definition. The low retinol state was set at ≤0.70 µmol/l to represent the subclinical and clinical stages of vitamin A deficiency and these stages were all accounted for in costs and DALYs. The blind health state was defined as a progressed state of low retinol where a child has little or no light perception and the dead health state represents the terminal state of the condition. Health states representing malnourishment were excluded as there is no evidence showing that home gardening of yellow cassava and orange maize has the potential to prevent malnutrition in children. Since yellow cassava and orange maize are the crops considered which primarily targets improving serum retinol levels in children, adding health state on malnutrition or other health conditions may not be appropriate. If other crops targeting wider nutritional benefits were considered, then it might have been appropriate to include malnutrition and other health conditions as a health state. I assumed that the intervention is for one year and households will continue to engage in home gardening in the subsequent years even after intervention support is withdrawn by replanting from their harvest. I assumed that there will be return to original levels of home gardening/community farming and original crops after one year. Although, one year of consuming vitamin A-rich diet may not be protective against vitamin A deficiency for a long time, however, the model assumes that households will continue to engage in planting and consuming yellow cassava and orange maize in the subsequent years. Besides preventing eye health problems, home food production can increase household income through sale of surplus yield. As evidence has shown that vitamin A deficiency increases the risk of diarrhoea and measles (Stevens et al., 2015), these health conditions were reflected in the model. A lifetime horizon of 80 years was used in the model to capture blindness which is irreversible and lasts a lifetime. The model used a cycle length of one year. A funder's (a charity organisation such as Sight Savers) and societal perspectives were used and run as separate analyses. My supervisors (Ed Wilson and Jennifer Whitty) validated my model from conceptualisation to writing up. They checked validity of results based on empirical evidence used to inform the model.

INTERVENTION

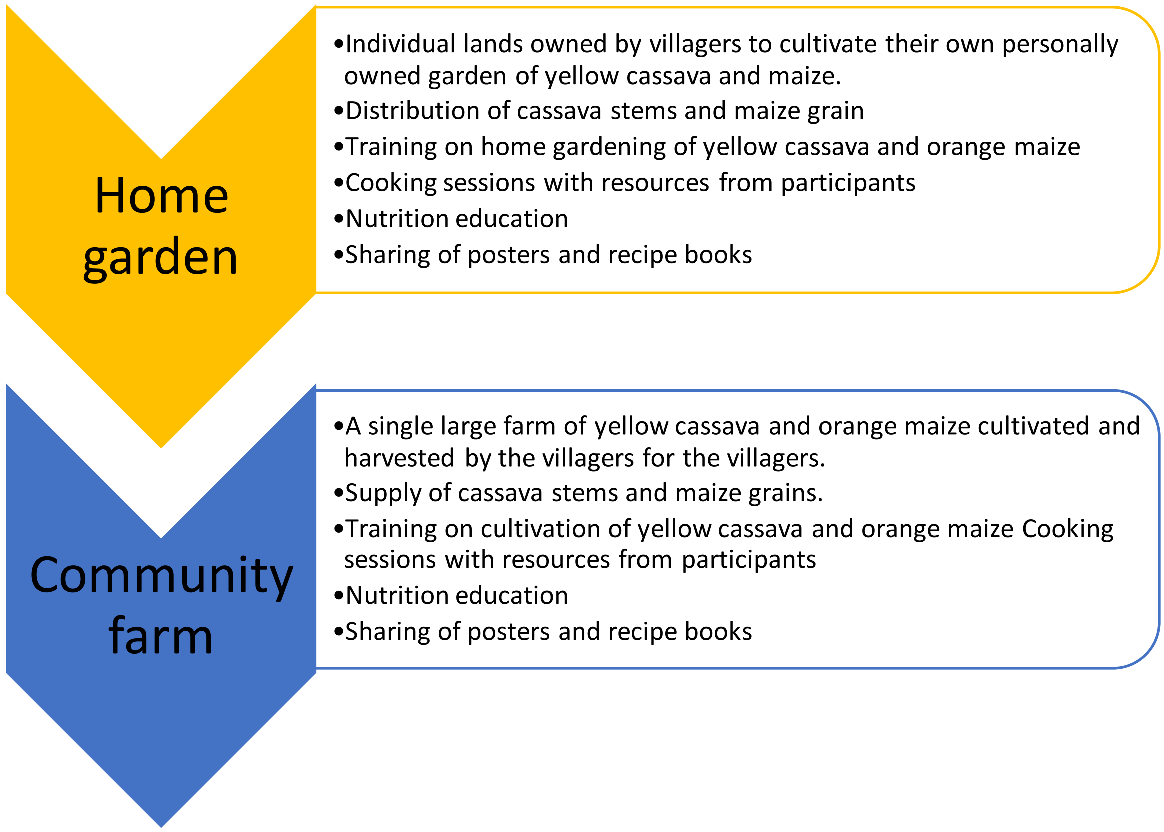
The intervention was assumed to consist of multicomponent parts interacting together, to comprise training households in home gardening/community farming of yellow cassava and orange maize, provision of cassava stems and maize seeds, nutrition education, cooking session and distribution of recipe books and posters detailing the health benefits of vitamin A-rich foods (Figure 3.4). This intervention was assumed to run for one year. The comparator was status-quo: no training or HG intervention. The systematic review in chapter two analysed studies with complex interventions (home gardening, nutrition education and cooking sessions) and this cost-effectiveness study is a continuation of that systematic review. Therefore, it is important to maintain consistency by ensuring that the cost-effectiveness of the same group of interventions is examined. Home gardening/community farming of yellow cassava and orange maize is focused on growing these crops for household consumption where the surplus can be sold to bring in additional income to the family. Community farming was explored as an alternative strategy to make yellow cassava and orange maize accessible to children.

Figure 3.4: Diagram showing intervention and comparator



Two intervention scenarios (Figure 3.5) were assessed – home gardening and community farming. Base case scenario (home gardening) – villagers will use their lands and cultivate their gardens individually, cooking utensils for the cooking sessions and village town hall will be used for free and nutrition education will be carried out. In the second scenario, a large community farm will be cultivated and harvested collectively by the villagers and the produce will be shared among the villagers. In addition, training and nutrition education will be carried out.

Figure 3.5: Scenarios assessed in the Markov model



HOME GARDENS: there will be a provision of cassava stems and maize grains to households. There will be hands-on training using model farms on seedbed preparation, insect and pest control, sowing methods, irrigation, garden layout and organisation, and fertiliser preparation. A total of 834 households will each receive 680g of maize seeds and 4 bundles of cassava stems. Each training session will be made up of 24 households (mother or father). A total of 36 training sessions will be organised. Technical assistance will be given weekly for the first six months of training and will be reduced to monthly visits for the next six months.

COMMUNITY FARM: the same quantity of cassava stems and maize distributed to households will be cultivated on single large farmland. Extra cost for tractor hire, weeding, planting and harvesting will be added. All other interventions (technical assistance, nutrition education, cooking sessions, distribution of posters and recipe books) will be as per home gardening.

NUTRITION EDUCATION: Behavioural change intervention will be conducted (in clusters of households) where men and women will be educated on the health dangers of vitamin A deficiency and the importance of feeding their children yellow cassava and orange maize. Nutrition education will be carried out during the planting season to prepare the minds of parents before the crops are ready for harvest. A one-hour talk will be delivered to households by trained personnel. Posters on the benefits of yellow cassava and orange maize will be given to each household.

COOKING SESSIONS: Twelve Cooking sessions will take place in the village after crops have been harvested, to train households on food preparation of cassava and maize suitable for children. Cooking sessions on pap preparation (maize porridge), maize pudding, fried cassava, cassava pancake, and cassava porridge will be organised to show households different ways of consuming yellow cassava and orange maize. A recipe book on varieties of foods that can be prepared from yellow cassava and orange maize in the local language of the participants will be given to each household.

COMPARATOR: No home garden/community farm intervention alternative was the comparator as it is assumed that the target population have not been exposed to any intervention related to preventing vitamin A deficiency because they live in a remote geographical area not covered by any vitamin A interventions such as vitamin A supplementation programmes.

3.4.3 POPULATION

The target population are households with children below the age of five from Ovia North-east Local Government Area in Edo State, Nigeria (Figure 3.6). Children below the age of five are more susceptible to vitamin A deficiency which is responsible for the death of about one million children yearly (UNICEF, 2020). Edo State is situated in the southern part of Nigeria and has a high prevalence (32.0%) of vitamin A deficiency (WHO, 2007). Ovia northeast local government area has a population of 217,461 and an area of 2,303.1 km^2 (City Population, 2021). Agriculture is the mainstay in Edo state with about 80% of the population involved in subsistence farming. Cassava and maize are staple crops grown in Edo state (Oriakhi et al., 2017). Data for children below the age of five in Ovia northeast local government were not found. I assumed that there are 2500 children below age five in a village in Ovia north-east local government area. Also, it was assumed that each household would have three children below the age of five, making 834 households in each village. The intervention was focused on just one village in Ovia north-east local government area. The unit of analysis was a village.

Figure 3.6: Map showing local government areas in Edo state

Source: (Agbeso, 2012)

3.4.4 TRANSITION PROBABILITIES

Transition probabilities were derived from the most relevant available evidence (Awasthi et al., 2013; Imdad et al., 2017). A systematic literature search was conducted to identify the most recent and relevant data used in estimating the progression of the cohort across different health states. Transition probabilities from well state to low retinol state were derived from Imdad et al. (2017), as were relative risks for low retinol and death. The transition probability of moving from low retinol to well and low retinol to blind was obtained from Awasthi et al. (2013). Imdad et al. (2017) is a Cochrane systematic review and meta-analysis of 43 trials with 215,633 children. This study evaluated the effect of vitamin A supplementation on all-cause mortality, measles and diarrhoea related mortality, the incidence of diarrhoea and measles, night blindness, bitot's spot and xeropthalmia. Imdad et al. (2017) did not present all the relevant data needed in this study. Hence another study Awasthi et al. (2013) included in the systematic review by Imdad et al. (2017) was used because it contained relevant data to inform the model. Awasthi et al. (2013) conducted a randomised controlled clinical trial with a population of one million children for five years with children aged one to six years. Awasthi and colleagues assessed the effect of vitamin A supplementation on mortality, diarrhoea, measles, night blindness, bitot's spots amongst others. This study was found relevant as it investigated an intervention (vitamin A supplementation programme) to prevent vitamin A deficiency, carried out in a LMIC and its population was in children. Probabilities were calculated as recommended by Fleurence and Hollenbeak, 2007 (Fleurence & Hollenbeak, 2007) using equation 3.1

Equation 3.1: $p = 1 - e^{-rt}$ where r is the rate per unit time t.

Transition probabilities for moving from well health state to dead was obtained from the Nigerian life table sourced from the WHO (WHO, 2016). An average of the male and female probabilities of dying was calculated from the life tables and used. The transition probability of dying from blindness was obtained from the WHO (WHO, 2000). Table 3.2 show the transition probabilities for progressing through the model.

Table 3.2: Model parameters and distributions for probabilistic sensitivity analysis

Transition probabilities	Mean	Distribution	Parameter 1	Parameter 2	Source
Well to low retinol	0.450	beta distribution	509	623	(Imdad et al., 2017)
Well to dead	Life table				(WHO, 2016)
Low retinol to well	0.060	Beta	155	2429	(Awasthi et al., 2013)
Low retinol to blind	0.035	Beta	90	2494	(Awasthi et al., 2013)
Low retinol to dead	0.026	Beta	67	2517	(Awasthi et al., 2013)
Blind to Dead	0.60	Uniform	0.1	0.9	(WHO, 2000)

For beta distribution – parameter 1 is alpha and parameter 2 is beta. For uniform distribution – parameter 1 is the minimum and parameter 2 is the maximum.

3.4.5 VALUATION OF RESOURCES

Two perspectives were used for this cost-effectiveness analysis – a funder's perspective and a societal perspective. From the funder's perspective, which is most likely to be a charity organisation, costs related to funders were estimated such as costs of personnel, costs of training, costs of cassava stems and maize grains. Societal perspective captured the cost of the wider benefit of intervention to participants such as the sale of surplus garden produce and costs of livelihood forgone while caring for children living in blindness. Table 3.3 describes the costs captured by the two perspectives in more detail. A breakdown of cassava and maize production was gathered independently from two Agric-economist experts using a step-by-step process of maize and cassava production. This was achieved through series of video calls. One of the Agric-economists is a known expert both in teaching on the economics of cultivation of local crops in Nigeria including cassava and maize as well as the practical experience of cultivation of these crops through numerous projects he has handled. A second opinion was sought from another Agric-economist who has carried out numerous cassava and maize cultivation projects especially in rural Nigeria. Costing was done using the activity-based costing method. Activity-based costing is a costing approach that identifies all activities, traces consumption of resources by activity and assigns costs to each activity (Bromwich & Hong, 1999). Costs were converted using purchasing power parity 2020 (PPP) international dollars at 148.69 naira for Intl$1 (IMF, 2020). A discount rate of 3.50% was applied based on the recommendation from WHO (WHO, 2008b). The costs of the cooking sessions, microphones, projectors, posters and recipe books were estimated based on market prices from vendors of these goods. Resources were costed for 834 households. Sales made from surplus garden produce were based on assumption and imputed in the model by subtracting it from the total cost of intervention.

Table 3.3: Activity-based costing of resources and health states (PPP international $ 2020)

Home garden	**Unit price (PPP International dollars (148.69), 2020)**	**Quantity**	**Total (USD, 2020)**	**Reference**
Home garden				
Maize seeds	1.14/kg (170 naira)	567.13kg (680g per family for 834 households)	107.71 Per village 107.71/12 = 8.975	Expert consultation
Cassava stems	6.72 per bundle (1000 naira)	3336 bundles (4 bundles per family)	22435.94	Expert consultation
Proceeds from the sale of	5.04 (750 naira)	834	4194.40	Based on assumption

surplus produce				
Health education				
Microphones	100.88 (15000 naira)	1	100.88	www.nigerianprice.com
Projector	73.97 (11000 naira)	1	73.97	www.nigerianprice.com
Posters	3.36 (500 naira)	834	2802.24	Based on assumption
Cooking session				
Recipe book	2.01 (300 naira)	834	1676.34	Based on assumption
Personnel				
NGO staff	1008.8 (150000 naira)	4	4035.20	Expert consultation
Proceeds from the sale of surplus produce	5.04 (750 naira)	834	4194.40	Based on assumption
Total			27,577.38	
Community farm				
Tractor hire	40,000		269.01	Expert consultation
Weeding, planting and harvesting	65,000		437.15	Expert consultation
Total			37,487.80	
Cost of health states				
Health state	Unit cost	Quantity	Total	Source/notes
Well	0	0	0	Based on assumption
Low retinol	Diarrhoea	3 episodes	56.40	Expert consultation

	• ORS – 1.34 (200 naira) • Zinc tablet – 1.34 (200 naira) • Floranom (Saccharomyces boulardii) 4 sachets – 4.03 (600 naira) Total = 18.8			
	Measles • Vitamin C – 1.34 (200 naira) • Paracetamol – 0.67 (100 naira) • Seven keys (Calamine lotion) – 5.38 (800 naira)	1 episode	7.39	
Blind	672.54 (100,000 naira)	12 months	8070.48	Expert consultation
Dead	0	0	0	

3.4.6 COST OF HEALTH STATES

Children in the well health state were assumed to lack vitamin A-rich foods, no cost was ascribed to the well health state based on this assumption. For the low retinol health state, the cost of three episodes of diarrhoea in a year was added as it was assumed that a child would have three episodes of diarrhoea yearly, (WHO, 2020) and the cost of one-off measles was estimated and added exogenously. The forgone monthly livelihood of caring for a blind child was estimated as the cost of being in the blind health state. No cost was ascribed to the dead state. See details in table 3.4. Opportunity cost of households working in home gardens was not included as it is assumed that these households are already engaging in home garden. The villagers involved in cultivating the community farm will be paid for their time (weeding, planting and harvesting). Changes in healthcare costs was not included due to lack of available data on monetary changes home food production would bring to the healthcare.

Table 3.4. Unit cost of health states.

Health states	Mean	Distribution	Parameter 1	Parameter 2	Source
Well	0	Uniform	0	0	
Low retinol	56.40	Uniform	50.84	61.14	Based on assumption
Blind	8070.48	Uniform	7263.43	8877.53	Based on assumption
Dead	0	Uniform	0	0	

For a uniform distribution – parameter 1 is the minimum and parameter 2 is the maximum.

3.4.7 EFFECT OF YELLOW CASSAVA AND ORANGE MAIZE SERUM RETINOL IN CHILDREN

Yellow cassava and orange maize are relatively new interventions, therefore, it is not a surprise that a systematic review examining their effects on serum retinol was found on searching. The systematic review (Chapter two) carried out in this thesis assessed the effects of home gardening of diverse crops including vitamin A-rich foods. A more suitable study that focused solely on the effect of yellow cassava was used. A randomised controlled trial conducted in Kenya (Talsma et al., 2016) examined the effectiveness of vitamin A cassava on serum retinol. This study recruited 342 children between 5 and 13 years of age and allocated them to white cassava and placebo supplement, yellow cassava (1460 mg b-carotene/d) and placebo supplement or white cassava and beta-carotene supplement. The children received this intervention six days per week for 18.5 weeks. Yellow cassava modestly increased serum retinol by 0.04mmol/L (95% CI: 0.00 to 0.07 mmol/L) and reduced the prevalence of vitamin A deficiency by 3.5% (95% CI 8.3 to 15.1). A 2 by 2 table was calculated using data from Talsma et al., 2016 (Talsma et al., 2016) and the relative risk of low retinol was estimated (Appendix 16).

3.4.8 HEALTH OUTCOMES

DISABILITY-ADJUSTED LIFE YEARS (DALYs)

Outcomes were measured in DALYs. The DALY was chosen as the health outcome as it is useful in quantifying disease burdens in developing countries (Sassi, 2006). The DALY measures the health burden of a population by accounting for a decrease in life expectancy of an individual and a reduction in quality of life (WHO, 2020b). The DALY burden for any condition can be defined as the sum of years of life lost due to mortality and the quality of life lost to a disability. Mathematically, a DALY is calculated as shown in equation 3.2

Equation 3.2: DALY =YLL+YLD.

In equation 3.2, YLL represents the years of life lost due to premature mortality and measures lost life expectancy. It is estimated as the number of deaths (n) multiplied by the standard life expectancy at age of death; whereas, YLD represents years lived in disability and is estimated as incidence rate multiplied by disability weight and the time spent in the disease condition before recovery or death (Global Health, 2021). Discounted DALYs accrued for one episode of measles was added exogenously to the total DALYs in the model. A model was set up separately to calculate the discounted DALY for one episode of measles using the DALY formula (Equation 3.2). DALYs for measles were discounted (Equation 3.1) for 47 years. The average age of death from measles is 5 years (WHO, 2020c), this was subtracted from the life expectancy in Nigeria (52.98 years) to give 47 years. Appendix 15 shows how the DALYs for measles were derived and the data used. Discounted DALYs for one episode of measles were added exogenously to the total DALYs in the model. Total DALYs in both the intervention and control arm were calculated for 834 households. Table 3.5 shows the estimation of DALYs for the health states.

DISABILITY WEIGHT

Disability weight is a measure of the severity of a disease in a health state ranging from 0 (perfect health) to 1 (death) (WHO, 2020b). Disability weights were assigned to each health state using the disability weights for the global burden of disease study 2019 (Global Health Data Exchange, 2019) . The disability weight for the well state was ascribed 0 and death was 1 (Appendix 17). In the health state of low retinol, disability weights of low serum retinol and blindness was obtained from the global burden of disease 2019 (Global Health Data Exchange, 2019) The discount rate for DALYs was 3.50% based on WHO recommendations and total DALYs accrued over the time horizon of the model were calculated and multiplied by 834 households.

Table 3.5. DALY accrued per year by health states

Health states	**Distribution**	**Mean**	**Parameter 1**	**Parameter 2**	**Source/notes**
Low retinol	**Beta**	**0.184**	**1.315**	**5.836**	(Global Health Data Exchange, 2019)
Well	Constant	0	0	0	
Blind	Beta	0.187	1.289	5.605	(Global Health Data Exchange, 2019)
Dead	Constant	1	1	1	(WHO, 2008b)

For a beta distribution – parameter 1 is alpha and parameter 2 is beta.

3.4.9 SENSITIVITY ANALYSIS

Probabilistic sensitivity analysis (PSA) was conducted by ascribing distributions to the model parameters. A lognormal distribution was used for the relative risk of low retinol and death. For the transition probabilities, a beta distribution was used apart from blind-to-death where a uniform distribution was used because of the source of data. A constant distribution was used for the disability weights (except for low retinol where a beta distribution was used) and a uniform distribution was used for costs data since the costs were based on expert opinion (plus or minus 10%). See tables 3.2, 3.4 and 3.5 for the distributions assigned to input parameters in the model.

A threshold analysis was used to explore the threshold of the relative risk of low retinol at which the intervention ceases to be cost-effective. All other parameters were held constant while the relative risk was varied and the tipping point at which cost-effectiveness was no longer possible was estimated. The tipping point of the relative risk of serum retinol where home gardening of yellow cassava and orange maize was no longer cost-effective was defined based on the decision rule of cost-effectiveness adopted by the study.

3.4.10 MODEL OUTPUT AND PRESENTATION

Mean cost and accrued DALYs were calculated from the PSA results run 5000 times for the control and intervention arm separately. Incremental costs and DALYs were calculated for each of the 5000 units of Monte Carlo simulations. Incremental ICERS were estimated for each simulation. Mean ICERS for both intervention and control arm were estimated. Incremental cost-effectiveness ratio (ICER) was calculated as per equation 3.3 and reported as incremental cost per DALY averted.

Equation 3.3: $ICER = (Costs_{intervention} – Costs_{n0\text{-}intervention})/(DALYS_{intervention} – DALYs_{no\text{-}intervention})$.

The incremental net benefit was calculated and the probability of cost-effectiveness at different thresholds was estimated. Incremental net benefit is the presentation of the results of a cost-effectiveness study in monetary terms when a threshold for a unit of benefit is given. Incremental net benefit involves the conversion of ICER to monetary units or benefits and is estimated by the difference between the monetized incremental effectiveness value and monetary incremental cost (Equation 3.4).

Equation 3.4: incremental benefit * threshold – incremental cost = incremental net benefit.

When the incremental net benefit is greater than zero, home gardening intervention is accepted as cost-effective compared to no intervention (Edlin et al., 2015). These data were used to plot the cost-effectiveness acceptability curve by plotting the probability that home gardening is cost-effective compared to no home gardening intervention at different thresholds. The cost-effectiveness acceptability plane was also plotted. Results were expressed with a 95% credible interval.

3.5 RESULTS

3.5.1 SOCIETAL PERSPECTIVE

3.5.1.1 ANALYSIS 1: BASE CASE – HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE

The results for the base case analysis from a societal perspective showed that the mean costs for 834 households are $6,123.29 for the control arm and $33,670.28 for the intervention arm. Incremental cost of home gardening of yellow cassava and orange maize is $27,546.98 (95% credible interval: $24,887.46 - $30,152.26). The mean DALY accrued in the control arm is 14,097.45 and 14,027.71 in the intervention arm, and the mean incremental benefit is 69.74 DALYs averted (95% credible interval - 264.84 to 109.32). The mean incremental cost-effectiveness ratio (ICER) is $395.00 per DALY averted. This means that at a threshold of $2,880, home gardening of yellow cassava and orange maize is likely to be cost-effective in preventing vitamin A deficiency in children below the age of five years. At a threshold of $2880 per DALY averted, there is uncertainty with a 72.27% likelihood (probability) that home gardening of yellow cassava and orange maize is cost-effective compared to no home gardening intervention (Table 3.6).

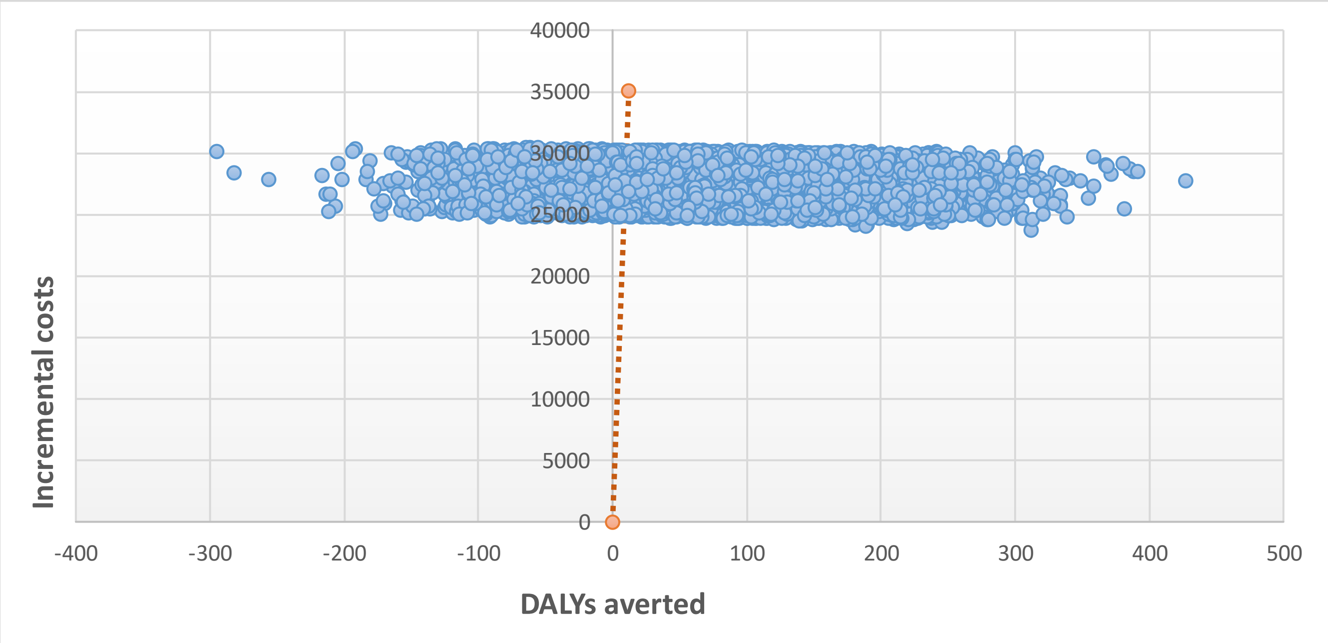
Table 3.6: Main results for the cost-effectiveness of home gardening and community farming yellow cassava and orange maize to prevent vitamin A deficiency in children

Costing perspective	Mean incremental cost (international dollars)	Mean incremental effects	Mean ICER per DALY averted	Likelihood of cost-effectiveness at $2,880 threshold
Societal perspective Home garden	$27,546.98 (95% credible interval: $24,887.46 - $30,152.26).	69.74 DALYs (95% credible interval - 264.84 to 109.32 DALY averted	$395.00 per DALY averted	72.27%
Societal perspective Community farm	$28,200.81 (95% credible intervals $25,487.39 to $ 30,895.41)	66.05 DALYs (95% credible interval - 261.30 to 116.53 DALYs).	$426.96 per DALY averted	70.59%
Funder's perspective Home garden	$31,704.42 (95% credible interval: $28,666.87 to $34,739.17)	68.55 DALYs (-268.35 to 113.39 DALYs)	$462.49 per DALY averted	72.39%
Funder's perspective Community farm	$32,410.98 (95% credible intervals $29,336.75 to $35,514.97	67.96 DALYs (95% credible interval - 262.10 to 109.55 DALYs).	$476.89 per DALY averted	71.42%

COST-EFFECTIVENESS PLANE OF HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED TO NO INTERVENTION FROM A SOCIETAL PERSPECTIVE

The cost-effectiveness plane was used to compare the incremental costs and DALYs averted by home gardening of yellow cassava and orange maize to no home gardening, generated from the PSA (Figure 3.7). The scatter plot shows that home gardening of yellow cassava and orange maize is 100% cost increasing (all points are north of the x-axis) with some portion of the ICERS on the dominated quadrant of the cost-effectiveness plane (north-west quadrant). The dotted orange line represents the threshold line of $2,880 per DALY averted. The cost-effectiveness plane shows that 72.27% of the ICERS fall within the threshold line of $2,880 per DALY averted on the north-east quadrant which means they are cost increasing but more effective and are therefore good value for money. The likelihood that home gardening of yellow cassava and orange maize is cost saving compared to no home gardening intervention is a very small probability.

Figure 3.7: Cost-effectiveness plane of home gardening of yellow cassava and orange maize compared to no intervention from a societal perspective

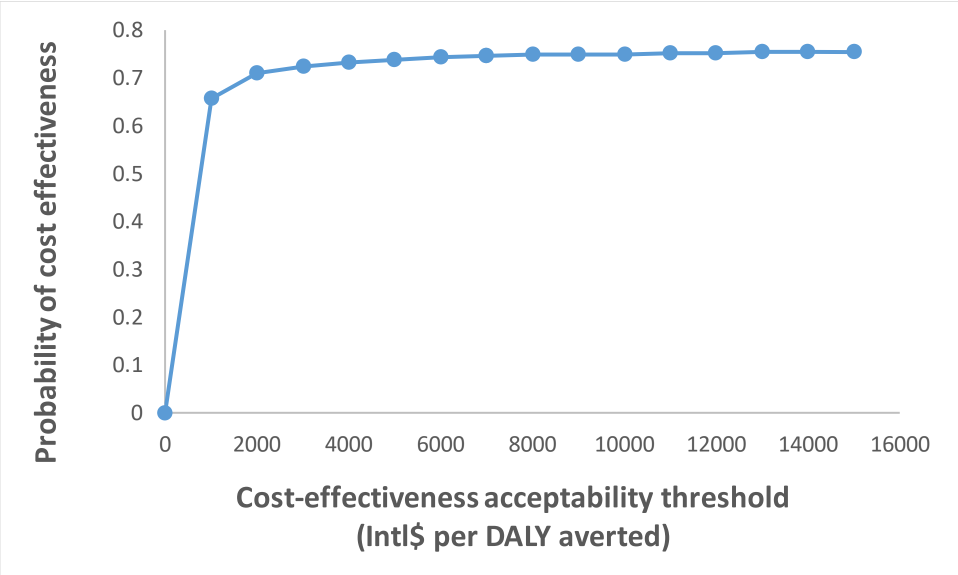


Footnote: The orange line represents a threshold value of $2,880 per DALY averted

COST-EFFECTIVENESS ACCEPTABILITY CURVE OF HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED WITH NO INTERVENTION FROM A SOCIETAL PERSPECTIVE

The Cost-Effectiveness Acceptability Curve (CEAC) shows the likelihood that home gardening of yellow cassava and orange maize from a societal perspective is cost-effective at varying thresholds. The results show that at a threshold value of $2,880 per DALY averted, home gardening of yellow cassava and orange maize is cost-effective with a likelihood of 72.27% compared to no home gardening (Figure 3.8).

Figure 3.8: Cost-effectiveness acceptability curve of home gardening of yellow cassava and orange maize compared with no intervention from a societal perspective



3.5.1.2 ANALYSIS 2: COMMUNITY FARM

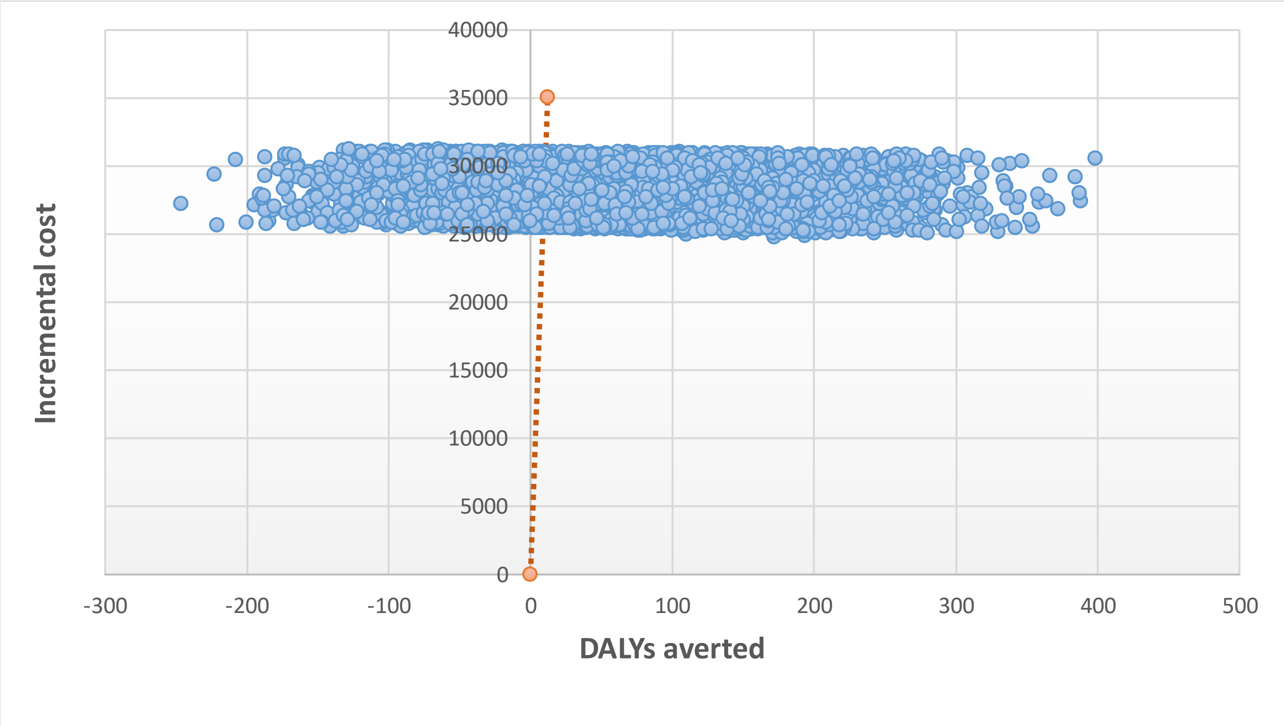
The cost-effectiveness of having a community farm rather than individual gardens in the villages was assessed from a societal perspective. All other interventions were still offered – cooking sessions, health education, distribution of posters and recipe books. Additional cost included in the community farm was for tractor hire (for ploughing, harrowing and ridging) and payment of villagers for weeding, planting and harvesting.

Results showed that the mean cost for 834 households is $6,191.80 for the control arm and $34,392.62 for the intervention arm. The mean incremental cost is $28,200.81 (95% credible intervals $25,487.39 to $30,895.41). The mean DALY accrued for the control arm is 14,091.95 and 14,025.90 for the intervention arm. The mean incremental benefit of community farm over comparator is 66.05 DALYs averted (95% credible interval -261.30 to 116.53 DALYs averted). The incremental expected cost per unit of benefit is estimated at $426.96 per DALY averted. There is uncertainty with a 70.59% likelihood that community farming of yellow cassava and orange maize is cost-effective compared to no intervention. This means that at a threshold of $2,880 per DALY averted, there is a likelihood of 70.59% that community farming is likely to be cost-effective compared to no intervention.

COST-EFFECTIVENESS PLANE OF COMMUNITY FARMING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED TO NO INTERVENTION FROM A SOCIETAL PERSPECTIVE

The cost-effectiveness plane was used to compare the incremental costs and DALYs of community farming of yellow cassava and orange maize to no community farming generated from the PSA (Figure 3.9). The cost-effectiveness plane shows that community farming of yellow cassava and orange maize is 100% cost increasing (all points are north of the x-axis) with some portion of the ICERS on the dominated quadrant of the cost-effectiveness plane (north-west quadrant). The dotted orange line represents the threshold line of $2,880 per DALY averted. Most of the ICERS fall within the threshold of $2,880 per DALY averted in the north-east quadrant which means that they are more costly and more beneficial.

Figure 3.9: Cost-effectiveness plane of community farming of yellow cassava and orange maize compared to no intervention from a societal perspective

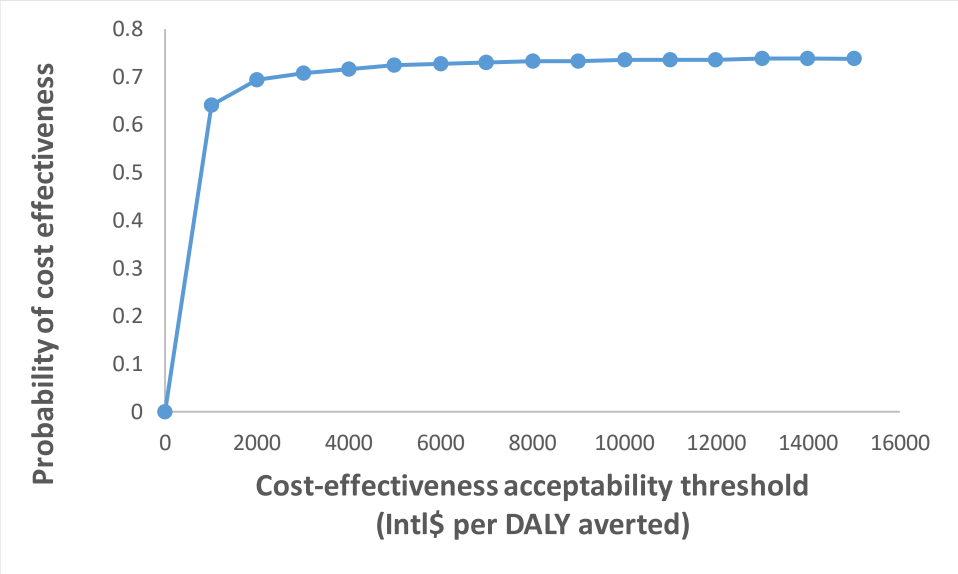


Footnote: The orange line represents a threshold value of $2,880 per DALY averted

COST-EFFECTIVENESS ACCEPTABILITY CURVE OF COMMUNITY FARMING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED WITH NO INTERVENTION FROM A SOCIETAL PERSPECTIVE

The cost-effectiveness acceptability curve shows the likelihood of community farming of yellow cassava and orange maize from a societal perspective being cost-effective at different willingness to pay. At a threshold value of $2,880 per DALY averted for cost-effectiveness, community farming of yellow cassava and orange maize is cost-effective with a likelihood of 70.59% compared to no community farming (Figure 3.10).

Figure 3.10: Cost-effectiveness acceptability curve of community farming of yellow cassava and orange maize compared with no intervention from a societal perspective



3.5.2 FUNDERS PERSPECTIVE

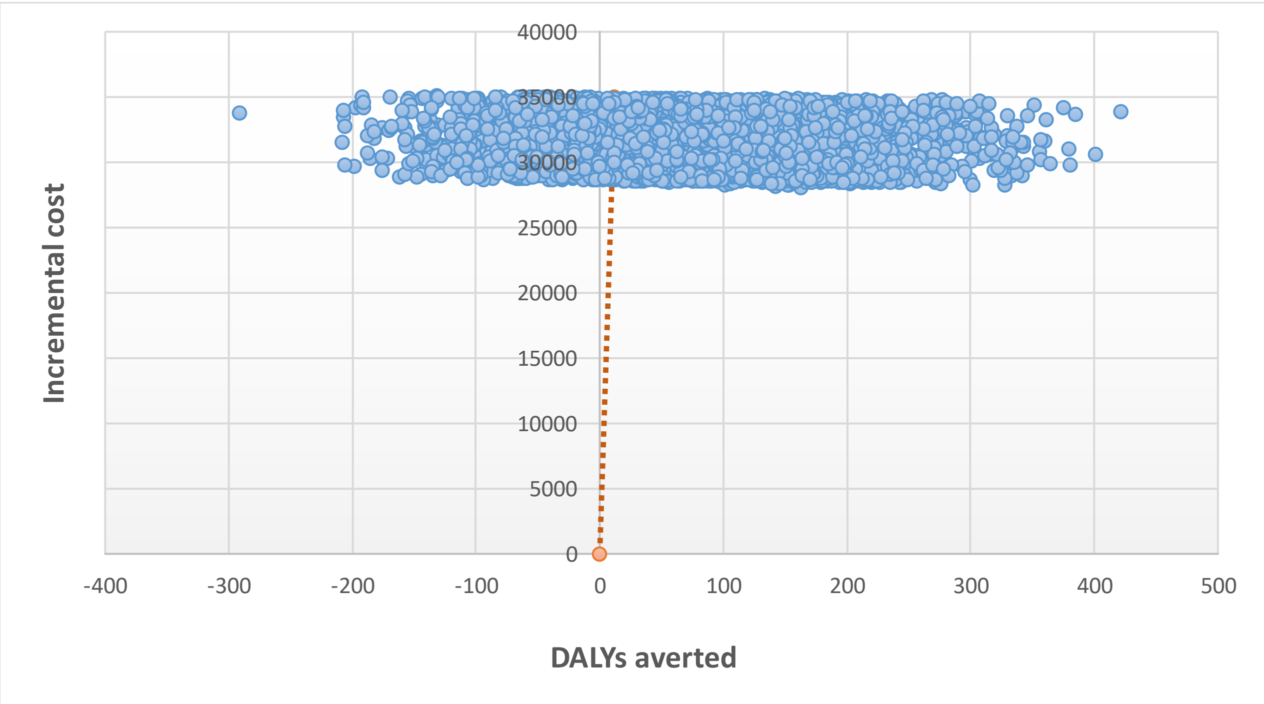
3.5.2.1 ANALYSIS 1: HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE

The mean cost of home gardening of yellow cassava and orange maize from the funder's perspective for 834 households is $6,108.33 for the control arm and $37,812.75 for intervention. The mean incremental cost of home gardening of yellow cassava and orange maize for 834 households is $31,704.42 (95% credible interval: $28,666.87 to $34,739.17). The mean DALY accrued for the control arm is 14,101.91 and 14,033.35 for the intervention arm, and the mean incremental benefit is 68.55 DALYs averted (95% credible interval: -268.35 to 113.39). The incremental cost-effectiveness ratio (ICER) is $462.49 per DALY averted. At a threshold of $2,880 per DALY averted, there is uncertainty with 72.39% likelihood that home gardening of yellow cassava and orange maize is cost-effective compared to no home gardening intervention.

COST-EFFECTIVENESS PLANE OF HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED TO NO INTERVENTION FROM A FUNDER'S PERSPECTIVE

The cost-effectiveness plane was used to compare the incremental costs and DALYs of home gardening of yellow cassava and orange maize to no home gardening generated from the PSA (Figure 2.1). The scatter plot shows that home gardening of yellow cassava and orange maize is 100% cost increasing (all points are north of the x-axis) with some portion of the ICERS on the dominated quadrant of the cost-effectiveness plane (north-west quadrant). The orange dotted line in figure 3.11 represents the threshold line of $2,880 per DALY averted. Figure 3.11 shows that 72.39% of the ICERS fall within the threshold line of $2,880 per DALY averted on the north-east quadrant which means they are cost increasing but more effective and are therefore good value for money. The likelihood that home gardening of yellow cassava and orange maize is cost-saving compared to no home gardening intervention is likely to be <0.1%.

Figure 3.11: Cost-effectiveness plane of home gardening of yellow cassava and orange maize compared to no intervention from a funder's perspective

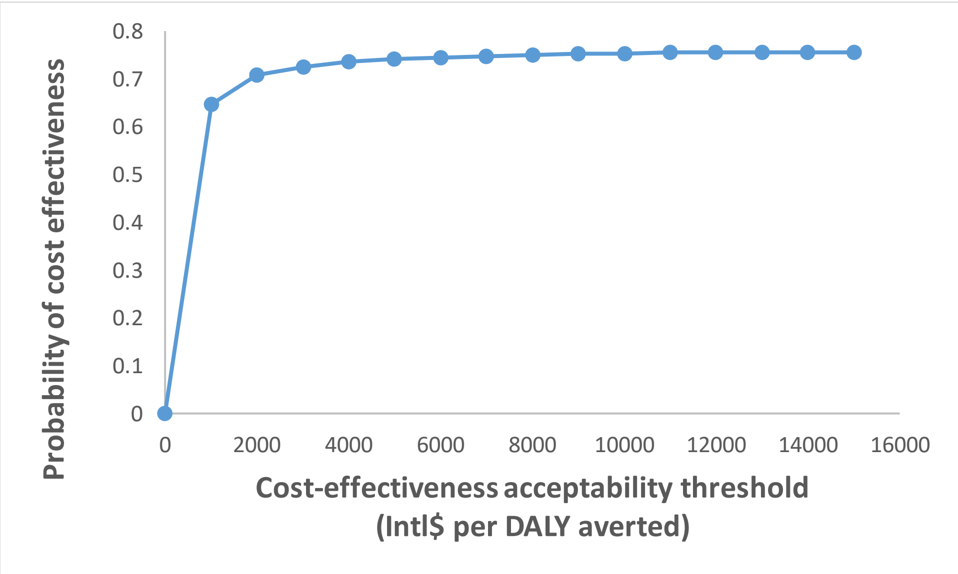


Footnote: The orange line represents a threshold value of $15000 per DALY averted

Cost-effectiveness acceptability curve of home gardening of yellow cassava and orange maize compared with no intervention from a funder's perspective

The cost-effectiveness acceptability curve shows the likelihood of home gardening of yellow cassava and orange maize from a funder's perspective being cost-effective at different willingness to pay. At a threshold value of $2,880 per DALY averted for cost-effectiveness, home gardening of yellow cassava and orange maize is cost-effective with a likelihood of 72.39% compared to no home gardening (Figure 3.12).

Figure 3.12: Cost-effectiveness acceptability curve of home gardening of yellow cassava and orange maize compared with no intervention from a funder's perspective



3.5.2.2 ANALYSIS 2: COMMUNITY FARMING OF YELLOW CASSAVA AND ORANGE MAIZE

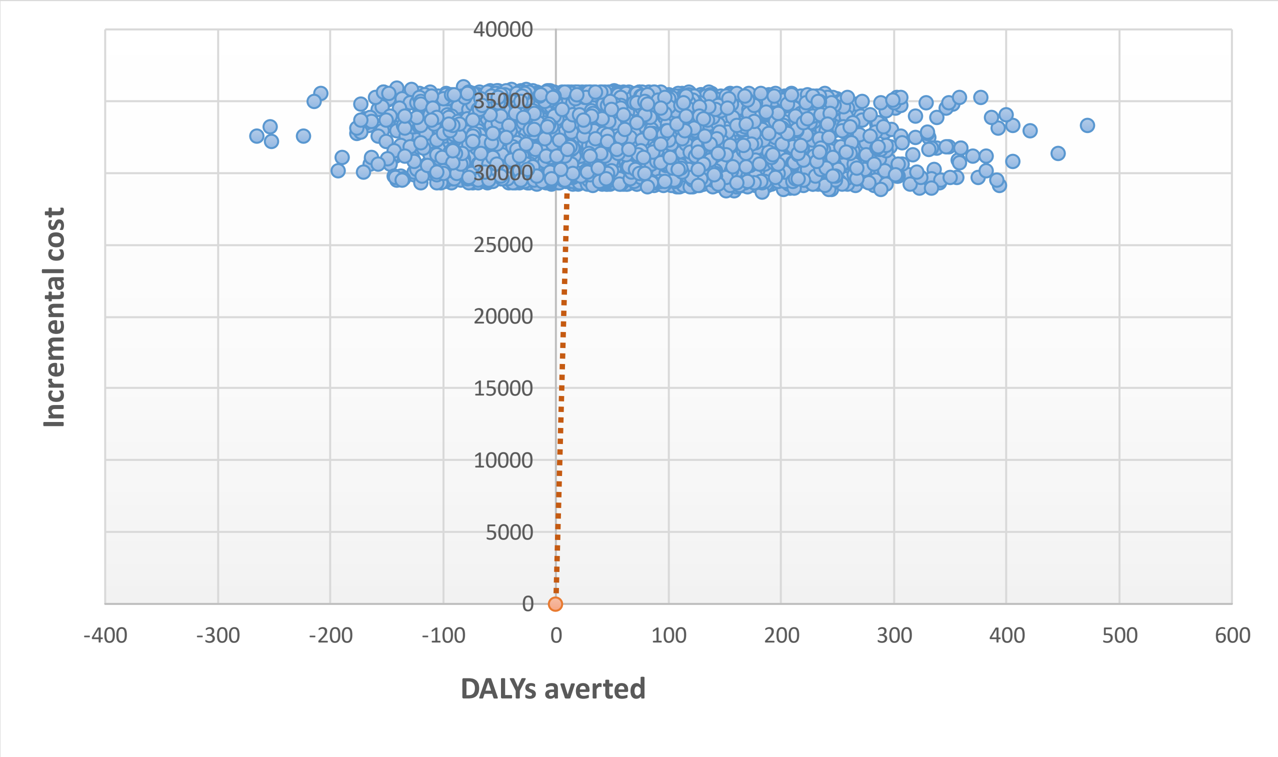
Results for community farm of yellow cassava and orange maize from a funder's perspective showed that the mean cost for the control arm is $6,138.91 and $38,549.89 for the intervention arm. The mean DALY accrued for control is 14,100.37 and 14,032.41 for the intervention arm. The mean incremental cost is $32,410.98 (95% credible intervals $29,336.75 to $35,514.97). The mean incremental benefit of community farm over comparator is 67.96 DALYs averted (95% credible interval -262.10 DALY to 109.55

DALY). The incremental expected cost per unit of benefit is estimated at $476.89 per DALY averted. There is uncertainty with a 71.42% likelihood that community farming of yellow cassava and orange maize is cost-effective compared to no community farming.

COST-EFFECTIVENESS PLANE OF COMMUNITY FARMING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED TO NO INTERVENTION FROM A FUNDER'S PERSPECTIVE

The cost-effectiveness plane was used to compare the incremental costs and DALYs of community farming of yellow cassava and orange maize to no community farming generated from the PSA (Figure 3.13). The cost-effectiveness plane shows that community farming of yellow cassava and orange maize is 100% cost increasing (all points are north of the x-axis) with some portion of the ICERS on the dominated quadrant of the cost-effectiveness plane (north-west quadrant). Figure 3.13 indicates that the intervention is more costly and more beneficial. The dotted orange line represents the threshold line of $2,880 per DALY averted. Most of the ICERS fall within the threshold of $2,880 per DALY averted in the north-east quadrant which means that they are more costly and more beneficial.

Figure 3.13: Cost-effectiveness plane of community farming of yellow cassava and orange maize compared to no intervention from a funder's perspective

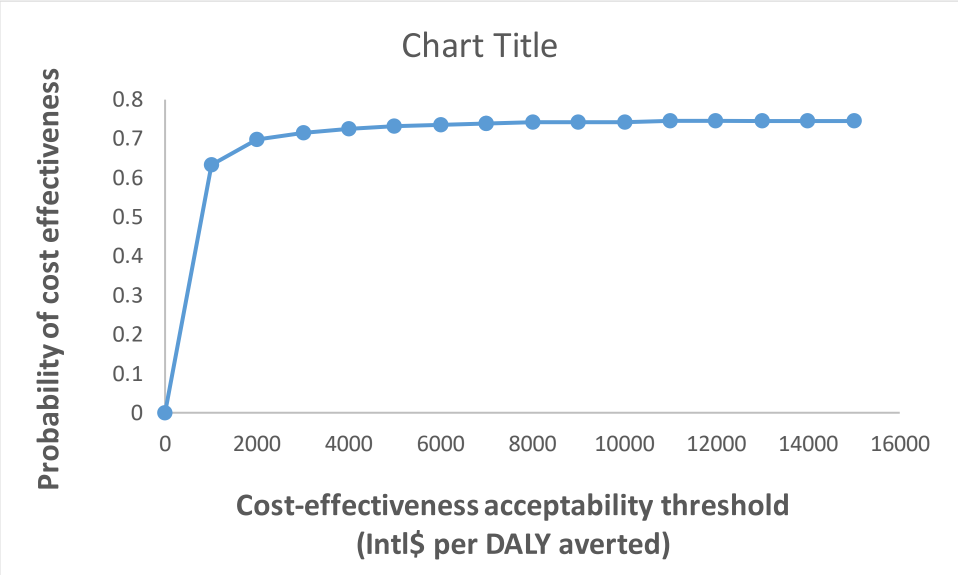


Footnote: The orange line represents a threshold value of $2,880 per DALY averted

COST-EFFECTIVENESS ACCEPTABILITY CURVE OF COMMUNITY FARMING OF YELLOW CASSAVA AND ORANGE MAIZE COMPARED WITH NO INTERVENTION FROM A FUNDER'S PERSPECTIVE

The cost-effectiveness acceptability curve shows the likelihood of community farming of yellow cassava and orange maize from a funder's perspective being cost-effective at different willingness to pay. At a threshold value of $2,880 per DALY averted cost-effectiveness, community farming of yellow cassava and orange maize is cost-effective with a likelihood of 71.42% (Figure 3.14).

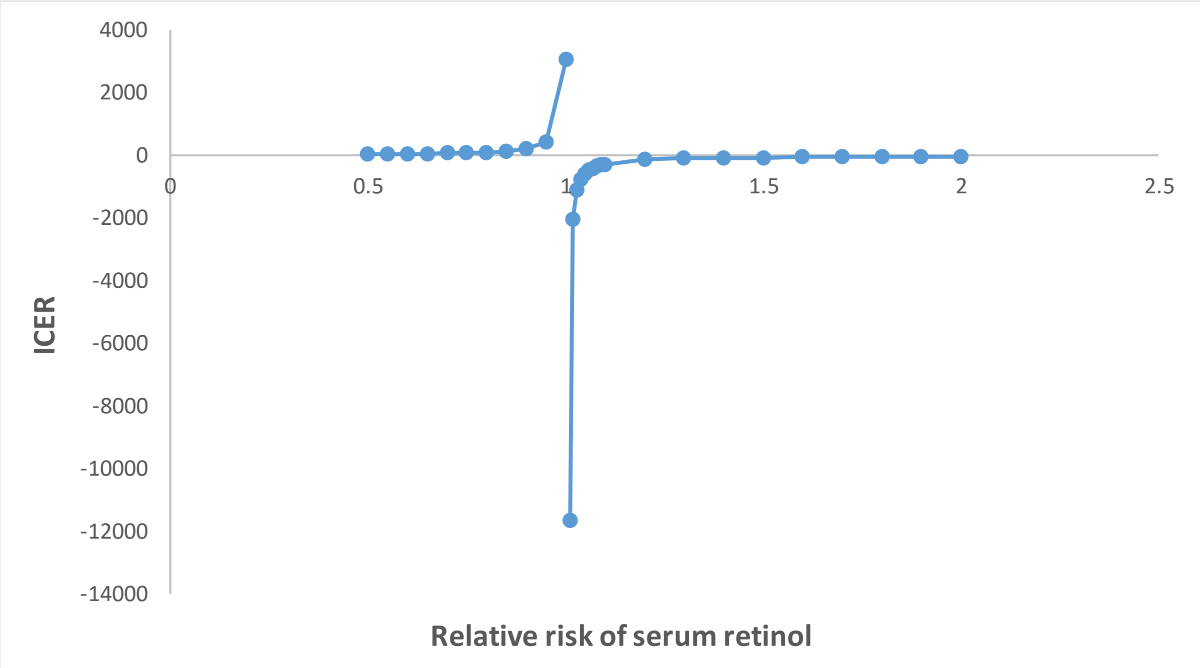
Figure 3.14: Cost-effectiveness acceptability curve of community farming of yellow cassava and orange maize compared with no intervention from a funder's perspective



3.5.3 THRESHOLD ANALYSIS

A threshold analysis of home gardening of yellow cassava and orange maize from the societal perspective was undertaken to examine the relative risk of serum retinol at which home gardening ceases to be cost-effective at a threshold of $2,880 per DALY averted. The relative risk of serum retinol was varied while other parameters were at a static value. At a relative risk of 0.1 to 1.0 of serum retinol, home gardening is cost-effective and ceases to avert DALY beyond a relative risk of 1.0. The steepness of the graph (Figure 3.15) shows that there is a breaking point at a serum retinol relative risk of 1.0 where home gardening stops averting DALYs. This signifies that at very small levels of efficacy of home gardening of yellow cassava and orange maize on serum retinol, the intervention is likely to be cost-effective.

Figure 3.15: Threshold analysis of the relative risk of home gardening of yellow cassava and orange maize from a societal perspective



3.6 DISCUSSION

This is an economic evaluation that used a Markov model to predict the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize in preventing vitamin A deficiency in children. Results from a societal perspective show that home gardening of yellow cassava and orange maize has a 72.27% probability of being cost-effective at a threshold of $2880 with an ICER of $395.00 per DALY averted. The ICERs for the community farm ($426.96 per DALY averted) is higher than the home garden from the societal perspective. For the funder's perspective the home garden (ICER of $462.49 per DALY averted) and the community farm (ICER of $467.89 per DALY averted) showed similar ICERs.

DALY is a metric that shows a numerical representation of the burden of disease (WHO, 2020b). It measures years of life lost and years lived in disability from disease. Public health interventions aim to avert DALYs in a population. This is achieved by reducing years of life lost and years lived in a disability caused by a disease condition (WHO, 2020b). At a threshold of $2880, home gardening and community farming from both perspectives are considered likely to be highly cost-effective. It is also important to state that the threshold analysis of the relative risk of serum retinol demonstrated that even a small efficacy of home gardening of yellow cassava and orange maize on serum retinol (from the societal perspective) will be cost-effective.

The results of this economic evaluation suggest that home gardening and community farming of yellow cassava and orange maize from both the societal and funder's perspectives have roughly the same probability of benefits and cost-effectiveness. This suggests that the choice to implement either a home garden or a community farm of yellow cassava and orange maize should not be based on health benefits but other factors such as logistics issues, economic and social benefits amongst others. However, there is no evidence to establish these suggestions from the model.

3.6.1 BENEFITS OF A HOME GARDEN VERSUS A COMMUNITY FARM

The main difference between community farming and individual home gardens is that a community farm is cultivated on a large piece of land collectively by the villagers for the villagers. Community farming can foster the practice of community development amongst people. Community development is the practice of community members uniting or collaborating to strategize, address and solve problems common to them by taking unanimous or synergistic actions (Campfens, 1997; Ledwith et al., 2005). One of the primary objectives of community development is to build a firm, unified and resolute community (Campfens, 1997). Creating sustainable agricultural projects can potentially achieve the goals and objectives of community development – it builds capacity among community members, considers social justice, promotes oneness among community members and takes health as an integral part of community development (Campfens, 1997; Ledwith et al., 2005). It also serves as crucial support to poor households in the community (Biddle & Biddle, 1965).

One major advantage of home gardening is that surplus produce can be sold and more income generated to the family (Lakzadeh, 2016; Low et al., 2007; Olney et al., 2009; Schreinemachers et al., 2016). The findings from the systematic review in chapter two (Bassey et al., 2020) corroborates this claim. Another advantage of home gardening is that it is dominantly cultivated by women which puts them in control of the produce and its use, and it has been adopted as a means of empowering women (Schreinemachers et al., 2016; Sraboni et al., 2014). A systematic review by Rao et al. (2019) found that empowering women through agriculture enhanced household dietary diversity and per capita calorie availability (Rao et al., 2019). It is important to mention that the economic evaluation in this thesis has focused on children below the age of five, however, the effect on other members of the family who would benefit from the consumption of yellow cassava and orange maize was not captured. Therefore, the true cost-effectiveness of the intervention may have been under-estimated.

3.6.2 BENEFITS OF A HOME GARDEN FROM A SOCIETAL PERSPECTIVE

While the difference in the results of home gardening and community farming of yellow cassava and orange maize are marginal and are all likely to be highly cost-effective and provide almost the same benefit, home gardens may be more beneficial to households than community farms. Households tend to have more control and ownership over a home garden than a community garden. A community farm requires more effort and protocols in planning and executing than a home garden which is relatively easier to manage by individual families. Households are also able to decide how to spend the extra income from their surplus produce while the extra income from a community farm may be used for public good. Home gardening is a good strategy to address food insecurity and the pervasiveness of hunger in LMICs (Galhena et al., 2013). Implementing home gardens from the societal perspective may be more beneficial compared to the funder's perspective. This is because the societal perspective of home gardening considers the monetary gain of selling surplus produce which has the potential of being beneficial economically to households (Ahmed et al., 2017; Kolapo & Kolapo, 2021). Also, the societal perspective will be implemented by government agencies in Nigeria which is more likely to receive attention from policymakers than from charity organisations who fund based on interest (funder's perspective). However, having explored the intervention from the funder's perspective is also important as charity organisations may desire to take on the fight against vitamin A deficiency in children.

3.6.3 SIMILARITY OF MODEL WITH OTHER STUDIES

This economic evaluation is the first to predict the cost-effectiveness of home gardening of yellow cassava and orange maize in preventing vitamin A deficiency in children using a decision-analytic model

(Markov model). Meenakshi et al. (2010) carried out an ex-ante modelling study that assessed the futuristic cost-effectiveness of biofortification in combatting micronutrient malnutrition in Ethiopia, Kenya and Nigeria. Their study included the evaluation of yellow cassava and orange maize in preventing vitamin A deficiency in children in optimistic and pessimistic scenarios. Their results, for the pessimistic scenario, showed that the cost per DALY saved in Nigeria is $137.40. Orange maize was cost-effective with an ICER of $113 per DALY averted in Kenya and $289 per DALY averted in Ethiopia. The optimistic scenario showed that both yellow cassava and orange maize will cost less than $20 per DALY averted for all three African countries (Meenakshi et al., 2010). The findings of Meenakshi et al. (2010) are in line with that of my study as they both show that yellow cassava and orange maize are likely to be cost-effective in Nigeria. However, Meenakshi et al. (2010) did not use a decision-analytic model (Markov model), and it was not a home gardening/community farming intervention. Other studies have mostly assessed the cost-effectiveness of commercial food fortification and vitamin A supplementation in tackling vitamin A deficiency (Fiedler et al., 2000; Fiedler & Afidra, 2010; Fiedler & Macdonald, 2009; Loevinsohn et al., 1997; M. Phillips et al., 1996). Fiedler and Afidra (2010) assessed the cost-effectiveness of fortifying sugar with vitamin A in Uganda. Their results showed that sugar fortification is cost-effective in preventing vitamin A deficiency. In 2009, Fiedler and Macdonald (2009) carried out a cost-effectiveness study of fortifying sugar and vegetable oil in 48 countries with a high prevalence of vitamin A deficiency. Their results also showed that these food items were cost-effective in combatting vitamin A deficiency. The concern with commercial fortification is that in very remote areas in LMICs, sugar and vegetable oil are not within the reach of people's purchasing power and may not be consumed in adequate quantity to prevent vitamin A deficiency. The cost-effectiveness analysis presented in this thesis differs from the other studies that have been discussed in that a decision-analytic framework was the method adopted. In addition, this study focused on children and has also explored the option of a community farm.

3.6.4 STRENGTHS AND LIMITATIONS OF THE MARKOV MODEL

The strength of this economic evaluation lies in the fact that a systematic review with high quality evidence was used to obtain some of the evidence used and a randomised controlled trial conducted in India with a large sample size of one million children below the age of six years was used as part of the evidence in this study. Some limitations of this study are that all costs were derived from expert consultation which is likely to introduce uncertainty to the model. Transition probabilities were obtained from a systematic review that examined the effectiveness of vitamin A supplementation programme on mortality, xeropthalmia, serum retinol amongst other outcomes. There was no systematic review that has assessed the impact of home gardening of yellow cassava and orange maize on serum retinol and other desired outcomes which would have been the ideal evidence to use. The systematic review carried out in chapter two of this thesis did not find any evidence for mortality and xeropthalmia. Therefore, it could not be used. The systematic review used to inform the parameters of this model was the best available evidence and a PSA was carried out to account for uncertainty. As costs for this model was derived from expert consultation, uncertainty was estimated at a plus or minus 10%. This may have caused the uncertainty regarding the cost to be small relative to the difference in the uncertainty regarding effects. This explains why the shape of the scatter plot appears flat and wide, and the CEACs appear steep. This model assumed that the intervention will be a one-off cost and households will continue with home food production after the first year, replanting from their harvests. This assumption may not be true as some households may quit the intervention once support is withdrawn or may not have a viable harvest to replant. Biofortification programmes require new variety of crops that have an improved resistance to disease, pests and a more viable harvest. These assumptions may have introduced bias to the model, making it more cost-effective than it may likely be. Using transition probabilities from a vitamin A supplementation intervention may likely have a greater chance of moving people from one health state to another compared with a home gardening intervention. Vitamin A supplementation provides a high dose of vitamin A to children whereas for home gardening, households may decide to sell their produce, harvest might be poor due to environmental factors such as crop disease, drought etc. vitamin A-rich foods will supply a lower proportion of retinol compared with vitamin A supplements. This may have exaggerated the results of this cost-effectiveness analysis. The benefit for this model was estimated from an intervention that exposed children to yellow cassava as the intervention arm and white cassava for the control group. It is important to state that this intervention may not be beneficial to every family as some families may not be covered by the intervention, some families may not consume the yellow cassava, some families may have a bad harvest or sell the harvest. These limitations may have influenced this analysis to appear more cost-effective.

Assumptions were made on the revenue derived from the sale of surplus farm produce. The quantity of farm produce sold would differ across households based on factors such as family size and needs. However, in the funder's perspective where revenue from the sale of surplus farm produce was omitted, the impact of this parameter was demonstrated in the model to have no remarkable influence on the model results. Opportunity cost of households' time in home gardening was not included as it is assumed that these households are already engaging in gardening activities. Changes in healthcare costs as a result of the intervention was not included due to unavailability of data. This may have impacted on the results of the cost-effectiveness analysis. The results of this cost-effectiveness analysis should be interpreted with caution bearing in mind the assumptions made in the study.

3.6.5 UNCERTAINTIES ASSOCIATED WITH THE COST-EFFECTIVENESS OF HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE IN PREVENTING VITAMIN A DEFICIENCY IN CHILDREN

Although the results of this study show that home gardening/community farming of yellow cassava and orange maize is likely to be highly cost-effective from a societal and funder's perspective, there is a 29.41% - 27.61% uncertainty associated with its cost-effectiveness. This means that there is a chance that these interventions may not be cost-effective. Gaining additional information to reduce uncertainty might be beneficial before deciding whether to adopt home gardening/community farming of yellow cassava and orange maize as an intervention to prevent vitamin A deficiency in children. Before proceeding to generate additional information, it is imperative to consider if this additional research (to reduce uncertainty) will yield a good return on investment. Therefore, carrying out a value of information analysis (VOI) is necessary to establish if more research would be worthwhile. A VOI analysis will establish whether a judgement of adopting home gardening of yellow cassava and orange maize can be made based on available evidence. The next chapter of this thesis will focus on a VOI analysis to assess the value of additional research to reduce the uncertainty associated with the results of this model.

CHAPTER FOUR

VALUE OF INFORMATION ANALYSIS ON THE COST-EFFECTIVENESS OF HOME GARDENING/COMMUNITY FARMING OF YELLOW CASSAVA AND ORANGE MAIZE TO PREVENT VITAMIN A DEFICIENCY IN CHILDREN

4.0 SUMMARY

Chapter three used a decision-analytic model to predict that home gardening/community farming of yellow cassava and orange maize is likely to be highly cost-effective with some uncertainty (29.41% - 27.61%) associated with its cost-effectiveness. This chapter assesses the value of additional research to resolve the probability (29.41% - 27.61%) of home gardening/community farming of yellow cassava and orange maize not being cost-effective in the prevention of vitamin A deficiency in children. The Sheffield Accelerated Value of Information Analysis (SAVI) software was used to carry out the analysis. The results showed that from the societal perspective: The expected value of perfect information (EVPI) for 31 million Nigerian children would be $925 billion and $1.01 billion for home garden and community farm respectively. From the funder's perspective, EVPI would be $926 billion and $904 billion for home garden and community farm respectively. The results of the expected value of perfect parameter information (EVPPI) showed that from both the societal and funder's perspective, additional research to resolve the uncertainties associated with all the parameters is not worthwhile except the relative risk of serum retinol which gave a value of $925 billion and $1.01 billion from the societal perspective (for home garden and community farm respectively) and $929 billion and $904 billion from the funder's perspective (for home garden and community farm respectively). The results have highlighted that carrying out additional research would yield a good return on investment before deciding whether

home gardening/community farming of yellow cassava and orange maize can be implemented in the prevention of vitamin A deficiency in children.

This chapter starts with the first section which is an overview of what VOI means, the second section will focus on the methods adopted, the third section will report the results of the analysis and the last section will discuss and interpret the results.

4.1 INTRODUCTION

4.1.1 WHAT DOES UNCERTAINTY MEAN IN A DECISION-ANALYTIC MODEL?

Decision models typically use evidence from different sources usually beset by uncertainty from the distributions surrounding the parameters (Briggs et al., 2006). Uncertainty in a cost-effectiveness analysis can be defined as the unreliability of the expected costs and benefits of implementing a healthcare intervention for a given population. Uncertainty differs from heterogeneity in that heterogeneity is the variability in patient population caused by the characteristics of the patients (Drummond et al., 2015). Estimating incremental costs and benefits of a healthcare intervention is carried out in uncertain conditions or circumstances. This means that decisions, whether to recommend or not to recommend a healthcare intervention based on the results of a cost-effectiveness study, is in itself uncertain (Briggs et al., 2006). Uncertainty is introduced into cost-effectiveness studies through several ways – evidence that informed the model parameters, assumptions made in building the model and suitability of evidence, (Briggs et al., 2006; Edlin et al., 2015).

In decision models, there are widely practised methods of exploring uncertainty. The deterministic sensitivity analysis was mostly used before PSA became more popular in building decision models. Deterministic sensitivity analysis is made up of two methods namely one way and multi-way sensitivity analysis. One way sensitivity analysis is achieved by varying individual parameters and recording their impact on the results of the model. It shows how a particular parameter affects model outputs. In a multi-way sensitivity analysis, the model parameters are varied at the same time to estimate their impact on model results (Drummond et al., 2015). When using a deterministic sensitivity analysis, some of its limitations are that it doesn't reveal the degree of uncertainty in a decision and it also doesn't show which parameters are likely to contribute more to the uncertainty associated with model results (Edlin et al., 2015). The decision on which alternative to adopt in a cost-effectiveness study is crucial. There are cases where huge changes to model input parameters will not change the decision (which alternative is more cost-effective). In contrast, sometimes, small changes in model input parameters can change the results of a model. Hence, it is appropriate for the changes in model input parameters to be tied to the uncertainty surrounding the estimation of these parameters. This explains why varying inputs parameters in a deterministic sensitivity analysis is inadequate. Due to these limitations, a deterministic sensitivity analysis is not recommended in accounting for uncertainty and a more comprehensive way (PSA) of investigating uncertainty in a model has been recommended by experts (Briggs et al., 2006; Edlin et al., 2015).

PSA assigns distributions to all the parameters in a model. A Monte Carlo simulation in which samples at random is used to sample these distributions. Expected costs and benefits are generated from each sample. This process is iterated as much as 10,000 times and the mean costs, effects and ICER are calculated for each sample. A possible range of values that costs and effects are likely to take is generated through this procedure. The CEAC plotted from the PSA results shows the probability of each strategy being cost-effective at a given willingness-to-pay. Most importantly, the CEAC deduced from the PSA results gives the percentage of uncertainty surrounding the decision from the model results and gives a headway to take the analysis further by assessing if additional information is needed or whether a decision can be made with available or existing information (Drummond et al., 2015). Making the wrong decisions due to uncertain results from models could be detrimental to the health of people affected by these decisions and would consequently be a waste of limited resources to healthcare funders. A logical way of reducing uncertainty in the results of a decision model would ideally be to conduct more research to reduce uncertainty, however, the decision to gather more evidence must be cost-effective or must be worthwhile in terms of comparing the cost of that research to its intended or potential benefits in reducing uncertainty in the adoption of a new health intervention (Briggs et al., 2006).

4.1.2 VALUE OF INFORMATION ANALYSIS (VOI)

VOI is a systematic structure that quantifies what the likely value of research would be in obtaining additional information to reduce decision uncertainty or whether to make a decision based on available evidence. Other areas of research such as engineering and environmental risk analysis have successfully employed VOI (Tuffaha, 2020) and it is now being used in evaluating healthcare technologies and in research prioritisation by the National Health Service (NHS) and for informing research advocacy by the National Institute for Health and Care Excellence (NICE) (Briggs et al., 2006).

VOI quantifies if additional research is worthwhile by estimating the overall expected value of perfect information (Briggs et al., 2006; Edlin et al., 2015). If the expected value of perfect information is greater than zero, the expected value of perfect parameter information for single parameters and groups of parameters is estimated. This shows the impact of each parameter on decision uncertainty (Briggs et al., 2006; Edlin et al., 2015). If the expected value of information for perfect parameter is greater than zero, the expected value of sample information (EVSI - the value of additional research for specific sample size) and expected net gain of sampling (ENGS - the difference between EVSI and research cost) is then estimated. By comparing the expected monetary benefits against the costs of carrying out the research, VOI provides information regarding reimbursement decisions of new health technologies when there is insufficient evidence to support their use (Briggs et al., 2006; Edlin et al., 2015). VOI analysis provides valuable information in the optimisation of trial designs by pointing out what sample size would generate the greatest economic value (Briggs et al., 2006; Edlin et al., 2015). Lastly, it helps in prioritizing research by providing information on which research design would give the maximum return on investments (Briggs et al., 2006; Edlin et al., 2015). While VOI may have some significant benefits as a decision tool, it has a limited application in practice. This is due to the intricacies surrounding its estimation particularly the expected value of sample information and the limited knowledge of VOI amongst researchers and decision makers (Tuffaha, 2020). Some researchers may view VOI as a hindrance in gaining research funding (Tuffaha, 2020). Nevertheless, it is an effective way to make appropriate use of limited funds in allocating resources for research. Contrary to researchers perceiving VOI as a hindrance to obtaining research funding, it could strengthen grant application by showing that the research would make good return on investments (Briggs et al., 2006; Edlin et al., 2015).

Results from the Markov model presented in chapter three showed an uncertainty associated with the results of the model ranging from 17.30% - 25.10%. This chapter is a sequel to chapter three and will present a VOI analysis of the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize in combatting vitamin A deficiency in children. The overall aim is to investigate if undertaking additional information is a good use of resources in deciding whether to adopt home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children. This chapter is presented in the following order – methods, results and discussion.

4.2 AIM:

To evaluate the value of further research on home food production in preventing vitamin A deficiency in children

4.2.1 RESEARCH QUESTIONS:

- Should further research be conducted based on the level of uncertainty surrounding the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize?
- If further research is to be conducted on home gardening/community farming of yellow cassava and orange maize, what type of studies should be prioritized?

4.3 METHODS

The VOI analysis was carried out based on the PSA of the Markov model developed in chapter three. The SAVI software (version 2.2.0) was used to carry out the VOI (Strong et al., 2014). SAVI is a quick and easy online based software that runs a VOI analysis by uploading the costs, effects and probabilistic results from a Markov model. SAVI simplifies the rigorous process of calculating the expected value of perfect parameter information (Strong et al., 2014). VOI analysis was chosen as a methodology for this work to quantify the value of future research to reduce the uncertainty associated with the results from the Markov model developed in chapter three. In this VOI analysis, the following were calculated: benefit, expected value of perfect information (EVPI), expected value of perfect parameter information (EVPPI) for single and group parameters. These were estimated for the two intervention scenarios in the two costing perspectives.

4.3.1 NET MONETARY BENEFIT

Net monetary benefit is the translation of the value of an intervention to monetary terms using a summary statistic at a given threshold or willingness-to-pay for a known unit of benefit (Edlin et al., 2015). Net monetary benefit was calculated by choosing a threshold of Intl$15,000, then multiplying it with DALY and subtracting from cost (Equation 4.1). The incremental net monetary benefit was calculated as the difference between the net monetary benefit in the control and intervention arm. This calculation was done for each iteration in the PSA in both the control and intervention arm.

Equation 4.1: Net monetary benefit = (E * WTP - C)

E = effectiveness; WTP = willingness-to-pay threshold; C = cost

4.3.2 EXPECTED VALUE OF PERFECT INFORMATION (EVPI)

In assessing EVPI, the value of obtaining perfect information for all parameters of a cost-effectiveness analysis at a given threshold or willingness-to-pay is estimated. It is the monetary value of eliminating all uncertainty from cost-effectiveness analysis. In simple terms, EVPI is the difference in monetary value between the expected net monetary benefit with perfect information and the expected net benefit with existing evidence or information (Briggs et al., 2006). A numeric approach was adopted in estimating EVPI where the output from the Monte Carlo simulation was used. For the Monte Carlo simulation, 5000 iterations were run, the maximum net monetary benefit for each of the iterations were estimated for both the control and intervention arm. An average of the maximum benefit was calculated. The difference in the maximum benefit between the control and intervention arm was estimated (Briggs et al., 2006; Edlin et al., 2015).

To calculate EVPI, first, calculate the maximum net benefit for each iteration from the simulation. Second, calculate the mean of the maximum net benefit estimated in step one (Briggs et al., 2006; Edlin et al., 2015). The EVPI can then be calculated (Equation 4.2) as the difference between the Expected NB given perfect information and the expected net benefit with the information at hand.

Equation 4:2: $EVPI = E_{\vartheta} max_j \, NB(j,\vartheta) - max_j \, E_{\vartheta} \, NB\,(j,\vartheta)$

Table 4.1: Hypothetical calculation of EVPI for a single patient

	No home garden	Home garden	Optimal choice	Maximum net benefit	Opportunity loss
Iteration 1	274,079	271,888	No home garden	274,079	2,191
Iteration 2	275,000	279,590	Home garden	279,590	0
Iteration3	282,536	281,900	No home garden	282,536	636
Iteration 4	265,333	266,454	Home garden	266,454	0
Iteration 5	283,100	282,334	No home garden	283,100	766
Expectation	276,009.6	276,433.2		277,151.8	781.6

All costs are in Intl$

The method described above is a hypothetical calculation of EVPI (Table 4.1) for two alternatives – home gardening of yellow cassava and orange maize and no home gardening. The table shows five iterations from a simulated output of a PSA. From this simulation, the best decision is to choose the alternative with the highest expected net benefit which in this case is home garden intervention with a value of Intl$276,433.2. The alternative with the maximum net benefit (from columns 2 and 3) can be chosen if perfect information is given. This means choosing home garden for iteration 1, no home garden for iteration 2, home garden for iteration 3, and home garden for iteration 4. Because the true value of the optimal choice is not known, the expected net benefit with perfect information is the average of the optimal choice in column 4. The EVPI is estimated as the difference between the expected net benefit with perfect information and the expected net benefit with current information (Intl$277151.8 – Intl$276009.6 = Intl$781.6). Another way to estimate the EVPI is to take the mean of the opportunity loss in the last column. The opportunity loss is estimated by calculating the difference between the net benefit of optimal choice and the alternative that would be chosen based on existing information for each iteration.

4.3.3 EXPECTED VALUE OF INFORMATION FOR THE POPULATION

When the EVPI has been estimated for a single patient, it is imperative to estimate the EVPI for the entire population affected by the decision to seek additional information to reduce uncertainty in a cost-effectiveness study. When the population EVPI is greater than the expected cost of obtaining additional research, it suggests that it is cost-effective to carry out additional research (Briggs et al., 2006). According to UNICEF, in Nigeria, there are about 31 million children under the age of five with 7 million babies born annually (UNICEF, 2021). The expected value of information for the population that would be affected by the decision is simply to multiply the EVPI by the number of the population. Though some children in Nigeria are receiving vitamin A supplements, all children under the age of five are at risk of vitamin A deficiency, hence 31 million was chosen as the population that would be affected by the decision made from the results of the research. Estimating the EVPI for the future population that would be affected by this decision is calculated by discounting at rate r (3.50% discount rate was chosen to maintain consistency with the model in chapter three using equation 4.3.

Equation 4.3: Discount rate = $1/(1+r)^t$

r is the rate of discount and t is time in years

This study estimated EVPI for a cumulative population of Nigerian children in 20 years. Table 4.2 shows the estimation of the cumulative population of Nigerian children in a 20-year time frame.

Table 4.2: Estimation of a cumulative population of Nigerian children in a 20-year time frame.

Time	**Population**	**Discount factor**	**Discounted Population**
0	31,000,000	1	31,000,000
1	7,000,000	0.966184	6,763,285
2	7,000,000	0.933511	6,534,575

3	7,000,000	0.901943	6,313,599
4	7,000,000	0.871442	6,100,096
5	7,000,000	0.841973	5,893,812
6	7,000,000	0.813501	5,694,505
7	7,000,000	0.785991	5,501,937
8	7,000,000	0.759412	5,315,881
9	7,000,000	0.733731	5,136,117
10	7,000,000	0.708919	4,962,432
11	7,000,000	0.684946	4,794,620
12	7,000,000	0.661783	4,632,483
13	7,000,000	0.639404	4,475,829
14	7,000,000	0.617782	4,324,473
15	7,000,000	0.596891	4,178,234
16	7,000,000	0.576706	4,036,941
17	7,000,000	0.557204	3,900,426
18	7,000,000	0.538361	3,768,528
19	7,000,000	0.520156	3,641,090
Total	107,443,641		

4.3.4 EXPECTED VALUE OF PERFECT PARAMETER INFORMATION FOR SINGLE PARAMETERS

In considering decision uncertainty, the EVPPI is the value of reducing uncertainty for individual parameters included in a model. However, some parameters might have more impact on uncertainty than others. It is important to do a disintegrated analysis when considering decision uncertainty to provide more precise evidence to decision-makers on how to prioritise research resources (Briggs et al., 2006; Edlin et al., 2015). EVPPI is a method of carrying out a disintegrated analysis in VOI analysis. EVPPI calculation is similar to calculating EVPI. It is the difference between the expected net health benefit with existing information and the expected net benefit with perfect information for a particular parameter in the model (Briggs et al., 2006; Edlin et al., 2015). To estimate the expected net benefit with perfect information, the iterations are run for each potential value of the parameter of interest whilst varying all the other model parameters through a Monte Carlo simulation. The maximum net benefit between the intervention and control is recorded for each run and the mean is taken. The mean gives the expected net benefit with perfect information for that particular parameter. Similar to the EVPI, the expected net benefit with perfect parameter information and existing parameter information is the EVPPI (Equation 4.4).

Equation 4.4: $EVPPI_{\varphi} = E_{\varphi} \max_j E_{\{\varphi\psi\}} NB(j, \varphi, \psi) - \max_j E_{\theta} NB(j, \theta)$

Where $\boldsymbol{\varphi}$ is the parameter of interest, $\boldsymbol{\psi}$ is the rest of the parameters included in the model, and $\boldsymbol{\theta}$ is the existing information on all parameters in the model (Briggs et al., 2006; Edlin et al., 2015).

4.3.5 EXPECTED VALUE OF PARAMETER PERFECT INFORMATION FOR GROUP PARAMETERS.

Another approach that was explored in calculating the EVPPI in this VOI analysis was by grouping parameters and estimating the value of additional research in obtaining perfect information. Briggs and his colleague stated that individual EVPPI for parameters do not add up to the EVPI. In the same vein, EVPPI for a group of parameters may be different from the individual sum of the EVPPIs of those parameters (Briggs et al., 2006). The EVPPIs for individual parameters may be zero but when analysed as a group, the value of additional research may be significant (Briggs et al., 2006; Edlin et al., 2015). Parameters that could be conducted as a study were grouped. The relative risk of serum retinol and costs of home gardening were grouped as a randomised controlled trial alongside a cost analysis.

Parameters that require baseline risk evaluation (observational study) were grouped and parameters were also grouped based on a cost analysis. Table 4.3 shows the grouping of the parameters.

Table 4.3: Group of EVPPI

Set	Parameters
1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead
2	relative risk of serum retinol and cost of home garden
3	well cost, cost of low retinol and cost of blindness

The EVPPI indicates what parameters to focus on and what study designs are needed. If the EVPPI shows that further research is potentially worthwhile, the next measurements of a VOI will be to estimate an EVSI and an ENGS (Edlin et al., 2015; Wilson, 2015). The EVSI is the process of reducing the expected cost of uncertainty associated with additional research with specified sample size. The EVSI indicates how much uncertainty is expected to be reduced thereby giving the value of additional research for a particular sample size. The ENGS is the difference between the expected cost from the trial and the cost of the trial (population EVSI – research cost = ENGS) (Edlin et al., 2015; Wilson, 2015). It gives the value of the return on investment and therefore demonstrates that the research is worthwhile if it has a value greater than zero (Edlin et al., 2015; Wilson, 2015). The EVSI and the ENGS are beyond the scope of this study due to the complexity of calculating them within the timeframe stipulated for this study.

4.4 RESULTS

4.4.1 SOCIETAL PERSPECTIVE

4.4.1.1 BASE CASE ANALYSIS: HOME GARDENING

4.4.1.1.1 OVERALL EVPI FOR HOME GARDENS

The overall EVPI per person affected by the decision of adopting home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children is estimated at Intl$29,843.50 per person. This means that the value of gaining perfect information in deciding whether to adopting home gardening of yellow cassava and orange maize is Intl$29,843.50 per person that will be affected by the decision. With an annual population of 31 million Nigerian children, overall EVPI would be Intl$925 billion in one year. This study used a time horizon of 20 years to estimate the EVPI and it is presented in Table 4.4. Researching to obtain perfect information would not be cost-effective if it costs more than Intl $925 billion. In reality, no research would cost Intl$9.25 billion, this means that carrying out additional research to resolve the uncertainty associated with home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children would be worthwhile.

Table 4.4: Overall EVPI for home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective.

Population	**Population**	**Overall EVPI (Intl$)**
Per Person Affected by the Decision		29,843.50
Per Year in Nigeria Assuming 31000000 Persons Affected per Year	31,000,000	925,100,000,000
5 Years	56,711,554	4,626,000,000,000
10 Years	84,253,806	925,500,000,000
15 Years	107,443,642	13,880,000,000,000
20 years	126,968,862	18,500,000,000,000

4.4.1.1.2 OVERALL EVPPI FOR SINGLE PARAMETERS

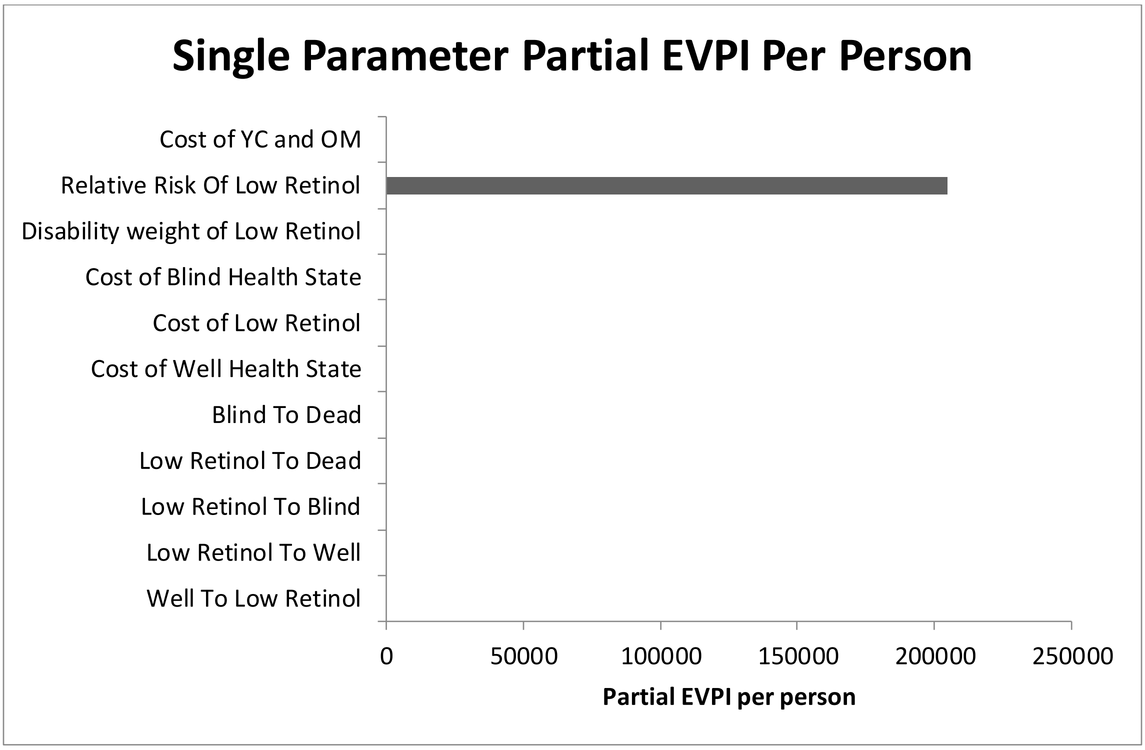
EVPPI for all the parameters was estimated and is presented below. Only the relative risk of low retinol showed a substantial value in carrying out further research to resolve uncertainty (EVPPI per person Intl$29,854.53, EVPPI per annual prevalence Intl$925 billion). All other parameters show that it is not worthwhile carrying out additional research and no further research is needed to eliminate the uncertainty associated with these parameters (Table 4.5 and figure 4.1).

Table 4.5: Overall EVPPI for single parameters for home gardening of yellow cassava and orange maize from a societal perspective

Parameters	Per Person EVPPI (Intl$)	EVPPI for Nigeria Per Year (Intl$)
TP Well to low retinol health state	0.0	0.00
TP Low retinol to 2well health state	0.0	0.00
TP Low retinol to blind health state	0.0	0.00
TP Low retinol to dead	0.0	0.00
TP Blind to dead	0.0	0.00
Relative risk of low retinol	29,854.53	925,500,000,000
Cost of well health state	0.0	0.00
Cost of low retinol health state	0.0	0.00
Cost of Blind health state	0.0	0.00
Disability weight of low retinol	0.0	0.00
Cost of HFP of yellow cassava and orange maize	0.0	0.00

TP – Transition probability

Figure 4.1: EVPPI for single parameters in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective



YC – Yellow cassava and OM – Orange maize

4.4.1.1.3 GROUP PARAMETER EVPPI

While it is important to calculate EVPPI for individual parameters, it is more useful to estimate EVPPI for groups of related parameters. This would point to what kind of research study should be prioritised. The following set of parameters were grouped and are represented in table 4.6. Set 1 (well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead) was grouped as they can be researched together as a cohort study. Set 2 (relative risk of serum retinol and cost of a home garden) can be researched as a randomised controlled trial. Only the group EVPPI for set 2 shows that additional research would be worthwhile (single person EVPPI – Intl$29,851.68 and population EVPPI – Intl$925 billion). Set 3 (cost of well state, cost of low retinol state, cost of blind state) can be researched as a cost analysis but showed that further research would not be worthwhile.

Table 4.6: EVPPI for group parameters in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective

Set	**Parameters**	**Per person EVPPI**	**EVPPI for Nigeria Per Year (Intl$)**
Set 1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead	0.0	0.00000
Set 2	relative risk of serum retinol and cost of home garden	29,851.68	925,401,925,897
Set 3	well cost, cost of low retinol and cost of blind health state	0.0	0.00000

4.4.1.2 ANALYSIS 2: COMMUNITY FARMING

4.4.1.2.1 OVERALL EVPI FOR COMMUNITY FARM

In eliminating all uncertainty, the overall EVPI per child that would be affected by the decision of implementing community farming of yellow cassava and orange maize to combat vitamin A deficiency in children is estimated at Intl$32,568.0 per child. An annual population of 31 million Nigerian children affected by the decision will amount to an overall EVPI of Intl$1.01 billion per year.

Measuring the health gain and costs with the return on investment from the research in obtaining perfect information that would give decision-makers the ability to decide whether to choose community farming should not cost more than $1.01 billion. Overall EVPI at a threshold of Intl$2,880 was estimated at different time intervals (Table 4.7). The results show that in 20 years, it would be valuable to carry out additional research to eliminate the uncertainty associated with the cost-effectiveness of community farming in preventing vitamin A deficiency in children.

Table 4.7: Overall EVPI of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective at various time intervals

No of years	**Population**	**Overall EVPI (Intl$)**
Per person affected by the decision	One person	32,568.0
Per year in Nigeria assuming 31000000 Persons affected per year in one year	31,000,000	1,010,000,000,
5 years	56,711,554	5,048,000,000,000
10 years	84,253,806	10,100,000,000,000
15 years	107,443,642	15,140,000,000,000
20 years	126,968,862	20,190,000,000,000

4.4.1.2.2 EVPPI FOR SINGLE PARAMETERS

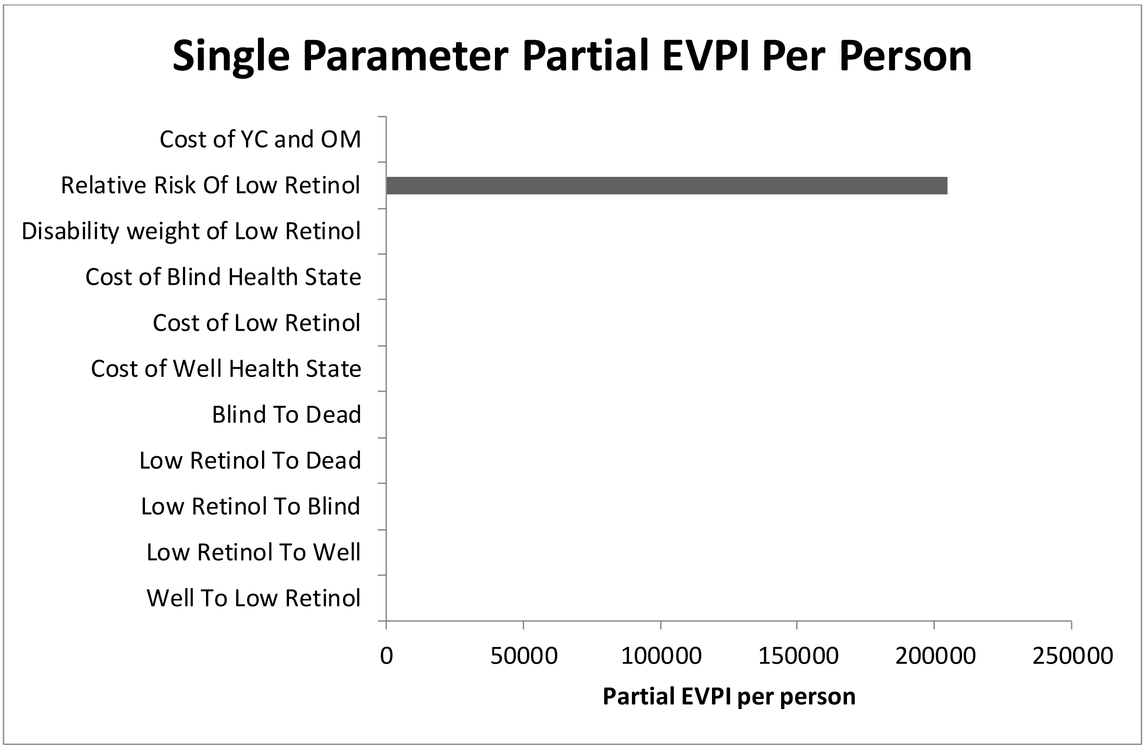
EVPPI for all the parameters was estimated and is presented below. All parameters showed that it is not worthwhile carrying out additional research to eliminate the uncertainty associated with these parameters (Table 4.8 and Figure 4.2). Only the relative risk of low retinol showed that further research would be valuable to eliminate the uncertainty associated with it (EVPPI per person Intl$210,022.90, EVPPI per annual population Intl$6.511 trillion).

Table 4.8: EVPPI for parameters in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective

Parameters	**Per Person EVPPI ($)**	**EVPPI for Nigeria Per Year (Intl$)**
TP of well to low retinol	0.0	0.00
TP of low retinol to well	0.0	0.00
TP low retinol to blind	0.0	0.00
TP low retinol to dead lowR2dead	0.0	0.00
TP blind to dead	0.0	0.00
Relative risk of low retinol	32,610.21	1,011,000,000,000
Cost of well health state	0.0	0.00
Cost of low retinol health state	0.0	0.00
Cost of blind health state	0.0	0.00
Disability weight of low retinol	0.0	0.00
Cost of community farm	0.0	0.000

TP – Transition probability

Figure 4.3: EVPPI for single parameters in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective



YC – Yellow cassava and OM – Orange maize

4.4.1.2.3 GROUP PARAMETER EVPPI

The following set of parameters were grouped and is represented in table 4.9. Set 1 (well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead) was grouped as they can be researched as a cohort study. Set 2 (relative risk of serum retinol and cost of a home garden) can be researched as a randomised controlled trial alongside a cost analysis. Set 3 (cost of well state, cost of low retinol state, cost of blind state) can be researched as a cost analysis. All the sets would not yield good value for further research as no value for EVPPI was generated. However, the EVPPI for a randomised trial assessing the effectiveness of community farming of yellow cassava and orange maize in improving serum retinol alongside a cost analysis shows that undertaking additional research is worthwhile and would yield a good return on research investment (EVPPI per person Intl$209,935.30, EVPPI per population Intl$6.507 trillion).

Table 4.9: EVPPI group parameters in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a societal perspective

	Parameters	Per person EVPPI (Intl$)	Approximate Standard error	EVPPI for Nigeria Per Year (Intl$)
Set 1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead	0.0	49.32	0.000000
Set 2	relative risk of serum retinol and cost of community farm	32605.22	137.28	1,010,762,000,000
Set 3	well cost, cost of low retinol and cost of blind health state	0.0	31.75	0.000000

4.4.2 FUNDER'S PERSPECTIVE

4.4.2.1 ANALYSIS 1: HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE

4.4.2.1.1 OVERALL EVPI FOR HOME GARDENS

The overall EVPI per person affected by the decision of undertaking additional research to resolve uncertainties associated with the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children is estimated at Intl$29,901.30 per person. With an annual population of 31 million children, overall EVPI per year would be Intl$926 billion for Nigeria in one year. The EVPI in future years is listed in table 4.10 and it shows that additional research would be valuable in 20 years in eliminating uncertainty in the cost-effectiveness of yellow cassava and orange maize to prevent vitamin A deficiency in children.

Table 4.10: Overall EVPI in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective

	Population	Overall EVPI (Intl$)
Per Person Affected by the Decision		29,900
Per Year in Nigeria Assuming 31000000 Persons Affected per Year	31,000,000	926,900,000,000
5 Years	56,711,554	4,635,000,000,000
10 Years	84,253,806	9,269,000,000,000
15 Years	107,443,642	13,900,000,000,000
20 years	126,968,862	18,540,000,000,000

4.4.2.1.2 EVPPI FOR SINGLE PARAMETERS

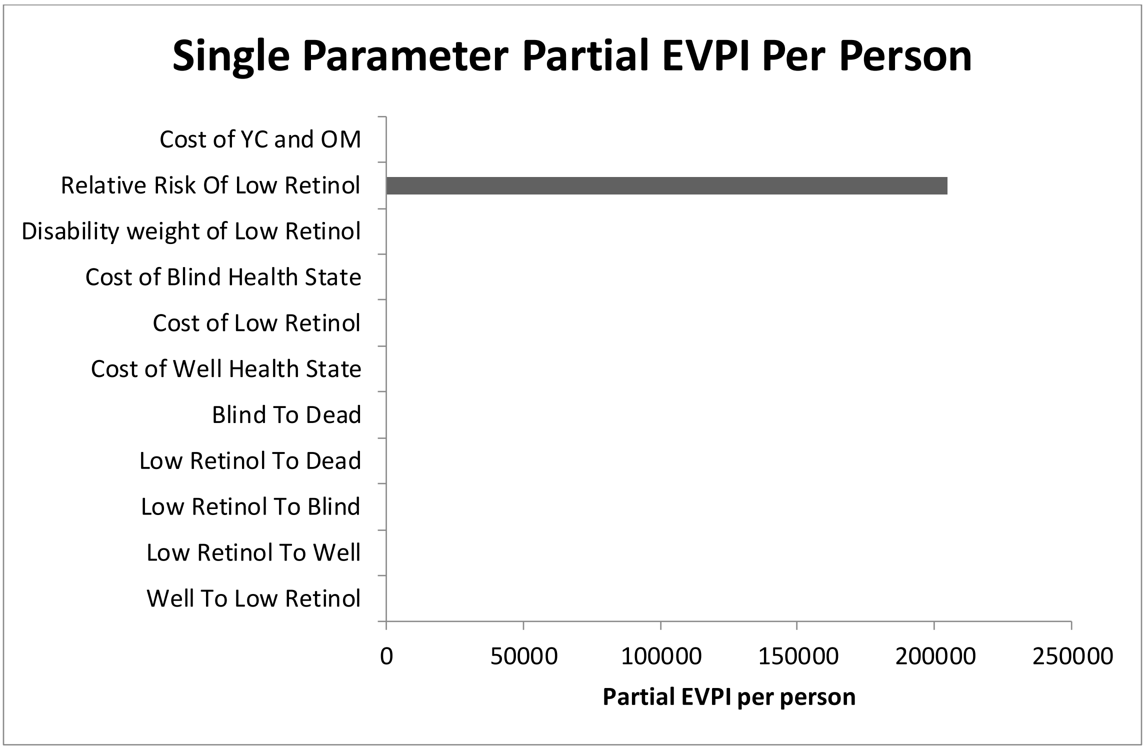
EVPPI for all the parameters was estimated and is presented below. All other parameters show that it is not worthwhile carrying out additional research and no further research is valuable for these parameters (Table 4.11 and figure 4.4). Only the relative risk of low retinol showed that further research would be valuable in eliminating the uncertainty associated with it (EVPPI per person Intl$29,972.67, EVPPI per annual population Intl$929 billion)

Table 4.11: EVPPI for single parameters in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective

Parameters	**Per Person EVPPI (Intl$)**	**EVPPI for Nigeria Per Year (Intl$)**
TP well to low retinol	0.0	0.000
TP low retinol to well	0.0	0.000
TP Low retinol to blind	0.0	0.000
TP low retinol to dead	0.0	0.000
TP blind to dead	0.0	0.000
Relative risk of low retinol	29,972.67	929,200,000,000
Cost of well state	0.0	0.000
Cost of low retinol health state	0.0	0.000
Disability weight of low retinol	0.0	0.000
Cost of HFP of yellow cassava and orange maize	0.0	0.000

TP – Transition probability

Figure 4.4: EVPPI for single parameters in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective



YC – Yellow cassava and OM – Orange maize

4.4.2.1.3 GROUP PARAMETER EVPPI

The following set of parameters were grouped and is represented in table 4.12. Set 1 (well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead) was grouped as they can be researched as a cohort study. Set 2 (relative risk of serum retinol and cost of a home garden) can be researched as a randomised controlled trial alongside a cost analysis. Set 3 (cost of well state, cost of low retinol state, and cost of blind state) can be researched as a cost analysis. All the sets would not yield good value for money apart from set 2 which shows value for money. All 3 sets showed that carrying out further research would be worthwhile (Table 4.12).

Table 4.12: EVPPI for group parameters in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective

	Parameters	**Per person EVPPI**	**EVPPI for Nigeria Per Year (Intl$)**
Set 1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead	11.78	365,246,467
Set 2	relative risk of serum retinol and cost of home garden	29,966.65	928,966,188,007
Set 3	well cost, cost of low retinol health state and cost of blind health state	1.63	50,534,734

4.4.2.2 ANALYSIS 2: COMMUNITY FARM

4.4.2.2.1 OVERALL EVPI FOR COMMUNITY FARM

In eliminating all uncertainty, the overall EVPI per child that would be affected by the decision of implementing a community farm to combat vitamin A deficiency is estimated at Intl$29,172.20 per child. An annual population of 31 million Nigerian children affected by this decision will amount to an overall EVPI of Intl$904 billion per year. Overall EVPI at a threshold of $2,880 was estimated at different periods (Table 4.12). From the table, conducting additional research to eliminate uncertainty in the cost-effectiveness of yellow cassava and orange maize to prevent vitamin A deficiency in children will still be valuable in 20 years.

Table 4.13: Overall EVPI in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective

Years	Population	Overall EVPI (Intl$)
Per Person affected by the decision		29,172.20
Per year in Nigeria assuming 31,000,000 Persons Affected Per Year	31,000,000	904,300,000,000
5 Years	56,711,554	4,522,000,000,000
10 Years	84,253,806	9,043,000,000,000
15 Years	107,443,642	13,570,000,000,000
20 Years	126,968,862	18,090,000,000,000

4.4.2.2.2 EVPPI FOR SINGLE PARAMETERS

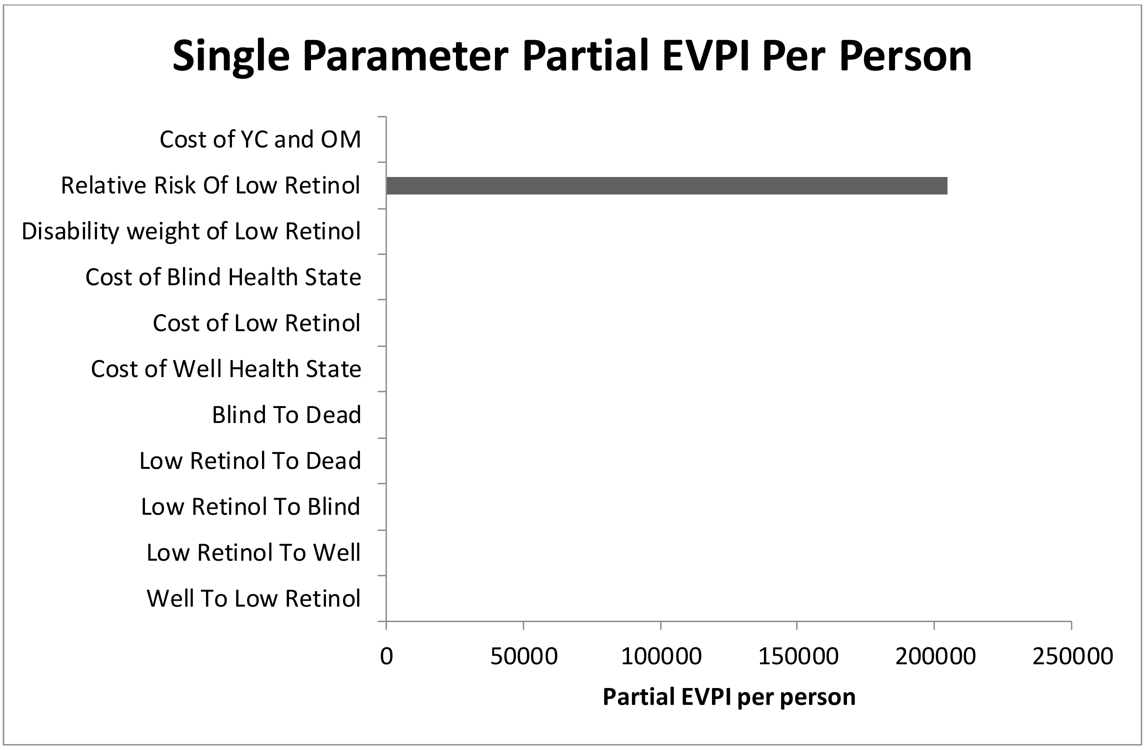
EVPPI for all the parameters was estimated and is presented below. All parameters show that it is not worthwhile carrying out additional research for these parameters (Table 4.13 and figure 4.5). Only the relative risk of low retinol showed that further research would be valuable to eliminate the uncertainty associated with it (EVPPI per person Intl$29,228.11 EVPPI per annual population Intl$906 billion)

Table 4.14: EVPPI for single parameters in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective

Parameter	**Per Person EVPPI**	**EVPPI for Nigeria Per Year (Intl$)**
TP well to low retinol health state	0	0
TP low retinol to well	0	0
TP low retinol to blind	0	0
TP low retinol to dead	0	0
TP blind to dead	0	0
Relative risk of low retinol	29,228.11	906,100,000,000
Cost of well health state	0	0
Cost of low retinol	0	0
Disability weight of low retinol	0	0
Cost of community farm	0	0

TP – Transition probability

Figure 4.5: EVPPI for single parameters in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective



YC – Yellow cassava and OM – Orange maize

4.4.2.2.3 GROUP PARAMETER EVPPI

The following set of parameters were grouped and is represented in table 4.14. Set 1 (well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead) was grouped as they can be researched together as a cohort study. Set 2 (relative risk of serum retinol and cost of a home garden) can be researched as a randomised controlled trial and a cost analysis. Set 3 (cost of well state, cost of low retinol state, and cost of blind state) can be researched as a cost analysis. All group parameters showed that additional research would be valuable except set 1 (well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead). Set 2 (EVPPI per person Intl$29,226.68, EVPPI per annual population Intl$906 billion) and set 3 (EVPPI per person Intl$2.15, EVPPI per annual population Intl$665,670) showed that additional research would be useful in reducing uncertainty in these parameters as groups.

Table 4.15: EVPPI for group parameters in the cost-effectiveness of community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children from a funder's perspective

	Parameters	**Per person EVPPI**	**Approximate Standard error**	**EVPPI for Nigeria Per Year (Intl$)**
Set 1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead	0	1.54	0
Set 2	relative risk of serum retinol and cost of community farm	29,226.68	122.55	906,027,200,000
Set 3	well cost, cost of low retinol health state and cost of blind health state	2.147320e -02	30.77	665,670.10

4.5 DISCUSSION

A value of information analysis was conducted based on the PSA results from the model developed in chapter three which assessed the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize in preventing vitamin A deficiency in children. The results of the VOI showed an overall EVPI of Intl$9.2 billion and Intl$1.01 billion for home garden and community farm respectively (societal perspective) for 31 million Nigerian children. From the funder's perspective, results demonstrated an overall EVPI of Intl$926 billion and Intl$904 billion for home gardens and community farms respectively. The results of the EVPPI showed that from both the societal and funder's perspective, all parameters yielded no value in performing further research except relative risk of serum retinol which gave a value of Intl$925 billion and Intl$1.01 billion from the societal perspective (for home garden and community farm respectively) and Intl$929 billion and Intl$906 billion from the funder's perspective (for home garden and community farm respectively) These EVPIs have very huge numbers because they represent the EVPI of a cumulative population that can be affected by vitamin A deficiency in Nigeria. In the real world, no research will cost as much as these EVPIs presented here. However, these figures will inform a funder considering to sponsor further research in this area that the research will be a good value for money and will yield a good return on investment. Though EVSI and ENGS were not carried out, given the very high EVPPI, there is a chance that ENGS will be greater than zero, implying that additional research on home gardening and community farming of yellow cassava and orange maize would yield a good return on investment

4.5.1 COMPARING A SOCIETAL PERSPECTIVE TO A FUNDER'S PERSPECTIVE

Most guidelines recommend using a societal perspective in cost-effectiveness studies, however, it is good practice to compare results with another costing perspective (Mohseninejad et al., 2013). The results of the EVPI (single parameters) for the two intervention scenarios considered demonstrated that the same type of research design (randomised controlled trial to investigate the effectiveness of home gardening/community farming of yellow cassava and orange maize on serum retinol in children) will be worthwhile to gain additional information to reduce uncertainty. This similarity in results from both costing perspectives may be attributed to both perspectives using the same data besides the costing data.

In the two costing scenarios, the group EVPPIs were different. The funder's perspective for home garden intervention scenario showed that additional research would be worthwhile for set 1, set 2 and set 3 compared to the societal perspective which showed good value for money for only set 2. One thing that this study is strongly suggesting is that VOI will generate different values for different healthcare systems, time horizons, population size and costing perspectives and Briggs and his colleagues corroborates these findings in their research on VOI (Briggs et al., 2006). The costing perspective of a healthcare intervention must be chosen carefully to avoid giving erroneous research priority from a VOI analysis. Home gardening from the societal perspective may be more beneficial and relevant, although more research is needed to establish this, the results of the VOI analysis of home gardening from a societal perspective should be recommended over the other scenario explored.

4.5.2 SIMILARITY WITH OTHER STUDIES

This study is the first as far as the author knows to use VOI analysis to explore decisions relating to the cost-effectiveness of vitamin A interventions in children. However, VOI analysis has been used to address the usefulness of carrying out further research in other areas of major public health concerns in Africa. Kim et al. (2017) carried out a VOI analysis to understand the value of reducing uncertainty in an evidenced-based Malaria Decision Analysis Support Tool (MDAST) in East Africa. They found that obtaining perfect information for the uncertainty of the model parameters would give an increased programme net benefit of 5 – 21%. In 2012, Maheswaran and Barton, 2012 Maheswaran and Barton. (2012) built an economic model to assess the cost-effectiveness of screening and treating tuberculosis in HIV positive patients in Sub-Saharan Africa. They also carried out a VOI analysis to inform future research prioritisation. Their VOI analysis showed that research on the effectiveness of non-insecticide-based vector control will be valuable in reducing uncertainty (Maheswaran & Barton, 2012). Also, Uthman et al. (2018) developed a Markov model and a VOI to assess the cost-effectiveness of directly administered antiretroviral drugs and self-administered anti-retroviral drugs to people living with HIV at high risk of defaulting in self-administered anti-retroviral drugs. Their VOI analysis suggested that more research on the effectiveness of direct administered anti-retroviral drugs over self-administered anti-retroviral would be of benefit in reducing uncertainty in the model (Uthman et al., 2018). The use of VOI analysis is gradually gaining popularity in prioritising research in Africa especially in the face of scarce resources and an avalanche of health problems to be tackled (Kim et al., 2017).

4.5.3 POPULATION EVPI

Though this study set out to investigate the cost-effectiveness of home gardening of yellow cassava and orange maize in children living in rural areas, an annual population of 31 million children in Nigeria was used as the population affected by vitamin A deficiency. Since home gardening of yellow cassava and orange maize is likely to be highly cost-effective as shown by the results of the model, propagating it to even children in urban areas is a reasonable thing to do. According to UNICEF (2021), one in three Nigerians lives below the poverty level (UNICEF, 2021). This means that even some children living in urban areas are living in abject poverty and planting yellow cassava and orange maize by households will not only be useful in fighting vitamin A deficiency but will be of economic value to these households. There is the possibility of incurring some monetary gains by sales of surplus produce which was also explored in this study. Evidence has suggested strongly that agricultural practices even at the household level can alleviate poverty (Irz et al., 2001; Schneider and Gugerty, 2011; Anowor, Ukweni And Ezekwem, 2013)

4.5.4 STRENGTHS AND LIMITATIONS OF STUDY

The results from this VOI have shown that carrying out additional research to resolve the uncertainty surrounding the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize is highly likely to be worthwhile. It has also highlighted that carrying out a randomised controlled trial and a costing analysis would be a good value for money. Though EVPI and EVPPI are necessary steps, they are not sufficient to recommend that additional research is worthwhile. One limitation of this study is that EVSI AND ENGS were beyond the scope of this study, however, the EVPPI for single and group parameters generated very high values, suggesting that ENGS is likely to generate a high value and will yield a good return on investment.

This cost-effectiveness analysis assumed that people will act in accordance with perfect information, meaning that they would carry on with all the requirements of the intervention such as planting and eating yellow cassava and orange maize and continuing with this practice after withdrawal of intervention support. This may not be the case as people may abandon the intervention after support is withdrawn. Home gardening intervention may not provide net benefit for some households such as those already involved in home gardening, those that consider home gardening tedious, harm to children engaging in home gardening and missing school days, households without vitamin A deficient children, those that will have poor harvest due to pests, diseases etc and those that could have spent their time in things more profitable to them. In addition, though I assumed that home gardening intervention can be propagated to all Nigerian children below the age of 5, not every household will be interested in growing this new variety of cassava and maize and the intervention will not be beneficial to all households involved in it.

Policymakers involved in fighting vitamin A deficiency in children should prioritise high quality randomised controlled trials alongside costing analysis to establish the clinical effectiveness of home gardening/community farming of yellow cassava and orange maize in improving serum retinol levels in children. While there is no such thing as perfect information, VOI analysis puts an upper bound value on returns when investments are made in research which is highly important in a world of scarce resources and competing health needs.

4.5.5 AUTHOR'S CONCLUSION

In conclusion, the VOI analysis presented in this study has shown that it is highly likely that undertaking further research to derive better evidence on the impact of home gardening/community farming of yellow cassava and orange maize on serum retinol in children would be worthwhile. The author recommends that this evidence should be derived from a randomised controlled trial alongside a costing analysis because randomised controlled trials are the gold standard in evaluating the effectiveness of interventions. This is due to its ability to reduce the risk of bias from confounding factors by randomising participants and carrying out allocation concealment (Higgins et al., 2011). It is imperative that health professionals pay great attention to the costing perspective chosen in economic evaluation and in VOI analysis to prevent recommending wrong research prioritisation. Policymakers should ensure that the relevant perspective has been applied before adopting a healthcare intervention for implementation.

CHAPTER FIVE

DISCUSSION

5.0 THESIS OVERVIEW

My thesis set out to understand the role of home food production in the prevention of vitamin A deficiency in children. I started by conducting a systematic review and meta-analysis to assess the impact of home food production in the prevention of vitamin A deficiency and nutritional blindness in children. Outcomes such as stunting, wasting, underweight, mortality, xeropthalmia, serum retinol and night blindness were assessed. The second step was to analyse the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in Nigeria. Yellow cassava and orange maize were the chosen crops mainly because they are staple crops in Nigeria, rich in vitamin A. Lastly, this thesis assessed the value of obtaining additional information before deciding whether to implement home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children. The findings of this thesis add a lot of relevance to the extant body of knowledge being that they are novel in their own right and as such, stand to pave the way for more research in the area of home food production and other methods of tackling vitamin A deficiency in children. Three core questions were asked and three methodologies were used to answer these questions. Table 5.1 shows the main research questions, methods and findings.

Table 5.1: Main research questions, methods and findings in this thesis

Question	Findings
Systematic review and meta-analysis What is the effectiveness of home food production of vitamin A-rich foods in preventing vitamin A deficiency in children?	Home food production may slightly reduce stunting (mean difference (MD) 0.13 (z-score), 95% CI 0.01 to 0.24), wasting (MD 0.05 (z-score), 95% CI -0.04 to 0.14) and underweight (MD 0.07 (z-score), 95% CI -0.01 to 0.15) in young children (all GRADE low-consistency evidence), and increase dietary diversity (standardized mean difference (SMD) 0.24, 95% CI 0.15 to 0.34). There were no studies that reported mortality, night blindness and xeropthalmia. The effect of home food production on serum retinol in children is inconclusive
Cost-effectiveness analysis What is the cost-effectiveness of home gardening/ community farming of yellow cassava and orange maize in the prevention of vitamin A deficiency in children?	**Societal perspective:** Home garden - $395.00 per DALY averted, 72.27% likelihood of cost-effectiveness. Community farm: $426.96 per DALY averted, 70.59% likelihood of cost-effectiveness **Funder's perspective:** Home garden -$462.49 per DALY averted, 72.39% likelihood of cost-effectiveness. Community farm: $476.89 per DALY averted, 71.42% likelihood of cost-effectiveness Home gardening/community farming of yellow cassava and orange maize is highly likely to be cost-effective in preventing vitamin A deficiency in Nigerian children from a societal and funder's perspective.
Value of information analysis • Is additional information a good use of resources in deciding whether to adopt home gardening/community farming of yellow cassava and orange maize to	**Societal perspective:** EVPI for 31 million children - $9.2 billion and $1.01 billion for home garden and community farm **Funder's perspective:** $926 billion and $904 billion for home garden and community farm.

prevent vitamin A deficiency in children? • If further research is to be conducted on home gardening/community farming of yellow cassava and maize, what kind of studies should be prioritized?	Undertaking additional research is worthwhile and is a good value for money in deciding whether to adopt home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children. The results of the EVPPI show that from both the societal and funder's perspective, all parameters yielded no value in performing further research except relative risk of serum retinol which gave a value of Intl$925 billion and Intl$1.01 billion from the societal perspective (for home garden and community farm respectively) and Intl$929 billion and Intl$906 billion from the funder's perspective (for home garden and community farm respectively). A randomised controlled trial alongside a cost analysis should be prioritised before deciding whether to implement home gardening/community farming of yellow cassava and orange maize to tackle vitamin A deficiency in children.

As earlier discussed in the first chapter, vitamin A deficiency continues to plague children from vulnerable communities especially in Africa and south-east Asia. These areas are underserved by health services and child mortality continues to rise partly due to vitamin A deficiency. Therefore, the need to combat vitamin A deficiency cannot be overstated. This is the overarching reason that this thesis was carried out – to understand the role of home food production in the prevention of vitamin A deficiency particularly for children (below the age of five) in rural areas. To understand the role of home food production in the prevention of vitamin A deficiency in children, it is important to investigate the effectiveness of home gardening of vitamin A-rich foods in preventing vitamin A deficiency in children, which is a cause of nutritional blindness in children.

Some factors can limit the bioavailability of retinol in the blood. Though these foods may be high in pro-vitamin A, their absorption rate in the body is very important. Some researchers have explored the conversion of beta-carotene to retinol in the body (Castenmiller & West, 1998; Tanumihardjo, 2002; Van Het Hof et al., 2000; Yeum & Russell, 2002). These studies have found that the diet content of the food, the preparation process and the food matrix all influence the bioconversion of beta-carotene to retinol. Also, worm infestation can inhibit the absorption of retinol. De Gier et al. (2014) reported in their systematic review of observational studies that worm infestation affects the bioavailability of serum retinol. Other infections such as malaria will also affect the absorption of vitamin A, circulation and concentration of serum retinol. Other factors include failure of the intervention to lead to significant uptake of home gardening, sale of produce instead of consumption and poor harvest. It is also important to mention that the systematic review in this thesis showed that home gardening increased the intake of vitamin A-rich foods (although this outcome was not intended from the beginning). This undoubtedly sets the stage for success in a home food production intervention, making children consume more vitamin A-rich foods through increased access. If other factors such as deworming and bioavailability are tackled, home food production may then have a positive impact. It is important to mention that home food production has limitations such as households abandoning the intervention after support is withdrawn. There are crucial equity issues associated with home food production such as land tenure and availability, women's time, child labour and demographics of other members of the household and their dietary requirements. These may hamper the success of a home food production in any context. Subgroup analysis on continent, duration of intervention and types of intervention were carried out to assess its impact on results. This is most likely a novel approach to reviews that have assessed the effectiveness on home food production on vitamin A deficiency in children. Though results showed that these subgroups made no important difference, it is significant that they were explored.

Home food production increased income in households which can be used as a means to alleviate poverty especially for households in rural areas. Christiaensen and Martin (2018) posited that encouraging households to grow food at home will not only be of health benefit but can lift poor families out of poverty. The results of the systematic review demonstrated that home food production may slightly improve stunting, wasting and underweight in children. The clinical implication is that for a 24-month-old boy, to move from a height-for-age z-score of -2 to -1, 3.1cm in height is achieved, or 3.2cm for a girl. A boy of 24 months needs a weight gain of 1.1kg to move from a weight-for-age z-score of -2 to -1 and a girl 1.2kg. At a height of 109.5cm, 1.3kg and 1.4kg weight gain will move a boy or girl from a weight-to-height z score of -2 to -1 respectively (WHO, 2006). Home food production improved dietary diversity in children. Most importantly, the systematic review showed that there were no trials that reported blindness outcomes in children, highlighting a research gap in this area. Some studies (Canet, 1996; Vijayaraghavan et al., 1997; Talukder et al., 2010; Campbell et al., 2011) that assessed blindness outcomes found that home food production was associated with a reduction in the prevalence of night blindness, bitot's spots and vitamin A deficiency in children. These studies were not included in the systematic review because they did not have a control arm and were mostly before/after studies. Though these studies are of poor quality, home food production may be of interest for further consideration.

No study in Nigeria has explored the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize in Nigeria. This thesis took the next step to assess the cost-effectiveness of home gardening of vitamin A-rich foods using a Markov model as no study has used a decision-analytic model to assess its cost-effectiveness. Before the implementation of any public health intervention, the cost-effectiveness of that intervention should be established. In a world of limited resources, public health interventions must be a good value for money before they can be recommended for implementation. To further understand the role of home gardening of vitamin A-rich foods in preventing blindness in children, this thesis carried out a cost-effectiveness analysis using a decision-analytic model. The results of the cost-effectiveness study showed that there are uncertainties associated with the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize. This informed my decision to carry out a VOI analysis to assess if further research is needed to reduce these uncertainties before deciding if home food production should be implemented.

A Markov model was developed in excel as has been presented in chapter three of this thesis. The results showed that both home gardening and community farming of yellow cassava and orange maize are likely to be highly cost-effective from the societal perspective (home garden: ICER Intl$395.00 per DALY averted, community farm: ICER - Intl $426.96 per DALY averted) and funder's perspective (home garden: ICER - Intl $462.49 per DALY averted, community farm: ICER - Intl $476.89 per DALY averted). These findings are in line with other studies that found that home gardening is a cost-effective intervention in tackling vitamin A deficiency in children (Lakzadeh, 2016; Schreinemachers et al., 2016). However, this study is the first to use a decision-analytic model to analyse the cost-effectiveness of home gardening to prevent vitamin A deficiency in children, comparing a societal perspective to funder's perspective. It is also the first to assess the cost-effectiveness of community farming of yellow cassava and orange maize from a societal and funder's perspective. The costing perspective did not make any difference in the ICERs. Nevertheless, it is important to state that the societal perspective may be more beneficial economically as it considers the income generated from the sale of surplus garden produce.

One important finding from the cost-effective analysis is that there is 29.41% - 27.61% % uncertainty associated with the results of the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize. What this means is that there is a 29.41% - 27.61% % chance that if the results of the cost-effectiveness analysis are relied upon, misleading decisions could be made. This uncertainty set the tone for the next phase of this thesis which is to assess if further information or evidence would be worth allocating resources to resolve or reduce the uncertainty or if home gardening of yellow cassava and orange maize can be adopted in the prevention of vitamin A deficiency in children based on available information.

The VOI analysis demonstrated that more research is worthwhile and will yield good value for money in resolving the uncertainty surrounding the cost-effectiveness of home gardening/community farming of yellow cassava and orange maize. The EVPIs from both home gardening and community for societal perspective (Intl$925 billion and Intl$1.01 billion respectively) and funder's perspective (Intl$926 billion and Intl$904 billion) are large because they represent a cumulative population that can become vitamin A deficient in Nigeria which is 31 million children. In the real world, no research will cost up to these large amounts. However, it reiterates that further research is worthwhile and important in deciding whether to adopt home gardening/community farming of yellow cassava and orange maize as an intervention to fight vitamin A deficiency in Nigeria, given the large number of children that could be affected. One interesting finding in the VOI analysis is that the costing perspective influenced the type of research that should be prioritised. Societal perspective prioritised only on the effect of yellow cassava and orange maize on serum retinol alongside a costing analysis while the funder's perspective prioritised researching a randomised controlled trial/costing analysis in addition to a costing analysis of health states. The societal perspective is more appropriate for the particular problem considered in this thesis because it accounts for the cost of livelihood lost as a result of caring for a blind child and accounts for income generated from home gardening which is crucial for vulnerable families. This is the first time the costing perspective has been explored in a VOI analysis in the cost-effectiveness of home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children.

In terms of understanding the role home gardening of vitamin A-rich foods play in tackling vitamin A deficiency in children, this thesis has shone light on its effectiveness, cost-effectiveness and whether it should be considered further for implementation. This thesis has strongly suggested that more research would be worthwhile especially in assessing the effectiveness of serum retinol in children and cost analysis of the intervention. This finding further supports the results of the systematic review in chapter two which demonstrated that the effect of home food production of vitamin A-rich foods on serum retinol is inconclusive.

5.1 WHAT KNOWLEDGE HAS THIS THESIS CONTRIBUTED?

To the best of my knowledge, my thesis is the first to carry out a VOI analysis to assess if further evidence is needed before deciding whether to adopt home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children. Yellow cassava and orange maize are relatively new biofortified crops being introduced to combat vitamin A deficiency in Nigeria. Fundamentally, this thesis has shown that home food production may clinically improve anthropometric measures in children, generate more income in families, improve dietary diversity and is likely to be cost-effective. However, more research is needed and worthwhile before it can confidently be recommended for preventing vitamin A deficiency in children. This study also went ahead to show the needed areas of research prioritisation – the effectiveness of home gardening/community farming of yellow cassava and orange maize in improving serum retinol in children and costing analysis of home gardening/community farming of yellow cassava and orange maize. My thesis is the first to compare the cost-effectiveness of home gardening and community farming of yellow cassava and orange maize. Not only was home gardening and community farming compared, but they were also explored from two different costing perspectives. It is important to reiterate that this is the first study to carry out such an in-depth analysis.

It demonstrated that community farming as a strategy would be expected to have similar cost-effectiveness to home gardening both from the societal and funder's perspective.

5.2 POLICY IMPLICATIONS OF FINDINGS

Since the effectiveness of vitamin A supplementation has been established by systematic reviews and controlled trials, policymakers should focus on solving the challenges surrounding programme coverage until the effectiveness of home gardening of vitamin A-rich foods on serum retinol is established in children. Only then should home gardening be recommended widely as an intervention to tackle vitamin A deficiency for children in rural areas.

This study demonstrated that home food production clinically improved stunting, wasting and underweight for children in rural areas. It should be recommended as a complementary intervention in malnourished communities to improve stunting, wasting and underweight in children. However possible limitations such as equity issues should be considered when implementing home food production.

Research institutions and stakeholders should focus on facilitating research on the effectiveness of home gardening of vitamin A-rich foods on serum retinol in children alongside a costing analysis of the intervention. The body of work contained in my thesis would provide compelling evidence to policymakers to fund this research and investigate the potential of home food production further.

5.3 AUTHOR'S RECOMMENDATION

I recommend that although home gardening of vitamin A-rich foods especially the new technology of biofortifying staple crops such as cassava, maize and potato with vitamin A seems likely to be highly cost-effective, the research community should focus on assessing its effectiveness and costing in improving serum retinol as well as tackling subclinical signs of vitamin A deficiency in children. Until its effectiveness is established, and until we understand in what contexts and under what conditions interventions to promote home gardening with yellow maize/cassava is effective, it should not be routinely adopted as an intervention to fight vitamin A deficiency in children living in rural areas. While research on the effectiveness of home gardening of vitamin A-rich foods is underway, there should be massive scaling up of vitamin A supplementation programmes to reach children in rural areas who are more susceptible to vitamin A deficiency. Home gardening of vitamin A-rich foods should be recommended as a complementary intervention in areas high in malnutrition

5.4 STRENGTHS AND LIMITATIONS OF THIS STUDY

The systematic review was guided by the Cochrane handbook which is a rigorous method of carrying out systematic reviews. By following the Cochrane guideline, two reviewers screened titles, abstracts, full text and two reviewers carried out data extraction. A third reviewer settled conflicts through discussion. This process ensured transparency in carrying out the systematic review.

High quality systematic reviews and randomised controlled trials were used as evidence in the economic evaluation. A PSA was run in the model that explored uncertainties associated with the input parameters of the model. This made the results robust. Using SAVI to assess the value of information in reducing uncertainties surrounding the cost-effectiveness of home gardens and community farms ensured an accurate analysis.

One major limitation of my thesis is that the costing of resources in the economic evaluation was through expert consultation. This may have introduced some bias to the study such as exaggerating the cost of intervention or under-estimating it. However, the VOI analysis explored the possible uncertainties associated with each parameter in the model. A vitamin A supplementation intervention was used to estimate some of the transition probabilities. This may have exaggerated the results as a vitamin A supplementation study will have a greater effect on serum retinol compared with a home gardening intervention. Changes in healthcare costs were not added to the model due to lack of availability of data. This may have impacted the results of the model. The model assumed that households will act in accordance with perfect information but this assumption may not be true as some households may decide to sell their produce rather than consume them or may abandon home food production when support is withdrawn. This assumption may introduce some bias to the results of the EVPI. There are some people that home food production may not produce net benefit for, such as households already involved in home gardening or households that had a poor harvest. The model assumed that after the first year of the intervention, households will continue to practice home food production. This may not be true as some households may abandon the intervention as soon as support is withdrawn. This may also introduce bias to the model. EVSI and ENGS could not be carried out as part of the VOI analysis due to the complexities of carrying them out. For the systematic review, studies that were not published in English were excluded, and some authors of the included studies did not respond to the request to provide more data. These may have introduced some bias in the systematic review. The results of this thesis should be interpreted cautiously bearing these limitations in mind.

It is important to mention that COVID-19 impacted this thesis as it thwarted the plans of carrying out a qualitative study to explore the barriers and facilitators in the home gardening of yellow cassava and orange maize in Nigeria.

5.5 PERSONAL REFLECTIONS

My PhD journey was one of growth, learning and reflection. Going through the different stages of my thesis, from the systematic review to the cost-effectiveness study and the VOI analysis each offered me different experiences which have shaped me into the researcher that I am today.

I found the systematic review interesting and challenging at the same time. Going through the process of developing my research questions to formulating a comprehensive search strategy and writing my proposal was a learning process for me. I used Covidence software which I found very helpful as studies could be screened by two reviewers separately and in duplicate. With Covidence, I was able to track what other reviewers were doing and I was able to communicate with them. Screening of titles and abstracts and screening full-text papers was quick for me. However, data extraction was time consuming as I had to carefully read through all the papers that I was going to include. Having to deal with missing data made the process daunting but I tried to resolve this issue by contacting corresponding authors of the papers that had missing results.

The economic evaluation was completely new to me and was a hilly path to climb. I attended economic evaluation M.Sc. modules which gave me a softer landing on my economic evaluation journey. With the guidance of my Supervisors, I was able to conquer the challenges it presented my way and successfully developed a Markov model in Microsoft Excel.

As part of my thesis, I originally planned to carry out a qualitative study to explore the facilitators and barriers of home gardening of yellow cassava and orange maize in Nigeria (See appendix 18 for the research proposal). I had fully developed my qualitative research proposal and was about to submit my ethics approval form when the pandemic broke out and the whole world went on lockdown. This made it difficult for me to travel to Nigeria to embark on fieldwork. I chose to adapt my thesis to carry out a VOI analysis. The VOI analysis was more feasible during the pandemic because I was going to work with the results from the Markov model rather than making human contact to obtain data for analysis. It had its challenges because it was my first time carrying out such an analysis. I had to read about VOI and how to interpret the results. My supervisors were helpful and this made the process a lot easier for me. I have successfully published my systematic review and I am about to submit the economic evaluation and VOI analysis manuscripts for publication. See Appendix 19 for the manuscript formatted to Plos One journal guideline for publication.

Generally, I would say that my three-year PhD journey was unique to me. It was for me a period of skills acquisition and self-development. It stretched me and I had to constantly step out of my comfort zone to make things happen. I am grateful for the entire process and wouldn't have wanted it any other way.

5.6 AREAS OF FURTHER RESEARCH

The next step from this thesis would be to carry out a qualitative study to explore the facilitators and barriers in the uptake of home gardening/community farming of yellow cassava and orange maize in Nigeria. This was supposed to be the third part of my thesis but it became impossible due to the pandemic in 2020.

My thesis has shown that there are gaps in particular areas of research concerning vitamin A deficiency in children. First, high quality randomised controlled trials that have properly carried out randomisation and allocation concealment should be carried out to further investigate the effectiveness of home food production on surrogate blindness outcomes in children. This is very important as high-quality studies are lacking in this area. While it is important to assess the effect of home food production on serum retinol, the focus should also be on subclinical signs of vitamin A deficiency in children. Other factors that can affect the bioavailability of retinol from vitamin A-rich foods should be considered when designing interventions to assess the effectiveness of home food production vitamin-A rich foods on serum retinol. The VOI analysis showed that more research is needed in deciding whether to adopt home gardening/community farming of yellow cassava and orange maize to prevent vitamin A deficiency in children, particularly a randomised controlled trial investigating its effectiveness on serum retinol. Carrying out this randomised controlled trial in clusters may be more reasonable to prevent contamination amongst villages. Ensuring that a good randomisation system is used and allocation concealment is properly carried out to eliminate bias from the results is important. Allowing a long period of follow-up to effectively assess the effect on serum retinol in children is important. Considering factors that inhibit the bioavailability of beta-carotene is also crucial. A costing analysis is needed to better understand how cost-effective this intervention is. Expert consultation was used in costing home gardening of yellow cassava and orange maize in this study. This implies that a detailed costing analysis is needed to reduce uncertainties and establish the cost of setting up a home garden/community farm of yellow cassava and orange maize.

In the process of data collection, I observed a deficit of data on the prevalence of vitamin A deficiency in Nigeria. The most recent national survey on the prevalence of vitamin A deficiency in Nigeria stratified by the 36 states of the federation was by WHO in 2007 (WHO, 2007). Updating this information is useful because it guides the formulation of interventions to combat vitamin A deficiency by pointing to areas in Nigeria where vitamin A deficiency is more prevalent and need to be targeted when planning interventions to fight vitamin A deficiency in children. It also provides information to evaluate if interventions implemented to combat vitamin A deficiency in children have been successful.

Community farming of yellow cassava and orange maize was explored in this economic evaluation alongside home gardening and the results showed that community farming is cost-effective from both societal and funder's perspectives. Exploring the advantages and feasibility of carrying out a community farm over home gardening is evidence that might be valuable in terms of strategizing how to encourage communities to grow yellow cassava and orange maize, either as a group or as individuals. Community farming should be made an important focus in the qualitative study to investigate facilitators and barriers in the uptake of growing yellow cassava and orange maize in Nigeria.

5.7 CONCLUSION

This thesis has carried out a novel study, assessing the effectiveness and cost-effectiveness of home gardening and community farming of yellow cassava and orange maize in preventing vitamin A deficiency in children from the societal and funder's perspective. In addition, it has carried out a value of information analysis being the first of its kind to explore if further research is worthwhile before deciding whether home gardening and community farming of yellow cassava and orange maize can be implemented to prevent vitamin A deficiency in young children. The summary of my findings underscores the fact that it would be a good value for money if more research is carried out before deciding whether home gardening or community farming of yellow cassava and orange maize can be recommended for implementation to prevent vitamin A deficiency in children. In the meantime, concerted efforts should be made for vitamin A supplementation programmes to be accessible to children in rural areas who are most vulnerable to vitamin A deficiency. For now, this may be the way forward to avoid needless death and blindness amongst vulnerable children in LMICs.

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APPENDIX ONE: PROSPERO REGISTRATION OF THE SYSTEMATIC REVIEW AND META-ANALYSIS ON THE EFFECTIVENESS OF HOME FOOD PRODUCTION ON NUTRITIONAL BLINDNESS IN CHILDREN

UNIVERSITY of York
Centre for Reviews and Dissemination

Systematic review

Please complete all mandatory fields below (marked with an asterisk *) and as many of the non-mandatory fields as you can then click *Submit* to submit your registration. You don't need to complete everything in one go, this record will appear in your *My PROSPERO* section of the web site and you can continue to edit it until you are ready to submit. Click *Show help* below or click on the icon
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1. * Review title.

Give the working title of the review, for example the one used for obtaining funding. Ideally the title should state succinctly the interventions or exposures being reviewed and the associated health or social problems. Where appropriate, the title should use the PI(E)COS structure to contain information on the Participants, Intervention (or Exposure) and Comparison groups, the Outcomes to be measured and Study designs to be included.

Impact of Home Food Production in the Prevention of Nutritional Blindness in Children

2. Original language title.

For reviews in languages other than English, this field should be used to enter the title in the language of the review. This will be displayed together with the English language title.

3. * Anticipated or actual start date.

Give the date when the systematic review commenced, or is expected to commence.

01/10/2018

4. * Anticipated completion date.

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31/07/2019

5. * Stage of review at time of this submission.

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The review has not yet started: no

Review stage	**Started**	**Completed**
Preliminary searches	Yes	No
Piloting of the study selection process	Yes	No
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Provide any other relevant information about the stage of the review here (e.g. Funded proposal, protocol not yet finalised).

6. * Named contact.

The named contact acts as the guarantor for the accuracy of the information presented in the register record.

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University of East Anglia, United Kingdom.

9. Named contact phone number.

Give the telephone number for the named contact, including international dialing code.

(+44) 07405637805

10. * Organisational affiliation of the review.

Full title of the organisational affiliations for this review and website address if available. This field may be completed as 'None' if the review is not affiliated to any organisation.

University of East Anglia

11. * Review team members and their organisational affiliations.

Give the title, first name, last name and the organisational affiliations of each member of the review team. Affiliation refers to groups or organisations to which review team members belong.

Mrs. Chizoba Nwabichie. University of East Anglia

Dr Lee Hooper. University of East Anglia
Professor Jennifer Whitty. University of East Anglia
Harriet Crooks. University of East Anglia

12. * Funding sources/sponsors.

Give details of the individuals, organisations, groups or other legal entities who take responsibility for initiating, managing, sponsoring and/or financing the review. Include any unique identification numbers assigned to the review by the individuals or bodies listed.

None

13. * Conflicts of interest.

List any conditions that could lead to actual or perceived undue influence on judgments concerning the main topic investigated in the review.

None

14. Collaborators.

Give the name and affiliation of any individuals or organisations who are working on the review but who are not listed as review team members.

15. * Review question.

State the question(s) to be addressed by the review, clearly and precisely. Review questions may be specific or broad. It may be appropriate to break very broad questions down into a series of related more specific questions. Questions may be framed or refined using PI(E)COS where relevant.

What is the effectiveness of home food production on nutritional blindness in children?

16. * Searches.

Give details of the sources to be searched, search dates (from and to), and any restrictions (e.g. language or publication period). The full search strategy is not required, but may be supplied as a link or attachment.

- MEDLINE Ovid
- Embase Ovid
- Scopus
- World Health Organisation International Clinical Trials Registry Platform
- Cochrane Central Register of Controlled Trials.

There were no restrictions on the date of publication and language for the searches conducted. Searches were conducted from October to December 2018

17. URL to search strategy.

Give a link to a published pdf/word document detailing either the search strategy or an example of a search strategy for a specific database if available (including the keywords that will be used in the search strategies), or upload your search strategy. Do NOT provide links to your search results.

https://www.crd.york.ac.uk/PROSPEROFILES/126455_STRATEGY_20190317.pdf

Alternatively, upload your search strategy to CRD in pdf format. Please note that by doing so you are consenting to the file being made publicly accessible.

Do not make this file publicly available until the review is complete

18. * Condition or domain being studied.

Give a short description of the disease, condition or healthcare domain being studied. This could include health and wellbeing outcomes.

Vitamin A deficiency is one of the most deficient micro-nutrient in children and has remained a public health problem in low and middle income countries. Vitamin A deficiency is the cause of nutritional blindness in children, and many of these children die in their first year of blindness. Vitamin A deficiency is caused by inadequate intake of vitamin A-rich foods over a long period of time.

Vitamin A supplementation program has been in place to tackle vitamin A deficiency in children but coverage in rural areas is challenging as many vulnerable children are missed by the program. Food fortification of vitamin A is also an effective intervention as evidence has shown. However, vulnerable people living in low and middle income countries are unable to afford food fortified with vitamin A due to financial constraints.

Some authors have argued that home food production may have the potential to provide vitamin A-rich food to children in rural areas over a long period of time, thereby tackling vitamin A deficiency and subsequently preventing the occurrence of nutritional blindness.

19. * Participants/population.

Give summary criteria for the participants or populations being studied by the review. The preferred format includes details of both inclusion and exclusion criteria.

Participants are mothers of young children. Outcome will be assessed in children below the age of 5.

20. * Intervention(s), exposure(s).

Give full and clear descriptions or definitions of the nature of the interventions or the exposures to be reviewed.

The following interventions will be included:

- Training in home gardening – training in the planting of vitamin A- rich foods on a piece of land attached to the home or in close proximity to the home primarily for household consumption.
- Home gardening – practice of home gardening to produce vitamin A-rich food for home consumption.
- Home Poultry development – rearing of chickens in small numbers at home for the family.
- Household dairy production – production of diary at home for household consumption.

Duration of intervention is a year and above.

21. * Comparator(s)/control.

Where relevant, give details of the alternatives against which the main subject/topic of the review will be compared (e.g. another intervention or a non-exposed control group). The preferred format includes details of both inclusion and exclusion criteria.

Intervention group compared against a non-exposed control group.

22. * Types of study to be included.

Give details of the types of study (study designs) eligible for inclusion in the review. If there are no restrictions on the types of study design eligible for inclusion, or certain study types are excluded, this should be stated. The preferred format includes details of both inclusion and exclusion criteria.

Randomized controlled trials

Controlled clinical trials.

23. Context.

Give summary details of the setting and other relevant characteristics which help define the inclusion or exclusion criteria.

24. * Main outcome(s).

Give the pre-specified main (most important) outcomes of the review, including details of how the outcome is defined and measured and when these measurement are made, if these are part of the review inclusion criteria.

Night blindness: the diagnostic criteria used in the study will be adopted.

Xeropthalmia: the diagnostic criteria used in the study will be adopted.

All-cause mortality.

Stunting – will be measured as a continuous data.

Wasting – will be measured as a continuous data.

Underweight – will be measured as a continuous data.

Timing and effect measures

25. * Additional outcome(s).

List the pre-specified additional outcomes of the review, with a similar level of detail to that required for main outcomes. Where there are no additional outcomes please state ‘None’ or ‘Not applicable' as appropriate to the review.

Income Dietary diversity – food variety score will be taken.

Serum retinol level- it will be measured as a continuous data.

Cost of intervention.

Timing and effect measures

26. * Data extraction (selection and coding).

Give the procedure for selecting studies for the review and extracting data, including the number of researchers involved and how discrepancies will be resolved. List the data to be extracted.

Data will be extracted by two independent reviewers using Covidence software. Discrepancies will be resolved by discussions.

The following data will be extracted from the included studies in this review:

• Study characteristics: study design, period of study, study location, sample size, number of study centers, study location, setting, mode of data collection, and bibliographic details of study reports.

•Characteristics of participants: total number of participants, socioeconomic status, mean age, age range.

•Interventions: type of intervention, duration, comparison, and any supporting behavioral intervention.

•Outcome variables: primary and secondary outcomes

27. * Risk of bias (quality) assessment.

State whether and how risk of bias will be assessed (including the number of researchers involved and how discrepancies will be resolved), how the quality of individual studies will be assessed, and whether and how this will influence the planned synthesis.

Risk of bias will be assessed by two independent reviewers with respect to random sequence generation, allocation concealment, blinding of participants, blinding of outcome assessment, incomplete outcome data, selective reporting and other possible sources of bias.

28. * Strategy for data synthesis.

Give the planned general approach to synthesis, e.g. whether aggregate or individual participant data will be used and whether a quantitative or narrative (descriptive) synthesis is planned. It is acceptable to state that a quantitative synthesis will be used if the included studies are sufficiently homogenous.

Data will be synthesized by one reviewer narratively and quantitatively using Revman if the studies are similar enough. Meta-analysis will be carried out using Revman. Aggregate data will be used in statistical synthesis, and the random effects model will be adopted. Heterogeneity analysis will be carried out by calculating the I^2 which would be used to denote the percentage of variation amongst studies. (I^2 50% indicates high heterogeneity). Sensitivity analysis will be carried out for the fixed effect model versus the random effects model. The quality of included studies will be assessed using the GRADE (Grading of Recommendations Assessments, Development and Evaluation)

29. * Analysis of subgroups or subsets.

Give details of any plans for the separate presentation, exploration or analysis of different types of participants (e.g. by age, disease status, ethnicity, socioeconomic status, presence or absence or co- morbidities); different types of intervention (e.g. drug dose, presence or absence of particular components of intervention); different settings (e.g. country, acute or primary care sector, professional or family care); or different types of study (e.g. randomised or non-randomised).

The following categories will be analyzed:

• Provision of training, seedlings and tools versus promotion of the practice of home food production without training and provision of tools and seedlings.

• Provision of training, seedlings and tools versus provision of nutrition education and promotion of the practice of home food production.

• Planting of fruits, vegetables and rearing of chickens versus only planting of fruits and vegetables.

• Planting of fruits, vegetables and rearing of chickens versus planting of a single staple

• Duration of 12-24 months versus 24 months.

• Orange-fleshed sweet potato versus vitamin A biofortified cassava.

• Orange-fleshed sweet potato versus vitamin A biofortified maize

• Practice of home food production in rural versus urban areas.

• Studies conducted in Africa versus studies conducted in Asia.

30. * Type and method of review.

Select the type of review and the review method from the lists below. Select the health area(s) of interest for your review.

Type of review

Cost effectiveness No

Diagnostic No

Epidemiologic No

Individual patient data (IPD) meta-analysis No

Intervention Yes

Meta-analysis No

Methodology No

Narrative synthesis No

Network meta-analysis No

Pre-clinical No

Prevention No

Prognostic No

Prospective meta-analysis (PMA) No

Review of reviews No

Service delivery No

Synthesis of qualitative studies No

Systematic review Yes

Other No

Health area of the review

Alcohol/substance misuse/abuse No

Blood and immune system No

Cancer No

Cardiovitamin A supplementationcular No

Care of the elderly No

Child health Yes

Complementary therapies No

Crime and justice No

Dental No

Digestive system No

Ear, nose and throat No

Education No

Endocrine and metabolic disorders No

Eye disorders Yes

General interest No

Genetics No

Health inequalities/health equity No

Infections and infestations No

International development No

Mental health and behavioural conditions No

Musculoskeletal No

Neurological No

Nursing No

Obstetrics and gynaecology No

Oral health No

Palliative care No

Perioperative care No

Physiotherapy No

Pregnancy and childbirth No

Public health (including social determinants of health) No

Rehabilitation No

Respiratory disorders No

Service delivery No

Skin disorders No

Social care No

Surgery No

Tropical Medicine No

Urological No

Wounds, injuries and accidents No

Violence and abuse No

31. Language.

Select each language individually to add it to the list below, use the bin icon to remove any added in error. English

There is an English language summary.

32. Country.

Select the country in which the review is being carried out from the drop down list. For multi-national collaborations select all the countries involved.

England

33. Other registration details.

Give the name of any organisation where the systematic review title or protocol is registered (such as with The Campbell Collaboration, or The Joanna Briggs Institute) together with any unique identification number assigned. (N.B. Registration details for Cochrane protocols will be automatically entered). If extracted data will be stored and made available through a repository such as the Systematic Review Data Repository (SRDR), details and a link should be included here. If none, leave blank.

34. Reference and/or URL for published protocol.

Give the citation and link for the published protocol, if there is one Give the link to the published protocol.
Alternatively, upload your published protocol to CRD in pdf format. Please note that by doing so you are consenting to the file being made publicly accessible.

No I do not make this file publicly available until the review is complete

Please note that the information required in the PROSPERO registration form must be completed in full even if access to a protocol is given.

35. Dissemination plans.

Give brief details of plans for communicating essential messages from the review to the appropriate audiences.

Do you intend to publish the review on completion?

Yes

36. Keywords

Give words or phrases that best describe the review. Separate keywords with a semicolon or new line. Keywords will help users find the review in the Register (the words do not appear in the public record but are included in searches). Be as specific and precise as possible. Avoid acronyms and abbreviations unless these are in wide use.

37. Details of any existing review of the same topic by the same authors.

Give details of earlier versions of the systematic review if an update of an existing review is being registered, including full bibliographic reference if possible.

38. * Current review status.

Review status should be updated when the review is completed and when it is published. For new registrations the review must be Ongoing.
Please provide anticipated publication date
Review: Ongoing

39. Any additional information

Provide any other information the review team feel is relevant to the registration of the review.

40. Details of final report/publication(s).

This field should be left empty until details of the completed review are available. Give the link to the published review.

APPENDIX TWO: EMBASE OVID SEARCH STRATEGY

1 (home* or hous* or kitchen* or commun* or women* or local* or (small adj scale*) or family or families or domestic* or traditional* or participatory).ti,ab. (5242669)

2 ((home* or hous* or kitchen* or commun* or women* or local* or (small adj scale*) or family or families or domestic* or traditional* or participatory) adj3 (goat* or poultry or dairy or dairies or fruit* or vegetable* or cow* or cattle or chicken*)).ti,ab. (12653)

3 ((home* or hous* or kitchen* or commun* or women* or local* or (small adj scale*) or family or families or domestic* or traditional* or participatory) adj3 (garden* or farm* or grow* or agricultur* or horticultur*)).ti,ab. (35999)

4 ((orange* or colour* or color* or dark* or carotene* or (vitamin* adj3 A) or betacarotene* or beta-carotene* or retinol*) adj3 (vegetable* or fruit* or potato* or tuber*)).ti,ab. (3524)

5 (garden* adj3 (vegetabl* or fruit* or traditional*)).ti,ab. (701)

6 ((food-based* or commun* or women*) adj3 ((vitamin* adj3 A) or carotene* or betacarotene* or beta-carotene* or retinol* or nutritio*)).ti,ab. (4543)

7 ((home* or house*) adj3 (nutritio* or food* or security)).ti,ab. (10101)

8 young adult/ or child/ or juvenile/ or infant/ or infant/ (2076505)

9 'crossover procedure'.de. (58047)

10 'double-blind procedure'.de. (157592)

11 (cross adj1 over*).de,ab,ti. (30559)

12 'randomized controlled trial'.de. (533609)

13 'single-blind procedure'.de. (33779)

14 (random* or factorial* or crossover*).de,ti,ab. (1661926)

15 (doubl* adj1 blind*).de,ti,ab. (194996)

16 (singl* adj1 blind*).de,ti,ab. (23496)

17 (placebo* or assign* or allocat* or volunteer*).de,ab,ti. (1091492)

18 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 (2335884)

19 animal husbandry/ or cattle farming/ or dairying/ or pig farming/ or poultry farming/ or sheep farming/ (29279)

20 1 and 19 (7231)

21 2 or 3 or 4 or 5 or 6 or 7 or 20 (70890)

22 8 and 18 and 21 (1169)

APPENDIX THREE: MEDLINE OVID SEARCH STRATEGY

1 (home* or hous* or kitchen* or commun* or women* or local* or (small adj scale*) or family or families or domestic* or traditional* or participatory).ti,ab. (4192447)

2 ((home* or hous* or kitchen* or commun* or women* or local* or (small adj scale*) or family or families or domestic* or traditional* or participatory) adj3 (goat* or poultry or dairy or dairies or fruit* or vegetable* or cow* or cattle or chicken*)).ti,ab. (11852)

3 ((home* or hous* or kitchen* or commun* or women* or local* or (small adj scale*) or family or families or domestic* or traditional* or participatory) adj3 (garden* or farm* or grow* or agricultur* or horticultur*)).ti,ab. (31326)

4 ((orange* or colour* or color* or dark* or carotene* or (vitamin* adj3 A) or betacarotene* or beta-carotene* or retinol*) adj3 (vegetable* or fruit* or potato* or tuber*)).ti,ab. (3112)

5 agriculture/ or animal husbandry/ or crop production/ or dairying/ or farms/ or gardening/ or gardens/ (69631)

6 1 and 5 (17500)

7 (garden* adj3 (vegetabl* or fruit* or traditional*)).ti,ab. (554)

8 ((food-based* or commun* or women*) adj3 ((vitamin* adj3 A) or carotene* or betacarotene* or beta-carotene* or retinol* or nutritio*)).ti,ab. (3692)

9 ((home* or house*) adj3 (nutritio* or food* or security)).ti,ab. (7769)

10 2 or 3 or 4 or 6 or 7 or 8 or 9 (69611)

11 randomized controlled trial.pt. (475046)

12 controlled clinical trial.pt. (92873)

13 randomized.ab. (435896)

14 placebo.ab. (195891)

15 randomly.ab. (306347)

16 trial.ab. (455120)

17 groups.ab. (1886657)

18 11 or 12 or 13 or 14 or 15 or 16 or 17 (2723247)

19 exp animals/ not humans.sh. (4539906)

20 18 not 19 (2306576)

21 adolescent/ or young adult/ or child/ or child, preschool/ or infant/ (3384237)

22 10 and 20 and 21 (2285)

APPENDIX FOUR: SEARCH STRATEGY FOR SCOPUS

1 (home* or hous* or kitchen* or commun* or women* or local* or (small W scale*) or family or families or domestic* or traditional* or participatory) (11524044)

2 ((home* or hous* or kitchen* or commun* or women* or local* or (small W scale*) or family or families or domestic* or traditional* or participatory) W/3 (goat* or poultry or dairy or dairies or fruit* or vegetable* or cow* or cattle or chicken*)) (30567)

3 ((orange* or colour*or color* or dark* or carotene* or (vitamin A) or betacarotene* or beta-carotene* or retinol*) W/3 (vegetable* or fruit* or potato* or tuber*)) (21490)

4 agriculture or animal husbandry or crop production or dairying or farms or gardening or gardens (49752)

5 1 and 4 (16991)

6 #2 OR #3 OR #5 (67700)

7 (randomized AND controlled AND trial.pt.)) OR (TITLE-ABS-KEY (controlled AND clinical AND trial.pt.)) OR (TITLE-ABS-KEY (randomized* OR placebo* OR trial* OR group*)) (9278588)

8 adolescent or young adult or child, preschool or infant (2655954)

9 6 and 7 and 8 (1018)

APPENDIX FIVE: SEARCH STRATEGY FOR COCHRANE CENTRAL REGISTER OF CONTROLLED TRIALS

#1 (home* or hous* or kitchen* or commun* or women* or local* or (small NEAR scale*) or family or families or domestic* or traditional* or participatory) (309242)

#2 ((home* or hous* or kitchen* or commun* or women* or local* or (small NEAR scale*) or family or families or domestic* or traditional* or participatory) NEAR (goat* or poultry or dairy or dairies or fruit* or vegetable* or cow* or cattle or chicken*)) (808)

#3 ((home* or hous* or kitchen* or commun* or women* or local* or (small NEAR scale*) or family or families or domestic* or traditional* or participatory) NEAR (garden* or farm* or grow* or agricultur* or horticultur*)) (2070)

#4 ((orange* or colour* or color* or dark* or carotene* or (vitamin* NEAR A) or betacarotene* or beta-carotene* or retinol*) NEAR (vegetable* or fruit* or potato* or tuber*)) (429)

#5 agriculture or animal husbandry or crop production or dairying or farms or gardening or gardens (1489)

#6 #1 AND #5 (754)

#7 (garden* NEAR (vegetabl* or fruit* or traditional*)) (44)

#8 ((food-based* or commun* or women*) NEAR ((vitamin* NEAR A) or carotene* or betacarotene* or beta-carotene* or retinol* or nutritio*)) (1698)

#9 ((home* or house*) NEAR (nutritio* or food* or security)) (1453)

#10 #2 OR #3 OR #4 OR #6 OR #7 OR #8 OR #9 (6371)

#11 adolescent or young adult or child or preschool or infant (259111)

#12 #10 AND #11 (2283)

APPENDIX SIX: SEARCH STRATEGY FOR INTERNATIONAL CLINICAL TRIAL REGISTRY PLATFORM (ICTRP)

1. carotene* or (vitamin A) or betacarotene* or beta-carotene* or retinol* (19 records for 16 trials found)

2. (home* or hous* or kitchen* or commun* or women* or local* or family or families or domestic* or traditional* or participatory) AND (garden* or agriculture or horticulture or farm* or goat* or poultry or dairy or dairies or fruit* or vegetable* or cow* or cattle* or chicken* or animal husbandry or crop production) (42 records for 28 trials found)

APPENDIX SEVEN: DATA EXTRACTION FORM

Study characteristics Title of study Names of authors Study design, Period of study Study location Number of study centers Setting Mode of data collection
Characteristics of participants General description of participants Total number of participants Socioeconomic status Age range
Interventions Describe intervention Describe comparison Categories for subgrouping Training provided to intervention: yes or no Provision of tools and seedlings to intervention: yes or no

Intervention includes: plant growing/ poultry/ dairy Orange-fleshed sweet potato included in intervention: yes or no Orange-fleshed sweet potato included in control: yes or no Biofortified maize included in the intervention: yes or no Biofortified maize included in the control: yes or no Biofortified cassava included in the intervention: yes or no Biofortified cassava included in the control: yes or no Was the intervention in a rural area: yes or no Was the intervention in an urban area: yes or no Was the intervention in Africa: yes or no Was the intervention in Asia: yes or no Duration of intervention 12 ≥ 24 months: yes or no ≥ 24 months: yes or no Duration of follow up for outcomes
Outcome variables No of children assessed No of families being assessed Primary outcomes (standard deviation and no of events) 1. Night blindness 2. Xeropthalmia 3. All-cause mortality 4. Stunting 5. Wasting 6. Underweight Secondary outcomes 1. Income 2. Dietary diversity

3. Serum retinol level
4. Cost of intervention

Baseline vitamin A supplementation

Base line vitamin A status

Prevalence of vitamin A

APPENDIX EIGHT: COCHRANE RISK OF BIAS TOOL

Bias domain	Source of bias	Support for judgment	Review authors' judgment (assess as low, unclear or high risk of bias)
Selection bias	Random sequence generation	Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups	Selection bias (biased allocation to interventions) due to inadequate generation of a randomised sequence
	Allocation concealment	Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen before or during enrolment	Selection bias (biased allocation to interventions) due to inadequate concealment of allocations before assignment
Performance bias	Blinding of participants and personnel*	Describe all measures used, if any, to blind trial participants and researchers from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective	Performance bias due to knowledge of the allocated interventions by participants and personnel during the study
Detection bias	Blinding of outcome assessment*	Describe all measures used, if any, to blind outcome assessment from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective	Detection bias due to knowledge of the allocated interventions by outcome assessment

Bias domain	Source of bias	Support for judgment	Review authors' judgment (assess as low, unclear or high risk of bias)
Attrition bias	Incomplete outcome data*	Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomised participants), reasons for attrition or exclusions where reported, and any re-inclusions in analyses for the review	Attrition bias due to amount, nature, or handling of incomplete outcome data
Reporting bias	Selective reporting	State how selective outcome reporting was examined and what was found	Reporting bias due to selective outcome reporting
Other bias	Anything else, ideally pre-specified	State any important concerns about bias not covered in the other domains in the tool	Bias due to problems not covered elsewhere

APPENDIX NINE: ALL META-ANALYSIS RESULTS ASSESSING EFFECT ON STUNTING, INCLUDING SENSITIVITY ANALYSES AND SUBGROUPING.

Outcome	Studies	Participants	Statistical Method	Effect Estimate	I²	Chi²
Stunting	9	9446	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	7	5469	Mean Difference (IV, Random, 95% CI)	0.13 [0.01, 0.24]	84 %	37.26 P < 0.00001
Adjusted for clustering	2	706	Mean Difference (IV, Random, 95% CI)	0.24 [-0.00, 0.48]	41 %	1.68 P = 1.68
Unadjusted for clustering	4	3271	Mean Difference (IV, Random, 95% CI)	0.03 [-0.05, 0.12]	0%	1.39 P = 0.71
Prevalence of stunting	6	4091	Risk Ratio (M-H, Random, 95% CI)	Subtotals only		
Adjusted for clustering	2	206	Risk Ratio (M-H, Random, 95% CI)	0.86 [0.66, 1.12]		
Unadjusted for clustering	5	3885	Risk Ratio (M-H, Random, 95% CI)	0.94 [0.84, 1.05]	52 %	8.85 P = 0.08
Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I²**	**Chi² test for subgroup differences, p - value**
Stunting sub-grouped by continent	7	5469	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Asia	2	1127	Mean Difference (IV, Random, 95% CI)	0.69 [-0.89, 2.28]	92 %	0.09
Africa	5	4342	Mean Difference (IV, Random, 95% CI)	0.13 [-0.01, 0.25]	83 %	P = 0.77
Stunting sub-grouped by duration	6	4137	Mean Difference (IV, Random, 95% CI)	Subtotals only		

12 to < 24 months	3	2052	Mean Difference (IV, Random, 95% CI)	0.19 [0.04, 0.34]	85 %	0.24
24+ months	3	2085	Mean Difference (IV, Random, 95% CI)	0.31 [-0.14, 0.76]	87 %	P = 0.63
Stunting sub-grouped by type of intervention	7	5468	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Home garden and poultry	6	4548	Mean Difference (IV, Random, 95% CI)	0.17 [-0.03, 0.32]	86 %	5.29
Home garden	1	920	Mean Difference (IV, Random, 95% CI)	-0.06 [-0.20, 0.08]	NA	P = 0.02
Sensitivity analyses	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I^2**	**Chi^2**
Sensitivity analyses for stunting	9	9446	Mean Difference (IV, Fixed, 95% CI)	Subtotals only		
Fixed effects, adjusted for clustering and other factors	7	5469	Mean Difference (IV, Fixed, 95% CI)	0.00 [-0.01, 0.01]	84 %	37.26 P < 0.00001
Fixed effects, adjusted for clustering	2	706	Mean Difference (IV, Fixed, 95% CI)	0.22 [0.04, 0.40]	41 %	1.68 P= 0.19
Fixed effects, unadjusted for clustering	4	3271	Mean Difference (IV, Fixed, 95% CI)	0.03 [-0.05, 0.12]	0%	1.39 P = 0.71

APPENDIX TEN: ALL META-ANALYSIS RESULTS ASSESSING EFFECT ON WASTING, INCLUDING SENSITIVITY ANALYSES AND SUBGROUPING.

Outcome	Studies	Participants	Statistical Method	Effect Estimate	I^2	Chi^2
Wasting	9	8486	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	6	4510	Mean Difference (IV, Random, 95% CI)	0.05 [-0.04, 0.14]	61 %	12.67 P = 0.03
Adjusted for clustering	2	706	Mean Difference (IV, Random, 95% CI)	0.06 [-0.13, 0.25]	0%	0.06 P =0.80
Unadjusted for clustering	4	3270	Mean Difference (IV, Random, 95% CI)	0.01 [-0.06, 0.09]	5%	3.15 P = 037
Prevalence of wasting	6	4090	Risk Ratio (M-H, Random, 95% CI)	Subtotals only		
Adjusted for clustering	1	206	Risk Ratio (M-H, Random, 95% CI)	0.91 [0.44, 1.87]		
Unadjusted for clustering	5	3884	Risk Ratio (M-H, Random, 95% CI)	0.89 [0.62, 1.28]	27 %	5.5 P = 0.24
Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I^2**	**Chi^2 test for subgroup differences, p - value**
Wasting (Type of intervention)	6	4510	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Home gardens and poultry	5	3589	Mean Difference (IV, Random, 95% CI)	0.06 [-0.05, 0.17]	63 %	0.47
Home garden	1	921	Mean Difference (IV, Random, 95% CI)	0.00 [-0.13, 0.13]	NA	P = 0.49
Wasting (duration of intervention)	6	4510	Mean Difference (IV, Random, 95% CI)	Subtotals only		

12 – 24 months	3	2052	Mean Difference (IV, Random, 95% CI)	-0.01 [-0.10, 0.09]	0	1.53
24+ months	3	2458	Mean Difference (IV, Random, 95% CI)	0.10 [-0.04, 0.25]	71 %	P = 0.22
Wasting (continent)	6	4510	Mean Difference (IV, Random, 95% CI)	Subtotals only	NA	5.87
Asia	1	3383	Mean Difference (IV, Random, 95% CI)	0.59 [0.15, 1.04]	48 %	P = 0.021
Africa	5	1127	Mean Difference (IV, Random, 95% CI)	0.04 [-0.03, 0.11]		
Outcomes	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I²**	**Chi²**
Wasting	9	8486	Mean Difference (IV, Fixed, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	6	4510	Mean Difference (IV, Fixed, 95% CI)	0.09 [0.08, 0.10]	61 %	12.67 P = 0.03
Unadjusted for clustering	2	706	Mean Difference (IV, Fixed, 95% CI)	0.06 [-0.13, 0.25]	0%	0.06 P = 0.80
Unadjusted for clustering	4	3270	Mean Difference (IV, Fixed, 95% CI)	0.01 [-0.06, 0.08]	5%	3.15 P = 0.37
Prevalence of wasting	6	4090	Risk Ratio (M-H, Fixed, 95% CI)	Subtotals only		
Adjusted for clustering	1	206	Risk Ratio (M-H, Fixed, 95% CI)	0.91 [0.44, 1.87]	NA	
Unadjusted for clustering	5	3884	Risk Ratio (M-H, Fixed, 95% CI)	0.89 [0.68, 1.16]	27 %	5.5 P = 0.24

APPENDIX ELEVEN: ALL META-ANALYSIS RESULTS ASSESSING EFFECT ON UNDERWEIGHT, INCLUDING SENSITIVITY ANALYSES AND SUBGROUPING.

Outcomes	Studies	Participants	Statistical Method Random effects	Effect Estimate	I^2	Chi^2
Underweight	8	7968	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	6	4510	Mean Difference (IV, Random, 95% CI)	0.07 [-0.01, 0.15]	63 %	13.61 P = 0.02
Adjusted for clustering	2	707	Mean Difference (IV, Random, 95% CI)	0.16 [-0.02, 0.34]	0%	0.93 P = 0.33
Unadjusted for clustering	3	2751	Mean Difference (IV, Random, 95% CI)	0.03 [-0.05, 0.11]	0%	0.69 P = 0.71
Prevalence of underweight	6	4095	Risk Ratio (M-H, Random, 95% CI)	Subtotals only		
Adjusted for clustering	1	207	Risk Ratio (M-H, Random, 95% CI)	0.82 [0.57, 1.19]		
Unadjusted for clustering	5	3888	Risk Ratio (M-H, Random, 95% CI)	0.95 [0.84, 1.07]	25 %	5.36 P = 0.25
Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I^2**	**Chi^2 test for subgroup differences, p - value**
Underweight (continent)	6	4510	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Africa	4	3383	Mean Difference (IV, Random, 95% CI)	0.05 [0.04, 0.06]	0%	0.62
Asia	2	1127	Mean Difference (IV, Random, 95% CI)	0.47 [-0.58, 1.52]	91 %	P = 0.43
Underweight (Duration)	6	3888	Mean Difference (IV, Random, 95% CI)	Subtotals only		

12 – 24 months	3	1552	Mean Difference (IV, Random, 95% CI)	0.08 [-0.08, 0.15]	0%	0.09
24+ months	3	2336	Mean Difference (IV, Random, 95% CI)	0.11 [-0.09, 0.30]	82 %	P = 0.77
Underweight (type of intervention)	6	3888	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Home garden and poultry	5	3344	Mean Difference (IV, Random, 95% CI)	0.09 [-0.01, 0.19]	68 %	1.76
Home garden	1	544	Mean Difference (IV, Random, 95% CI)	-0.02 [-0.15, 0.11]	NA	P = 0.18
Outcomes	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I^2**	**Chi^2**
Underweight	8	7968	Mean Difference (IV, Fixed, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	6	4510	Mean Difference (IV, Fixed, 95% CI)	0.05 [0.04, 0.06]	63 %	13.61
Adjusted for clustering	2	707	Mean Difference (IV, Fixed, 95% CI)	0.16 [-0.02, 0.34]	0%	0.93
Unadjusted for clustering	3	2751	Mean Difference (IV, Fixed, 95% CI)	0.03 [-0.05, 0.11]	0%	0.69
Prevalence of underweight	6	4095	Risk Ratio (M-H, Fixed, 95% CI)	Subtotals only		
Adjusted for clustering	1	207	Risk Ratio (M-H, Fixed, 95% CI)	0.82 [0.57, 1.19]	NA	
Unadjusted for clustering	5	3888	Risk Ratio (M-H, Fixed, 95% CI)	0.95 [0.86, 1.05]	25 %	5.36

APPENDIX TWELVE: ALL META-ANALYSIS RESULTS ASSESSING EFFECT ON SERUM RETINOL, INCLUDING SENSITIVITY ANALYSES AND SUBGROUPING.

Outcomes	Studies	Participants	Statistical Method Random effects	Effect Estimate	I^2	Chi^2
Serum retinol	3	780	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	1	413	Mean Difference (IV, Random, 95% CI)	0.01 [-0.06, 0.05]		
Unadjusted for clustering	2	367	Mean Difference (IV, Random, 95% CI)	-0.07 [-0.37, 0.24]	92%	13.15
Outcomes	**Studies**	**Participants**	**Statistical Method Fixed Effects**	**Effect Estimate**	**I^2**	**Chi^2**
Serum retinol	3	780	Mean Difference (IV, Random, 95% CI)	Subtotals only		
Adjusted for clustering and other factors	1	413	Mean Difference (IV, Fixed, 95% CI)	-0.01 [-0.06, 0.05]		
Unadjusted for clustering	2	367	Mean Difference (IV, Fixed, 95% CI)	0.05 [0.00, 0.10]	92%	13.15

APPENDIX THIRTEEN: ALL META-ANALYSIS RESULTS ASSESSING EFFECT ON DIETARY DIVERSITY, INCLUDING SENSITIVITY ANALYSES AND SUBGROUPING.

Outcomes	Studies	Participants	Statistical Method	Effect Estimate	I^2	Chi^2
Dietary diversity	3	2643	Std. Mean Difference (IV, Random, 95% CI)	Subtotals only		
Unadjusted for clustering	3	2643	Std. Mean Difference (IV, Random, 95% CI)	0.24 [0.15, 0.34]	0%	1.06
Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I^2**	**Chi^2 test for subgroup differences, p - value**
Dietary Diversity (continent)	3		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only		
Africa	2	2169	Std. Mean Difference (IV, Random, 95% CI)	0.25 [0.14, 0.36]	0%	0.07
Asia	1	474	Std. Mean Difference (IV, Random, 95% CI)	0.22 [0.04, 0.41]	NA	P = 0.80
Dietary diversity (duration)	3		Std. Mean Difference (IV, Random, 95% CI)	Subtotals only		
12 – 24 months	1	1210	Std. Mean Difference (IV, Random, 95% CI)	0.23 [0.12, 0.34]	NA	0.17
24+ months	2	1433	Std. Mean Difference (IV, Random, 95% CI)	0.27 [0.11, 0.43]	0%	P = 0.68
Outcomes	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**	**I^2**	**Chi^2**
Dietary diversity	3	2643	Std. Mean Difference (IV, Fixed, 95% CI)	Subtotals only		
Unadjusted for clustering	3	2643	Std. Mean Difference (IV, Fixed, 95% CI)	0.24 [0.15, 0.34]	0%	1.06

APPENDIX FOURTEEN: CHARACTERISTICS AND RISK OF BIAS ASSESSMENT OF INCLUDED STUDIES

Faber 2002

Methods	Controlled clinical trial
Participants	Women
Interventions	Intervention arm:Training in home gardening and nutrition education Control arm: No intervention was received location: South Africa Period of study: 2 years
Outcomes	Serum retinol level in children in micromole/litre

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	a nearby village was chosen as the control. randomisation was not done
Allocation concealment (selection bias)	Unclear risk	no clear information was given
Blinding of participants and personnel (performance bias)	Unclear risk	no clear information was given
Blinding of outcome assessment (detection bias)	Unclear risk	no clear information was given
Incomplete outcome data (attrition bias)	Unclear risk	no clear information was given

Selective reporting (reporting bias)	Unclear risk	no clear information was given
Other bias	High risk	Orange-fleshed sweet potato and butter-nut squash was not in season when follow-up was done. this may have affected the response

Gelli 2018

Methods	Cluster randomised controlled trial
Participants	Women aged above 14 years
Interventions	Intervention arm: Training in agricultural practices and distribution of chicks and seedling. Loans granted to households, cooking sessions, nutrition education. Control group was exposed to child nutrition education Location: Malawi Period of study: 1 year
Outcomes	Stunting, wasting and underweight measured in children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	first and second level randomization was done
Allocation concealment (selection bias)	High risk	enumerators were not blinded to the allocation
Blinding of participants and personnel (performance bias)	Unclear risk	no information was provided
Blinding of outcome assessment (detection bias)	Unclear risk	no information was provided
Incomplete outcome data (attrition bias)	Low risk	information on the number of incomplete data and reason was given. 7% attrition

Selective reporting (reporting bias)	Low risk	some outcomes were published in another journal
Other bias	Low risk	no others source of bias was noted

Hotz 2012

Methods	Cluster randomised trial
Participants	Women with mean age of 28.9 years
Interventions	Distribution of orange sweet potato vines and nutrition education, demand creation for selling surplus orange fleshed sweet potato. Control was exposed to no intervention Period of study: 3 years Location: Mozambique
Outcomes	Retinol activity equivalent in children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	clusters were selected
Allocation concealment (selection bias)	Unclear risk	no clear information was provided
Blinding of participants and personnel (performance bias)	Unclear risk	no clear information was provided
Blinding of outcome assessment (detection bias)	Unclear risk	no clear information was provided
Incomplete outcome data (attrition bias)	Low risk	the rate of attrition was given, 9 - 11%
Selective reporting (reporting bias)	Unclear risk	no clear information was given

Other bias	Low risk	no other source of bias was noted

Hotz 2012a

Methods	Cluster randomised controlled trial
Participants	Women with mean age of 34 years
Interventions	Distribution of orange sweet potato vines and nutrition education, demand creation for selling surplus orange fleshed sweet potato. Control group had no intervention Location: Uganda Period of study: 2 years
Outcomes	Serum retinol in children measured in micromole/litre.

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	no clear information was given
Allocation concealment (selection bias)	Unclear risk	no clear information was given
Blinding of participants and personnel (performance bias)	Unclear risk	no clear information was given
Blinding of outcome assessment (detection bias)	Low risk	a separate research design team evaluated outcomes

Incomplete outcome data (attrition bias)	High risk	information was not provided
Selective reporting (reporting bias)	Unclear risk	no clear information was given
Other bias	High risk	Judgement Comment: It is unclear whether the control group was exposed to the area-wide interventions (community radio etc) or not. The prevalence of vitamin A deficiency was very low in the women at baseline, compared to previous known local/national averages. The authors mention that a secular trend for improving vitamin A status may have had an impact on their findings, such as through food fortification and vitamin A supplementation

Khamhoung 2000

Methods	Controlled clinical trial
Participants	Women aged 15 - 45 years
Interventions	Training on setting up home gardens and animal rearing. Control group received no intervention Location: LAOs Period of study: 2 years
Outcomes	stunting, wasting and underweight in children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	no clear information was given
Allocation concealment (selection bias)	High risk	no allocation concealment was done

Blinding of participants and personnel (performance bias)	High risk	this was not considered in the study
Blinding of outcome assessment (detection bias)	High risk	this was not considered in the study
Incomplete outcome data (attrition bias)	Low risk	information was provided
Selective reporting (reporting bias)	Unclear risk	insufficient information
Other bias	High risk	Judgement Comment: large differences in baseline data

Kidala 2000

Methods	Quasi-experimental
Participants	Women
Interventions	Training and distribution of seedlings, nutrition education, cooking sessions. Control arm received no intervention Location: Tanzania Period of study: 2 years
Outcomes	Serum retinol in children measured in micromole per litre

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	one district was the intervention, another was the control - unclear how this was chosen, but the intervention had occurred in one place, it is unclear whether the control group was considered at that time.
Allocation concealment (selection bias)	High risk	Information on how allocation concealment was done was not provided

Blinding of participants and personnel (performance bias)	High risk	Not stated in the study
Blinding of outcome assessment (detection bias)	High risk	This was not stated to have been carried out
Incomplete outcome data (attrition bias)	High risk	Data only available for half of the children included in the survey
Selective reporting (reporting bias)	Unclear risk	No trials register found, intentions unclear, baseline data lost.
Other bias	High risk	No information on baseline similarity of groups - high risk of bias

Kuchenbecker 2017

Methods	Cluster randomised controlled trial
Participants	Women with a mean age of 27.2 years
Interventions	Distribution of farming items, livestock and training in farming. Nutrition education. Control arm received only agricultural practices with no nutrition education. Location: Malawi Period of study: 3 years
Outcomes	Stunting, wasting and underweight in children. Vitamin A-rich food intake

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A two-stage probability sampling strategy was applied. At the first sampling stage, villages were sampled proportional to population size using the software ENA for Smart. At the second sampling stage, 15 households

		with children under two years of age were randomly selected from each village using the software R.
Allocation concealment (selection bias)	Unclear risk	no clear information was given
Blinding of participants and personnel (performance bias)	Unclear risk	Information not provided
Blinding of outcome assessment (detection bias)	Unclear risk	information not provided
Incomplete outcome data (attrition bias)	Low risk	data at both baseline and endline almost similar
Selective reporting (reporting bias)	Unclear risk	information on protocol is unclear
Other bias	Low risk	None

Lakzadeh 2010

Methods	Cluster randomised trial
Participants	Women
Interventions	Training and distribution of seedlings for home gardening. Creation of fish ponds. 3 arms – HFP plus fish pond, HFP Control arm had no intervention Location: Cambodia Period of study: 22 months
Outcomes	income, cost of intervention, vitamin A retinol activity equivalent

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	a two-stage randomised cluster sampling method
Allocation concealment (selection bias)	Unclear risk	no information given
Blinding of participants and personnel (performance bias)	Unclear risk	no information given
Blinding of outcome assessment (detection bias)	Unclear risk	no information given
Incomplete outcome data (attrition bias)	Low risk	attrition rate was provided
Selective reporting (reporting bias)	Low risk	protocol was checked
Other bias	Low risk	no other source of bias noted

Low 2007

Methods	Quasi-experimental
Participants	Women
Interventions	Training and distribution of orange sweet potato vines, demand creation, nutrition education. Control group was not exposed to the interventions Location: Mozambique Period of study: 2 years
Outcomes	Dietary diversity, vitamin A retinal activity equivalent, income

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	no clear information was given

Allocation concealment (selection bias)	Unclear risk	No information given
Blinding of participants and personnel (performance bias)	Unclear risk	No information was given
Blinding of outcome assessment (detection bias)	Unclear risk	No information given
Incomplete outcome data (attrition bias)	Low risk	information on attrition was given and it was almost the same in both arms
Selective reporting (reporting bias)	Unclear risk	No trial registry number or protocol given to compare
Other bias	Low risk	no other source of bias noted

Marquis 2017

Methods	Cluster randomised trial
Participants	Women
Interventions	Training, distribution of seedlings, chicks and orange sweet potato vines, cooking sessions, nutrition education. Control group received no intervention Location: Ghana Period of study: 1 year
Outcomes	stunting, wasting and underweight in children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The 16 clusters were randomly assigned to treatment group(sequential, using random numbers

Allocation concealment (selection bias)	Unclear risk	information was not provided
Blinding of participants and personnel (performance bias)	Low risk	The clusters were geographically distant enough from each other to avoid direct contamination—that is, no control community participants received inputs or took part in educational activities planned for intervention participants
Blinding of outcome assessment (detection bias)	Low risk	it was not possible to mask the treatment assignment; therefore, the project maintained separate field staff for the implementation of the intervention and survey data collection.
Incomplete outcome data (attrition bias)	Low risk	rate of study attrition was 14.4%
Selective reporting (reporting bias)	Low risk	protocol was assessed
Other bias	Low risk	no other source of bias noted

Olney 2009

Methods	Randomised controlled trial
Participants	Women
Interventions	Training and distribution of seedlings and chicks, nutrition education. Control arm received no intervention Location: Cambodia Period of study: 19 months
Outcomes	Stunting, wasting, underweight and dietary diversity in children, income

Risk of bias table

Bias	Authors' judgement	Support for judgement

Random sequence generation (selection bias)	High risk	a selection was done rather than randomisation
Allocation concealment (selection bias)	Unclear risk	no clear information was given
Blinding of participants and personnel (performance bias)	Unclear risk	no clear information was given
Blinding of outcome assessment (detection bias)	Unclear risk	no clear information was given
Incomplete outcome data (attrition bias)	Unclear risk	no clear information was given
Selective reporting (reporting bias)	Unclear risk	no clear information was given
Other bias	High risk	difference in characteristics between the two arms

Olney 2015

Methods	Cluster randomised controlled trial
Participants	Women
Interventions	Training in home garden, distributions of seedlings and chicks, nutrition education. Control arm received no intervention. Nutrition education was carried out by two groups of women – health committee and older women group Location: Burkina Faso Period of study: 2 years
Outcomes	Stunting, wasting and underweight in children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	No information on randomisation of clusters

Allocation concealment (selection bias)	Unclear risk	no clear information was given
Blinding of participants and personnel (performance bias)	Unclear risk	no clear information was given
Blinding of outcome assessment (detection bias)	High risk	data was collected at home
Incomplete outcome data (attrition bias)	Low risk	attrition rate was given
Selective reporting (reporting bias)	Unclear risk	no clear information was given
Other bias	Low risk	no other source of bias was noted

Osei 2015

Methods	Cluster randomised trial
Participants	Women
Interventions	Training in home gardening, and poultry. Nutrition education. Three arms were used- HFP, HFP plus micronutrient powder and control arm Control group received no intervention. Location: Nepal Period of study: 4 years
Outcomes	Stunting, wasting and underweight in children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	A multistage cluster sampling procedure. A simple random sampling procedure was then used to select four pairs of Ilakas. The same procedure was used to assign one of the selected Ilakas in each pair to EHFP or control

Allocation concealment (selection bias)	Unclear risk	insufficient information
Blinding of participants and personnel (performance bias)	Low risk	Investigators and field workers were not blinded. However, the assignment of clusters rather than individuals to the study groups prevented participants in one group from knowing the treatment received by those in the other groups.
Blinding of outcome assessment (detection bias)	Unclear risk	no clear information was given
Incomplete outcome data (attrition bias)	Low risk	The baseline characteristics of those who dropped out of the study were not different from those who completed the study
Selective reporting (reporting bias)	Unclear risk	no clear information was given
Other bias	Low risk	no other source of bias was noted

Raneri 2017

Methods	Custer randomised controlled trials
Participants	Women
Interventions	Training in home garden, nutrition education and cooking demonstrations. Control group had no intervention. Location: Vietnam Period of study: one year
Outcomes	intake of vitamin A-rich foods

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	no clear information was given

Allocation concealment (selection bias)	Unclear risk	no clear information was given
Blinding of participants and personnel (performance bias)	Unclear risk	no clear information was given
Blinding of outcome assessment (detection bias)	Unclear risk	no clear information was given
Incomplete outcome data (attrition bias)	Unclear risk	no clear information was given
Selective reporting (reporting bias)	Unclear risk	no clear information was given
Other bias	Unclear risk	Insufficient information

Reinbott 2018

Methods	Cluster randomised trial
Participants	Women
Interventions	Training in home gardening, nutrition education and giving out of vouchers. Control arm received agricultural practices with no nutrition education Location: Cambodia Period of study: 2 years
Outcomes	Stunting, wasting, underweight and dietary diversity in Children

Risk of bias table

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The sampling was conducted using a two-stage probability sampling strategy. Initially, three villages per commune were sampled proportional to population size. Intervention and comparison areas were identified using the software package 'Experiment' and the operation 'randomise'. The 'Experiment' package is a software extension to the statistical software R©

Allocation concealment (selection bias)	Unclear risk	no clear information was provided
Blinding of participants and personnel (performance bias)	Low risk	Difficult due to nature of study. However, did attempt to conceal from field researchers as participants invited to a central meeting point for participating in the survey
Blinding of outcome assessment (detection bias)	Low risk	At impact, enumerators were blind to group assignment.
Incomplete outcome data (attrition bias)	Low risk	Attrition rate less than 20%
Selective reporting (reporting bias)	Unclear risk	no clear information was provided
Other bias	Low risk	no other source of bias was noted

Schreinemachers 2016

Methods	Quasi-experimental
Participants	Women
Interventions	Training in home gardening, distribution of seedlings and orange sweet potato vines. Control arm received no intervention Location: Bangladesh Period of study: 3 years
Outcomes	Income

Risk of bias table

Bias	Authors' judgement	Support for judgement

Random sequence generation (selection bias)	Unclear risk	'Randomly selected' – no further information given
Allocation concealment (selection bias)	Unclear risk	Insufficient information
Blinding of participants and personnel (performance bias)	Unclear risk	no information given.
Blinding of outcome assessment (detection bias)	Unclear risk	insufficient information
Incomplete outcome data (attrition bias)	Low risk	the 5 per cent sample attrition was explained by women being absent from their home during the visit
Selective reporting (reporting bias)	Unclear risk	no information given
Other bias	Low risk	There is potential bias from spill over effects of the intervention on the control group because the trained women had been encouraged to share their new knowledge with their neighbours. If such spill over did occur, then the evaluation is likely to underestimate the true impact of the intervention. Although the intervention and control groups were in different villages and there is only a 12-month period between baseline and follow up, spill over could affect the findings here. The authors have discussed this however there is no way to quantify the impact of any spill over effect with the design used.

APPENDIX FIFTEEN: DALY FOR ONE EPISODE OF MEASLES

DALYs for measles		
Deaths	817	(Ibrahim et al., 2019)
Cases	131732	(Ibrahim et al., 2019)
Life expectancy	52.98	(Crave, 2020)
Disability weight	0.152	(WHO, 2008a)
Cases in Sokoto	284.63	(Ibrahim et al., 2019)
Population	100000	(Ibrahim et al., 2019)
Duration	7	(WHO, 2020c)
Relative risk of measles	0.5	(Imdad et al., 2017)
YLL	0.32858121	(Death/cases) × life expectancy
YLD	0.002915068	1 × disability weight × (duration/365)
DALY	0.331496279	YLL + YLD
DALY control arm	0.000943538	DALY × (cases In Sokoto/population)
DALY intervention arm	0.000471769	DALY control arm × relative risk
discounted DALY control arm	0.000976562	$1/(1+D)^t$ D – discount factor, t - time
discounted DALY intervention	0.013950881	

APPENDIX SIXTEEN: RELATIVE RISK OF LOW RETINOL USING DATA FROM TALSMA ET AL. (2016)

	Control	**Intervention**		
No of events (%)	30	27		
Total number of participants	113	109		
2 by 2 table				
	Disease (Yes)	Disease (No)	Total	
Control	34 participants	79 participants	113 participants	34÷113 = 0.300884956
Intervention	29 participants	80 participants	109 participants	29÷109 = 0.266055046
Relative risk	0.26605÷0.30088 = 0.88424177			
Standard error	(1÷34) + (1÷29) + (1÷79) + (1÷80) = 0.089052751			

APPENDIX SEVENTEEN: DISABILITY WEIGHT FROM GLOBAL BURDEN OF DISEASE STUDY 2013

Health states	Disability weights	Reference
Well	0	
Low retinol	0.184	(Global Health Data Exchange, 2019)
Blindness	0.187	(Global Health Data Exchange, 2019)
Dead	1	

APPENDIX EIGHTEEN: PROPOSAL ON A QUALITATIVE STUDY TO EXPLORE BARRIERS AND FACILITATORS IN THE IMPLEMENTATION OF HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE IN THE PREVENTION OF VITAMIN A DEFICIENCY IN CHILDREN

BARRIERS AND FACILITATORS IN THE UPTAKE OF HOME GARDENING OF YELLOW CASSAVA AND ORANGE MAIZE TO PREVENT VITAMIN A DEFICIENCY IN CHILDREN: A QUALITATIVE STUDY

Vitamin A deficiency is one of the most prevalent micronutrient deficiencies (WHO, 2011) with about 33.3% of preschool children vitamin A deficient worldwide (WHO, 2009). Vitamin A deficiency is the main cause of preventable childhood blindness also known as nutritional blindness (Gilbert, 2013). Nutritional blindness in children manifests as xeropthalmia, an array of ocular signs and symptoms which presents as night blindness, bitot's spots, conjunctival xerosis, corneal xerosis, corneal ulcer, corneal scarring and keratomalacia (cornea ulcer covering up to 1/3rd of the cornea) (Gilbert, 2013). Xerophthalmia is caused by insufficient intake of vitamin A-rich foods (Akhtar et al., 2013). Globally, approximately 0.9% of children are suffering from xeropthalmia (WHO, 2009)). Childhood blindness has a huge impact both socially and economically. Blind children grow up to become blind adults and vision loss can hamper their quality of life, educational attainment, independence and social function (Gilbert, 2013b)

In 2003, a national survey in Nigeria revealed that about 54.5% of pre-school children are vitamin A deficient with 1.1% xeropthalmic cases (Ajaiyeoba, 2001). A recent cross-sectional study in Northern Nigeria established that 55% of pre-school children are vitamin A deficient (Abubakar et al., 2017). Table 1 below shows that there are higher rates of vitamin A deficiency and xeropthalmia in Nigeria compared to the global average. A lot of children in

Nigeria are not covered by the vitamin A supplementation programme to make up for their insufficient intake of vitamin A-rich foods. Data from the 2013 Nigerian Demographic Health Survey suggests that for children aged 6 – 59 months, vitamin A supplementation coverage was 41.5% (Aghaji et al., 2019). Coverage was significantly higher in urban (53.5%) than in rural areas (34.7%). North-western Nigeria, with the lowest vitamin A supplementation coverage (26.1%) had the highest prevalence of nutritional blindness (affecting 11 out of 20 children). In line with the findings of the 2013 Nigerian Demographic Health survey, Adamu and Muhammad (Adamu & Muhammad, 2016) carried out a cross-sectional survey to assess the success of coverage of vitamin A supplementation programme in Sokoto, Northern Nigeria. The results of their study demonstrated that only 41.6% of children received the WHO recommended two-dose vitamin A supplement. These findings explain the reason for the persistently high prevalence of vitamin A deficiency in Nigeria.

Table 1: burden of vitamin A deficiency

Variable	Global 1995 - 2005	Nigeria 2004
Vitamin A deficiency	33%	54.5%
Xeropthalmia	0.9%	1.1%

Home gardening of vitamin A-rich foods has been reported by some studies to be effective in controlling nutritional blindness in children below the age of 5 years. Home gardens, also known as compound gardens, kitchen gardens, backyard gardens are small plots of land near the home or within a trekkable distance from the house managed by members of the household with meagre cost input mainly for household consumption. Home gardens may stretch across a few meters to a few acres (usually from 0.2 to 0.5 hectares) and are primarily grown for household consumption, where the surplus produce is sold to generate income for the family (Faber, Phungula, et al., 2002). A mixed cropping method is usually adopted in home gardens where pawpaw trees, cassava, orange-fleshed sweet potato, yam, green leafy vegetables, chicken and goats are grown and reared on the same portion of land. A home garden of 15m by 10m has the potential of supplying adequate fruits and vegetables to meet the vitamin A requirements for a family of six all through the year (Faber, Phungula, et al., 2002). An evaluation of the Helen Keller Asian homestead food production programmes showed that children aged 12 – 59 months who were omitted by the vitamin A supplementation programme had a 66% lower prevalence of night blindness in households with a home garden compared to households without a home garden (Talukder et al., 2010).

Vitamin A is derived from a variety of both animal and plant sources. Some plant sources are dark green leafy vegetables (for example spinach), orange and yellow vegetables and fruits (for example carrots, bell peppers, pawpaw, mangoes), biofortified staple crops such as orange-fleshed sweet potato, yellow maize and yellow cassava. Animal sources include eggs, liver, milk and breast milk. Oils such as palm oil are rich in vitamin A (Gilbert, 2013b).

WHY WAS CASSAVA CHOSEN?

Cassava (Manihot esculenta) is a major staple crop in Nigeria, consumed by over 70 million Nigerians daily, and processed into garri, fufu and abacha. Garri is a coarse granular flour made from frying fermented cassava with or without palm oil. Fufu is made from cooking and pounding fermented cassava dough. Abacha is dried cassava chips (FAO, 1999). International Institute for Tropical Agriculture (IITA, 2020). Cassava provides about 37% of dietary energy and is rich in carbohydrates, vitamin B, C, calcium and other essential minerals (IITA, 2011).

Generally, cassava is known to have a white colour, however, new varieties biofortified with vitamin A is yellow (also known as yellow cassava). Yellow cassava was developed by a research team led by IITA. Similar to white cassava, yellow cassava can be processed into garri, fufu, abacha and flour (IITA, 2020). Yellow cassava is a significant innovation as it can improve the nutritional status of high consumers of cassava.

Nigeria is the largest producer of cassava worldwide (about 54 million metric tons produced annually), with approximately 95% consumed in the country and contributing greatly to food security and income generation in the country (FAO, 1999). Amongst all vitamin A biofortified staple, cassava is more widely consumed in Nigeria, for this reason, it would be the focus of this study. In Nigeria, the average consumption of cassava per person per day is about 700g while vitamin A biofortified maize is 300g (Onuegbu et al., 2017). Before the Nigerian civil war, between 1967 – 1970, cassava was mainly produced by women and was known as a woman's crop (Unanma, 2003). In recent times, men have become greatly involved in the production of cassava though the extent of their participation and contribution is different from that of women (Ironkwe et al., 2007). Thus, it is expected that there will be gender disparity in challenges encountered in the cultivation of cassava. Ezeibe et al., 2015 (Ezeibe et al., 2015) assessed the gender differences in the cultivation of cassava in Abia State, Nigeria. The results corroborate that both men and women are involved in cassava production but face challenges differently. In 2019, Olaosebikan et al., 2019 (Olaosebikan et al., 2019) analysed gender-based constraints in the cultivation, processing and marketing of vitamin A-rich cassava in Oyo and Benue states, Nigeria, using semi-structured interviews and focus group discussion. Their findings showed that women lacked access to hired labour, market infrastructure and training, and processing equipment was unaffordable which inhibited the scale of production. Further, Olasebikan et al., 2019 (Olaosebikan et al., 2019) showed that men in Oyo had a higher production of vitamin A cassava resulting from their strong ties and collaboration with agricultural research institutes located in the state. Investigating gender-responsive strategies and the influence of extension workers from research institutes in other vitamin A cassava producing states in Nigeria is crucial.

While home gardening of vitamin A-rich foods has the potential to control vitamin A deficiency in children not covered by vitamin A supplementation programmes in rural areas, it is not widely adopted in Nigeria. Lack of awareness on the importance of consuming vitamin A-rich foods and challenges to its cultivation impede implementation. Olowoniyan, Owolabi and Anigo, 2010 (Olowoniyan et al., 2010) carried out a study in 12 rural communities of Kaduna, Kebbi and Kwara states, reaching 300 households using a semi-structured interview and Rural Rapid Appraisal to explore the consumption of vitamin A-rich food. They reported that the foods were mainly used as traditional medicines stemming from a lack of knowledge of their nutritive value alongside inadequate storage and preserving facilities. Researchers have tried to identify some of the barriers and challenges in the home growing of vitamin A-rich foods. Jenkins et al., 2015 (Jenkins et al., 2015) conducted a qualitative study in Mozambique to explore factors affecting farmers willingness to adopt and plant orange-fleshed sweet potato (OFSP). Their findings showed that environmental factors, accessibility of planting materials, agronomic factors, taste preferences and organoleptic qualities affected farmers willingness to grow orange-fleshed sweet potato. A systematic review conducted by Jenkins, Byker Shanks and Houghtaling, 2015 (Jenkins et al., 2015) showed that some challenges in growing OFSP include management of pests and disease, preservation of vine, market development and storage of produce.

This project has just completed a systematic review that investigated the effectiveness of home gardening of vitamin A-rich foods (such as green leafy vegetables, orange-fleshed sweet potato and vitamin A bio-fortified maize) in the prevention of nutritional blindness in children under the age of 5 years in a rural setting. The results of the systematic review showed that home gardening of vitamin A-rich food improved dietary diversity increased consumption of vitamin A-rich foods and two studies (Hotz, et al., 2012; Low et al., 2007) included in the systematic review reported that home gardening of vitamin A-rich foods was associated with an increase in serum retinol in children. Despite the potential for home gardening of vitamin A-rich foods to address vitamin A deficiency and related inequities in rural populations, it is not widely implemented in Nigeria. Evidence on barriers/facilitators of growing vitamin A-rich foods at home would help inform its successful implementation. This proposed research draws upon the findings of the systematic review and aims to further assess the challenges of home gardening of vitamin A-rich foods in Nigeria.

CONTEXT

Yellow cassava will be the focus of this project, however, other vitamin A-rich foods (OFSP, vitamin A biofortified maize, yellow fruits among others) will also be explored. We intend to work with the IITA and HarvestPlus to recruit men and women that have participated in the home production of vitamin A cassava. These organisations have been contacted and are willing to support me on this project. IITA is a non-profit organisation focused on agricultural innovations to tackle serious challenges such as malnutrition, poverty and hidden hunger. IITA is a member of the CGIAR (the Consultative Group for International Agricultural Research) consortium of International Agricultural Research Centres. HarvestPlus is a non-profit organisation that combats hidden hunger and improves public health through the biofortification of staple crops. HarvestPlus collaborates with IITA in improving the nutrient content of staple crops and is a part of the CGIAR research programme on agriculture for nutrition and health (A4NH). IITA and HarvestPlus have undertaken several projects on vitamin A biofortified crops such as The Building Nutritious Food Basket (BNFB) and the release and distribution of vitamin A-rich cassava to Nigerian Farmers.

Imo state (Figure 1) has been proposed for this work and was chosen because it was one of the states where the biofortification delivery programme was rolled out by HarvestPlus. In 2011, the biofortification delivery programme distributed vitamin A cassava stems to farmers in ten local government areas each in Oyo, Imo, Akwa Ibom and Benue states. By 2012, a total of 60 villages per state were reached in vitamin A cassava stem multiplication and distribution. The programme trained farmers on cost-efficient stem multiplication, production and distribution. Farmers were also trained on the processing of vitamin A cassava and marketing strategies. After stem multiplication in 2011 – 2012, massive stem delivery to farmers commenced in 2013 and by 2015, over two million bundles of the stem had been delivered resulting in over a million households cultivating vitamin A cassava. Demand creation for vitamin A cassava was done through media sources – print, radio and television programmes (Harvestplus, 2020). I am familiar with Imo state and can speak the local language which would facilitate easy interaction with participants. Imo state is situated in the southeastern part of Nigeria and inhabited by the Ibo people. Imo is one of the most densely populated areas in Nigeria, has an area of 5,530 km², lies between lower river Niger and upper and middle river Imo, and has a population of about 5 million people. Agriculture is the primary occupation in Imo – yam, maize, cocoyam and cassava are the staple crops (Imostate.gov.ng, 2020).

Figure 1: Map showing the local governments in Imo state

Source: (Ikeduru Union UK, 2015)

IMPORTANCE OF RESEARCH

Home growing of bio-fortified vitamin A crops has been implemented by some organisations (HarvestPlus and IITA, Helen Keller Organisation) in Asian and African communities, and this has shown great potential in tackling nutritional blindness. However, the adoption of home growing of vitamin A-rich foods by healthcare stakeholders as a policy to tackle nutritional blindness in children under the age of 5 has not been successfully achieved in Nigeria. Evidence from this research will help promote the adoption of home gardening of vitamin A-rich crops as an acceptable policy in tackling nutritional blindness for children in rural areas not covered by the vitamin A supplementation programme. Exploring the role of gender will support the development of gender-informed strategies in the implementation of home gardening of vitamin A-rich foods. This research will bring together agricultural and healthcare professionals to work towards the elimination of nutritional blindness in Nigerian children.

RESEARCH QUESTIONS

- What are the barriers and facilitators to home gardening of vitamin A-rich foods in Nigeria?
- What are the potential costs and wider benefits of home gardening to society?

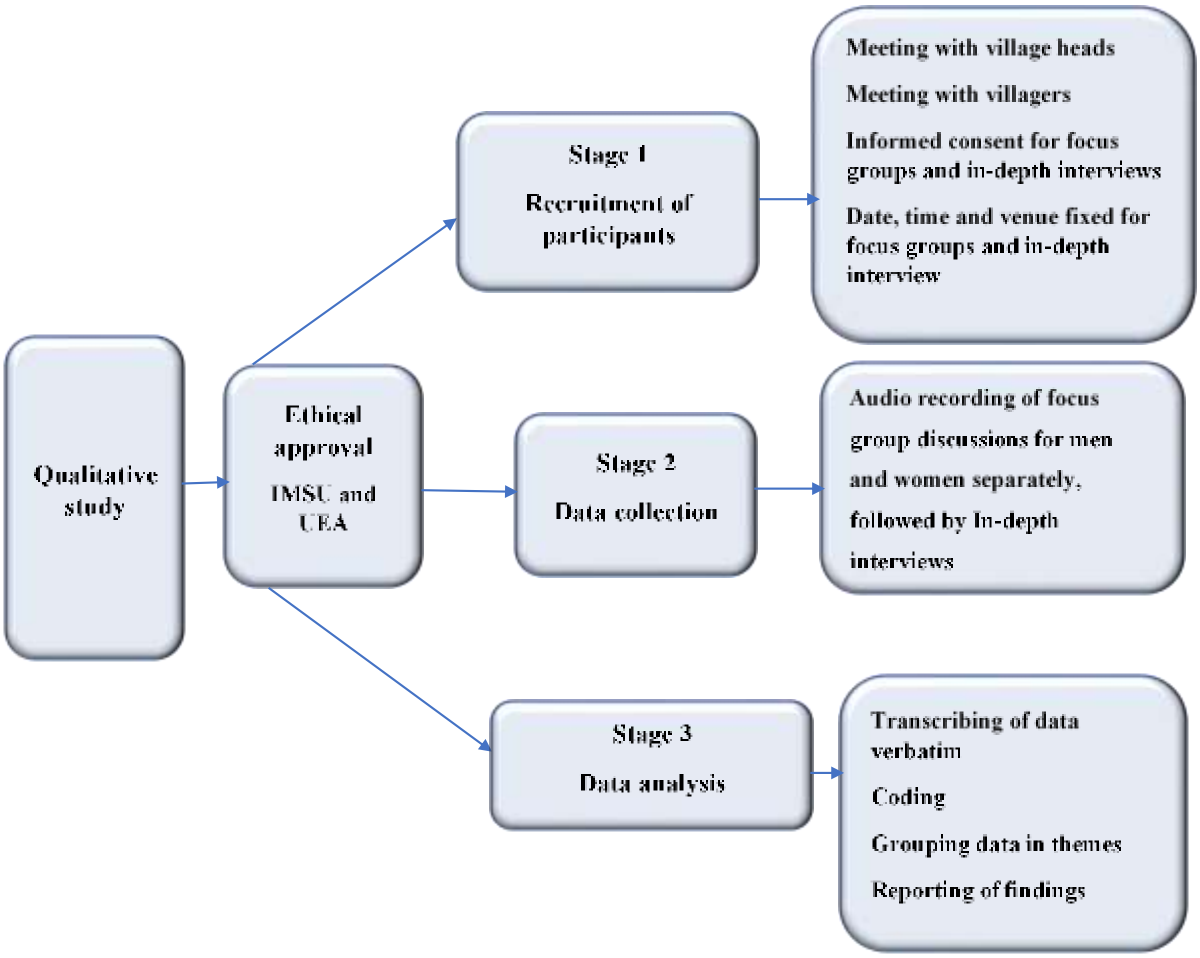
SUB-QUESTIONS

- What are the different roles men and women play in home gardening? What is the role of gender in household production of vitamin A cassava?
- What is the level of awareness of vitamin A cassava and its health benefits?
- What are the costs and benefits of vitamin A cassava to the household and society?
- What is the role of extension workers in the home gardening of vitamin A cassava?

RESEARCH DESIGN

A qualitative research methodology will be adopted that aims to understand people's lived experiences, attitudes, beliefs and behaviours (Pathak et al., 2013). This work will take place in Imo state from May to October 2020, mainly seeking to understand the barriers, facilitators and costs of home gardening of vitamin A-rich foods. Men and women that have participated in the home growing of vitamin A-rich foods will be recruited. Focus group discussions and in-depth interviews will be used in data collection. Data will be analysed using thematic analysis. This study will go through the following stages (Figure 2).

Figure 2: Visual representation of proposed work



STAGE 1: RECRUITMENT OF PARTICIPANTS

Criterion sampling is a type of purposive sampling strategy that selects participants on the premise that they have been involved in the phenomenon of interest, therefore they have the needed knowledge and experience to provide an in-depth and generalizable account of the subject matter (Palinkas et al., 2015). Criterion sampling will be used in recruiting participants as it will enable me to recruit participants that can answer the research questions.

INCLUSION CRITERIA

- Indigenes of Imo State
- Men and women with children below the age of five years
- Households with lands for home gardening

A total of 30 participants will be recruited - twenty participants that have engaged in cultivating vitamin A cassava and ten participants that have not engaged in vitamin A cassava cultivation. The sample size will be a mixture of households headed by men, households headed by women, households of different sizes and households of different social classes. Men and women from the same household and different households will be recruited.

RECRUITMENT PROCEDURE

I will go through village heads and leaders to reach households that meet the inclusion criteria. Written letters will be sent out to village heads and meetings will be scheduled and held with them to discuss all my research. The village heads will convey our intentions to the villagers and schedule a meeting between myself and the villagers. A meeting with the villagers (potential participants) will provide the opportunity to discuss the research objectives and participants' inclusion criteria with them. I will also discuss modes of data collection, location and expected duration of data collection. I will explain to the villagers that they can take part in the focus groups and/or the in-depth interviews if they wish.

INFORMED CONSENT FOR FOCUS GROUP DISCUSSIONS AND IN-DEPTH INTERVIEWS

At the meeting with the villagers, information on the participants' sheet will be read and explained to the villagers (Appendix 1). The participants' sheets written in both English and the local language (Ibo) will be given to them to take home. This will give them enough time to make up their minds if they want to take part in the study.

Another meeting will be scheduled to obtain written consent from people that have decided to take part in the study. A written consent form (Appendix 2) in the local language of the people will be read out to them and they will indicate a willingness to participate by signing the form or writing their names at the end of the form. People willing to take part in the focus group and /or the in-depth interview will be asked and noted. The date and venue for the focus groups and in-depth interviews will be fixed at the meeting. Focus groups will hold at the village town hall and in-depth interviews will hold at the participants home if they are okay with it, otherwise a place of their choice will be used. The focus groups will be conducted first, afterwards, the in-depth interviews will be conducted. Participants will be informed that they can take part both in focus group discussions and in-depth interviews or either of them depending on if they meet the inclusion criteria for both.

STAGE 2: DATA COLLECTION

Focus group discussions and in-depth interviews will be adopted in data collection. General or broader questions will be discussed in the focus groups to understand social norms and preferences, and specific aspects of knowledge and practice will be further probed during in-depth interviews.

FOCUS GROUP DISCUSSIONS

INCLUSION CRITERIA

- Indigenes of Imo State
- Men and women with children below the age of five years
- Households with lands for home gardening

Focus group discussion is a methodology whereby a moderator leads about 8 to 10 persons in an open discussion on a topic of interest. Focus groups are used for understanding the acceptability of an intervention in a target population as well as probing into a topic about people's social and cultural norms (Ayala & Elder, 2011). Focus group discussion was chosen for this study as it will help to understand the acceptability of vitamin A cassava and it will offer more understanding on the factors that could impede or enable the successful implementation of a home food production intervention. The following factors will be considered in building the structure of the focus groups; size, setting, facilitator and number of focus groups. The focus groups will comprise about 8 to 10 persons as larger groups may be difficult to coordinate (Ayala & Elder, 2011). A setting that is conducive, easily accessible and private to a reasonable extent preferably the town hall shall be chosen. The focus groups will be homogenous as only women and men of the same ethnicity will be grouped for discussions. This will create a comfortable environment for the women to freely discuss the subject matter (Woźniak, 2014).

Focus groups will be organised for men and women separately. For this study, four to six focus groups will be held. Data will be captured with an audio recorder with the permission of the participants. I will moderate or facilitate the focus group discussions. A focus group guide tailored to the research questions and objectives will be developed, mostly covering awareness of vitamin A and the role of gender and extension workers in home gardening (Appendix 3). The guide will consist of a set of questions that will be used by the moderator to facilitate the group discussion. My local supervisor will support me as a co-moderator during the focus group discussions. To create a friendly and relaxed environment, questions will start from general topics to more specific topics on the research objectives (Gill et al., 2008). The discussions will start with a warm-up activity before progressing to discuss the research topic. This is to set up a relaxed and friendly atmosphere. Both open and closed ended questions will be used to gather information during the focus group discussion. The focus group discussion will be started with open-ended questions to retrieve a lot of information on the subject matter. It will ideally end with close-ended questions (Gill et al., 2008). After the focus group discussions, participants will be invited for an in-depth interview.

IN-DEPTH INTERVIEW

INCLUSION CRITERIA

- Indigenes of Imo State
- Men and women with children below the age of five years

- Households with a home garden.
- Men and women that have participated in the home growing of vitamin A cassava

In-depth interviews are used to get a detailed and rich understanding of one's experience with a programme or situation. It provides a relaxed and conducive atmosphere for collecting information. Further, using an in-depth interview, individual experiences can be distinguished about a programme and some people may be uncomfortable to divulge information openly (Guest Namey E. & Mitchell M, 2013). Interviews will be conducted by me. Open-ended questions will be used in the in-depth interview which would allow the participants to use their own words to discuss deeply on the topic and to avoid a "yes" or "no" answer (Guion et al., 2011). The interview will be structured in such a way that would make it conversational with me asking questions or probing further based on the participants' responses to get a better understanding of what the participant is saying. An interview guide with questions on barriers, facilitator, costs and benefits of home gardening will be developed (Appendix 4) and used as a guide to ensure I cover all the research questions, sustain consistency across interviews with other participants and be on track at all times during the interviews (Guion et al., 2011). Active listening skills will be adopted to better understand what the respondents are saying per time.

At the beginning of the interview, an introduction will be made, and the purpose of the study will be explained. Permission for audio-recording the interview will be obtained from the participant before the interview commences. The equipment for recording will be tested before the start of the interview to be sure that it is functioning properly (Boyce & Neale, 2006). Interviews will take place at the residence of the participants or a public area of their choice. About 15 to 20 interviews will be conducted.

Data collection has been planned to take place between May - October 2020 (See Table 2 for two research questions and method of data collection). Field notes, hand-written in a small notebook will be kept by the researcher to capture non-verbal cues, impressions, environmental contexts which the audio-recording may not be able to capture. Field notes serve as additional information that aid data interpretation (Sutton & Austin, 2015).

Table 2: Research questions and method of data collection

Question	**Data**	**Method**
What are the barriers and facilitators in the home gardening of vitamin A-rich foods in Nigeria	Qualitative data from men and women that have participated in home gardening of foods rich in vitamin A such as the yellow cassava, OFSP, yellow maize among others.	In-depth Interview of men and women involved in home gardening. Sample size - 20
What are the costs and wider benefits of home gardening?	Qualitative data from men and women that have participated in home gardening of foods rich in vitamin A such as the yellow cassava, OFSP, yellow maize among others.	In-depth Interview of men and women involved in home gardening. Sample size - 20
What are the different roles men and women play in home gardening?	Qualitative data men and women that have participated in home gardening of foods rich in vitamin A such as the yellow cassava, OFSP, yellow maize among others.	Focus group discussion with men and women. Sample size - 10

What is the role of gender in household production of vitamin A cassava?	Qualitative data from men and women that have participated in home gardening of foods rich in vitamin A such as the yellow cassava, OFSP, yellow maize among others	Focus group discussion with men and women. Sample size - 10
What are the costs and wider benefits of vitamin A cassava?	Quantitative and qualitative data from men and women that have participated in home gardening of foods rich in vitamin A such as the yellow cassava, OFSP, yellow maize among others.	In-depth Interview with men and women. Sample size - 20
What is the role of extension workers in the home gardening of vitamin A cassava?	Qualitative data men and women that have participated in home gardening of foods rich in vitamin A such as the yellow cassava, OFSP, yellow maize among others	In-depth interviews with men and women in the community. Sample size - 20

STAGE 3: DATA ANALYSIS

Data collected from focus groups and in-depth interviews will be audio-recorded and transcribed verbatim after each session. Each line of text will be kept anonymous and numbered when transcribed. Notations will be inserted on the transcribed text to denote pauses, happiness, signs of discomfort and other gestures. Thematic analysis will be used in analysing the transcribed data. Thematic analysis is a procedure that identifies, analyses and reports patterns or themes from a set of collected data (Braun and Clarke, 2006). After transcribing has been completed, data will be broken down into smaller pieces and placed in meaningful groups or topics. This process is known as coding. The NVivo software will be used in analysing data as it is known to usefully support the analysis of qualitative data (Castleberry, 2014). Themes will be identified across the coded data. After data has been successfully grouped into themes and subthemes, it will then be interpreted and reported in line with the research questions (Castleberry & Nolen, 2018).

ETHICAL APPROVAL

Ethics approval will be sought from the Ethics Committee, School of Health Sciences, Imo State University, Owerri, Nigeria and administrative approval will be sought from the Faculty of Medicine and Health Sciences Research Ethics Committee at The University of East Anglia.

Permission will be obtained from the community leaders of the various communities where this study will take place through verbal communication. The participants' information sheet will be used to explain the aims and objectives of the study in the local language. Written consent for the focus group discussion and in-depth interviews will be obtained from participants recruited from Imo State before data collection. This has been discussed in previous sections. Confidentiality of information will be guaranteed by deleting audio-recording after transcription, limiting access to identifiable information to the research team (Local supervisor) and using password protection, and data will be deleted after use consistent with the timeline required for ethical approval. The participants will be given a mug crested with the UEA logo to thank them for their time.

POTENTIAL RISK

Any risks to this study are negligible, however, participants will be informed before data collection that they can withdraw from the study at any time. I could be exposed to physical harm such as a road traffic accident due to constant travels during fieldwork. This will be minimised by staying close to the research location. To ensure my safety during data collection, I will set up a system where I call my local supervisor as soon as I set off for interviews and as soon as I am done.

POSITIONALITY

My positionality during this work will be affected by my circumstances of being an indigene of Imo state and growing up there, understanding the culture of the people and their language. Knowing the language and the culture of Imo State will help me to relate with the participants in an appropriate manner while being sensitive to their values and beliefs. As an indigene of Imo state, I will be accepted by the participants as they would perceive me as their own. My gender as a woman could determine how much men would be willing to share with me. However, the support of my local supervisor will make the men feel comfortable in being a part of the study. Coming as a student from abroad will be advantageous as it is perceived as a good thing to school abroad. My profession as an Optometrist may boost the confidence of the participants in me.

PROJECT TEAM

Researcher – PhD student from the Faculty of Medicine and Health Sciences, University of East Anglia, United Kingdom.

Local supervisor – Dr G.C Agu is a practising Optometrist and an Associate Professor in the Department of Optometry, Imo State University, Owerri. He will act as the local supervisor to the project, overseeing the recruitment of participants and data collection in Nigeria.

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Appendix one

University of East Anglia

IMO STATE UNIVERSITY
EXCELLENCE IN SERVICE

Participant's information sheet

USING HOME GARDENING IN THE PREVENTION OF CHILDHOOD NUTRITIONAL BLINDNESS IN NIGERIA

An invitation to participate

You are invited to participate in a study on "**Using home gardening in the prevention of childhood nutritional blindness in Nigeria"** It is entirely your decision if you would like to take part in this study and you can decide to discontinue at any time during the study. There are no binding rules to start and complete the study. It is voluntary.

The information contained here will guide you in deciding if you want to be a part of this study. We will go through this document with you and answer any questions that you may have. If you need to talk to other people before deciding to join in the study, you can contact us thereafter, you don't have to decide today.

If you decide to participate in this study, you will be asked to give your consent verbally to indicate that you agree to participate. Thank you for your interest.

Please make sure you have read and understood all the pages and feel free to ask questions.

What is the purpose of the study?

This study aims to explore possible barriers and enablers that Nigerians encounter in growing food at home to prevent vitamin A deficiency. This study will also help understand the roles of men and women in home gardening of vitamin A-rich foods.

Why have I been invited to participate?

You have been invited to participate in this study because you are an indigene of Imo State. Being an indigene of this local government area where a high volume of cassava is produced, your opinion and experience are important to this study.

What will my participation in the study involve?

Your participation will involve talking about your opinion and experience of home gardening vitamin A cassava and other vitamin A-rich staples. Men and women from Imo State will be interviewed on a one to one basis and through focus groups to understand what challenges they face in growing yellow cassava at home and the possible factors that made the intervention successful for them. You can take part in both focus groups and in-depth interviews if you want to. Focus group discussions of eight to ten people will be organized where these men and women will voice their opinions freely. There will also be an in-depth interview with participants. The focus group discussion and in-depth interview are expected to last about an hour each and be held at different times. The lead investigator will arrange an interview with participants after the focus group discussions and the venue, date and time will be arranged to suit the participants' convenience if they choose to participate.

What are the possible risk and benefits of taking part in this study?

We don't expect there to be any risks in participating in this study, however, you are free to discontinue at any time you wish.

There is no direct benefit of taking part in this study however, the findings of this research will help us understand the role of home gardening as one way to prevent childhood nutritional blindness amongst children not covered by vitamin A supplementation programmes.

Who pays for the study?

This study is self-funded by Chizoba Bassey, a PhD student at the University of East Anglia. Being a part of this study will not cost you anything. You will be compensated for your fares to interview venues.

What are the rights of the participants?

Participation is voluntary. If you agree to participate, you will be asked to give verbal consent which will be recorded. You can withdraw from the study at any time during the study.

Will the information obtained from this study be kept confidential?

The lead investigator will ensure that a high level of information confidentiality is maintained by limiting access to identifiable information to the research team and using a password to secure the data, and data will be deleted after use. The participants will be protected as all information given by them will be de-identified.

What will happen to the results of this study?

The result of this study will not identify any individuals who participated. The results will be reported in a PhD dissertation at the faculty of Medicine and Health Science, University of East Anglia. In addition, the results of this study may be disseminated at conferences and published in peer-reviewed journals. If you are interested in the results of this study, please contact Chizoba Bassey at c.nwabichie@uea.ac.uk

Contact for further information on this research:

Name: Chizoba Bassey

Position: Research student

Institutions: University of East Anglia, United Kingdom

Email: c.nwabichie@uea.ac.uk

Name: Nitya Rao

Position: Supervisor

Institutions: University of East Anglia, United Kingdom

Email: n.rao@uea.ac.uk

Name: Dr G. C Agu

Position: Supervisor

Institutions: Imo State University, Owerri, Nigeria

Email: drgcagu2005@gmail.com

Contact for complaints about the conduct of this research:

Name: Ethics Committee, Faculty of Health Sciences

Institution: Imo State University, Owerri, Nigeria

Appendix two

Consent Form for Participation in a Research Study

The University of East Anglia and Imo State University

Title of Study: Using Home Gardening in The Prevention of Childhood Nutritional Blindness in Nigeria.

Purpose of research and your participation

You have been invited to take part in this study conducted by Chizoba Bassey. This research aims to understand the barriers and facilitators of home gardening of vitamin A-rich food by Nigerian women and men. If you consent to participate in this study, you will be invited to participate in focus group discussions and/or in-depth interviews. The data you provide will be used to understand barriers and facilitators to home gardening in preventing vitamin A deficiency. All personal data will be made anonymous.

Risks and discomforts

Any risks to this study are negligible however, you are free to discontinue at any time. This study is voluntary. A high level of information confidentiality and data protection will be maintained by not sharing information given by you with a third party. All information obtained for this study will be anonymized.

Potential benefits

There are no immediate benefits from participating in this study, however, this study will work towards the prevention of nutritional childhood blindness for children in rural areas through the uptake of home food production of vitamin A-rich foods.

Voluntary participation

Participation in this research is voluntary. You may decide not to take part in this study and if you choose to participate, you are free to withdraw from the study at any time you wish. There are no penalties for withdrawing from the study at any time

Contact information

If you wish to contact someone for more information about this study, kindly contact the lead researcher, Chizoba Bassey at c.nwabichie@uea.ac.uk or the ethics committee, Imo State University. To raise concerns about the conduct of this study, kindly contact the Supervisors Dr G.C Agu at drgcagu2005@gmail.com or Nitya Rao at n.rao@uea.ac.uk

Consent

I have read and understood this consent form and agree to take part in this study.

Participant's signature________________________________ Date:_________________

A copy of this consent form should be given to you.

Appendix three

Focus group guide for participants

Instructions: This FGD will be conducted with eight to ten participants.

Introduction: thank you for agreeing to be a part of this research. We are interested in learning about vitamin A cassava in your community. I would go over the consent form with you to ensure you know why you are taking part in this research and that you participate voluntarily. Be rest assured that all the information you give today will be used solely for this research and will be anonymized. The sessions will be recorded with this device I am holding with your permission. Please feel comfortable discussing your opinions freely. It is okay to have different opinions during the discussion.

Background information on participants

Before the start of the focus group discussion, please take down the following information for each participant

Name

Age

Gender

Number of children below the age of five

Marital status

Level of education

Household income

Employment status

Ethnicity

Have you ever grown vitamin A cassava or any vitamin A biofortified staple? [Y or N]

Household head [Y or N]

Gender of household head

Do your children below the age of five receive the two-dose vitamin A supplements?

Module 1: What are the different roles men and women play in home gardening? What are their different contributions towards land control and management?

Can you tell me how households in this community acquire land for home gardening?

In households in this community, do men and women use the same plots or different plots of land for agricultural activities?

For a piece of land owned by a household in this community, who decides what types of crops are grown on the piece of land?

What factors do you consider when deciding on the type of crops to cultivate in your home garden? (for example, marketability of crop, soil type, yield, maturity, security, taste preference, size of plot in relation to quantity and so on)

What factors do you consider when making a decision on the quantity of a crop to be cultivated on a piece of land?

Who in the household decides how produce will be used and can you explain to me what factors are considered in the decision? (For example, for-profit, consumption, stored away, given out and so on.)

Module 2: What is the level of awareness of vitamin A and its health benefits?

Can you describe the functions of vitamin A in the human body? How did you learn this?

How do you think you can prevent vitamin A deficiency for yourself and your household?

What types of food are rich in vitamin A?

What are some of the consequences of vitamin A deficiency in children?

Can you describe what a vitamin A supplementation programme is like in this village?

How would you prefer to prevent your children from becoming vitamin A deficient?

Module 3: What are the gender differentials in the awareness and acceptance to grow vitamin A cassava?

In this village, are men or women more willing to grow yellow cassava? Why?

Which gender is more aware of the yellow cassava?

Are men or women more likely to sell or buy yellow cassava? why?

Which of the cassava types is more preferred in this village? White or yellow? Why?

Please rank the following traits in order of importance (Probe to find out the reason some traits are more important than others).

- Yield
- Shorter maturity
- Health/nutrition benefits
- Access to vines (planting materials)

Module 3: What is the role of gender in household production of vitamin A cassava?

How is a man's role different from a woman's role in cultivating vitamin A cassava?

How is a man's role different from a woman's role in the processing of cassava?

Can you describe why a man's role is different from a woman's role in cultivating cassava?

Can you describe why a man's role is different from a woman's role in processing cassava to finished products?

Module 4: What is the role of gender in diffusing vitamin A cassava vines to other households?

What information is available in this community about planting yellow cassava?

Who do people go to for information about planting yellow cassava? An NGO? An extension worker? Friend or family?

How do people obtain yellow cassava vines for planting?

Is man/woman likely to give vines to their fellow men/women for free? Or for profit? Why?

Appendix 4

In-depth interview guide for participants

Instructions: This interview will be conducted with only one person

Introduction: Thank you for agreeing to be a part of this research. I am interested in learning about your personal experience of home gardening of vitamin A cassava. I would go over the consent form with you to ensure you know why you are taking part in this research and that you participate voluntarily. Be rest assured that all the information you give today will be used solely for this research and will be anonymised. The sessions will be recorded with this device I am holding with your permission. Please feel comfortable discussing your opinions freely.

Background information on participants

Before the start of the interview, please take down the following information for each participant

Name

Age

Gender

Number of children below the age of five

Marital status

Level of education

Household income

Employment status

Ethnicity

Have you ever grown vitamin A cassava [Y or N]

Household head [Y or N]

Gender of the household head?

Do your children below the age of five receive the two-dose vitamin A supplements?

Module 1: What are the barriers and facilitators in the home gardening of vitamin A-rich foods in Nigeria

Can you describe your experience of home gardening?

How long have you had a home garden?

Why did you decide to have a home garden?

Are you a landowner?

How big is your land?

How far away is your land from where you live?

Can you tell me about the crops you grow?

Do you know about the yellow cassava?

How did you know about the yellow cassava and when?

Why did you start growing the yellow cassava?

How do you feel about the yellow cassava since you started growing it?

Can you elaborate on the difference between white and yellow cassava?

How do you feel about eating the yellow cassava?

Can you describe your experience growing yellow cassava?

Can you elaborate on some difficulties you encountered if any?

How did you overcome these difficulties?

How do you describe some facilitators of successfully growing yellow cassava?

Based on your role as a man/woman in cultivating yellow cassava, what difficulties have you had?

As a man/woman, what challenges have you faced in the processing of yellow cassava?

As a man/woman, what challenges have you faced in selling your surplus yellow cassava?

How do you think the yellow cassava project can be improved in the future?

Apart from the yellow cassava, are there other crops you grow?

Can you describe your experience growing these crops?

Why did you choose to grow these crops?

What has been the challenges so far?

What can you say has helped you to grow these?

Do you see yellow cassava as a long-term project for you?

Module 2: What are the costs and wider benefits of home gardening?

How much does it cost you to run your home garden in a month?

How many months per year do you run your home garden?

Who runs the home garden in the household?

How many hours per day does it take to run your home garden?

How much income do you make from your home garden monthly?

can you describe how affordable the cost of running a home garden is for you?

What takes most of the cost? Buying seedlings? Vines? Fertilizer? Poultry feed? And so on

How are you able to sell your surplus produce? Is it marketable?

How are you able to sell your surplus yellow cassava?

Can you describe the demand for yellow cassava? What is influencing the demand?

How has the sale of yellow cassava affected your household income?

In what way does home gardening help your household income?

In what way does home gardening affect you generally

As a woman, does home hardening influence your decision-making power in your household?

What other benefits can you say you derive from home gardening?

Do you see home gardening as a long-term project?

Module 3: What is the role of extension workers in the home gardening of vitamin A cassava?

Have you been trained by agricultural extension workers in cultivating yellow cassava?

Can you describe the training you received from the extension workers?

How can you say that this training has influenced your cultivation of yellow cassava?

Home gardening of yellow cassava and orange maize for the prevention of nutritional blindness in children: An economic evaluation and value of information analysis

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Home gardening of yellow cassava and orange maize for the prevention of nutritional blindness in children: An economic evaluation and value of information analysis

Vitamin A deficiency is the leading cause of childhood blindness worldwide affecting mostly Sub-Saharan Africa. We aimed to predict the cost-effectiveness of home gardening (HG) of yellow cassava and orange maize to prevent nutritional blindness in children below five years and to assess the likely value of obtaining additional information in reducing uncertainty surrounding its cost-effectiveness. We developed a Markov model and carried out probabilistic sensitivity analysis (PSA) with a value of information analysis (VOI). HG was estimated to cost an additional Intl$395.00 per DALY averted, with a 72.27% likelihood of being cost-effective at a threshold of Intl$2,800 per DALY. The EVPI was estimated to be Intl$29,843.50 for one child or Intl$9.251 billion for 31 million Nigerian children affected by the decision. Further research is only worthwhile for one parameter (relative risk of low serum retinol; EVPPI Intl$29,854.53 per child and Intl$925 billion for 31 million children). HG of yellow cassava and orange maize is expected to be highly cost-effective in preventing nutritional blindness in children in Nigeria. A cost analysis of the intervention and a high-quality randomised trial to assess the effectiveness of HG on serum retinol in young children will be worthwhile before recommending the intervention.

Keywords: vitamin A deficiency, nutritional blindness, value of information analysis, home gardening, cost-effectiveness analysis

Introduction

According to the World Health Organisation (WHO), vitamin A deficiency (VAD) is the leading cause of preventable childhood blindness, affecting 250,000 to 500,000 children globally, with about half of these children dying within one year of going blind (WHO, 2021). Globally, 190 million (33.3%) children below 5 years are suffering from vitamin A deficiency (Dong et al., 2017). Hypovitaminosis A is most prevalent in Africa and South-East Asia, and Africa solely bears more than half of the global burden of night blindness, a subclinical symptom of vitamin A deficiency (Black et al., 2013). Furthermore, vitamin A deficiency is a fundamental cause of death following measles and diarrhoea in children under 5 years through the impairment of immune functions (UNICEF, 2018). About 800,000 disability adjusted live years (DALYs) are lost to Vitamin A deficiency in Nigeria, annually (Meenakshi et al., 2010).

Vitamin A deficiency is caused by prolonged poor dietary intake of vitamin A-rich foods and has been defined by the WHO as serum retinol level < 0.7umol/I (WHO, 2007). Vitamin A supplementation has been used to combat vitamin A deficiency in children and studies have shown that it is a cost-effective intervention (Neidecker-Gonzales et al., 2007). However, there is limited coverage for children living in rural areas (Aghaji et al., 2019). A study by Aghaji and colleagues using the 2013 Nigeria Demographic and Health survey data showed that vitamin A supplementation programme coverage was 41.5%, with coverage being higher in urban (53.5%) than in rural areas (34.7%) (Aghaji et al., 2019).

Home gardens are small plots of land near the home which are managed by members of the household with minimal cost input. A home garden of 150 square metres has the potential to supply adequate fruits and vegetables to meet the vitamin A requirements for a family of six throughout the year (Faber & van Jaarsveld, 2007). Cassava (Manihot esculenta) and maize

(Zea mays L. or corn) are major staples widely grown and consumed in Nigeria (Maziya-Dixon et al., 2004). Biofortification is a means of improving or enhancing the nutritional content of staple crops through selective breeding of crops and biotechnology (HarvestPlus, 2020). Vitamin A biofortified maize (Orange maize) and cassava (yellow cassava) are distinctly coloured and can provide up to 50% and 25% of vitamin A daily requirement in children (Harvestplus, 2020; IITA, 2011).

In a world of unlimited resources, health care outcomes of interventions targeting health improvement would be the only information needed to decide which intervention to implement. Nevertheless, because resources are always limited, an intervention being effective is not sufficient reason for it to be adopted in the healthcare setting (Phillips, 2005). Choices must be made on what healthcare intervention to fund. To make this decision, it becomes imperative to know whether the intervention represents good value for the cost of implementing it. Therefore, a cost-effectiveness analysis is a crucial step before implementing an intervention. Economic evaluation is the method of comparing the added costs and outcomes of healthcare interventions based on the best available evidence of its impacts (Drummond et al., 2015). While economic evaluation is a crucial step, some forms of economic evaluation especially decision modelling, typically use evidence from different sources each beset by uncertainty from the distributions surrounding the parameters (Briggs et al., 2006). Value of information analysis is a systematic approach that quantifies the likely value of research to reduce decision uncertainty or whether to make a decision on implementation based on available evidence (Briggs et al., 2006).

This study is based on evidence from a systematic review that assessed the impact of home food production of vitamin A rich foods on nutritional blindness in children (Bassey et al., 2020). To the best of the authors' knowledge, no study has examined the cost-effectiveness of home gardening of vitamin A-rich foods or vitamin A biofortified crops using a decision analytic model. Thus, this study aims to assess the cost-effectiveness of home gardening of yellow cassava and orange maize in preventing vitamin A deficiency in children below the age of five in Nigeria. Additionally, a value of information analysis assessing the value of obtaining additional information on adopting home gardening of yellow cassava and orange maize to prevent vitamin A deficiency in children so as to reduce uncertainty in the evidence has not been conducted before. Thus, it was assessed as part of this study.

Methods

A cohort Markov model consisting of 4 health states (well, low serum retinol, blindness and death) was programmed in Microsoft Excel (Figure 1) to evaluate the cost-effectiveness of home gardening of yellow cassava and orange maize compared to no home gardening from a societal perspective, targeting children from Ovia North-East Local Government, Edo State, Nigeria. This location was chosen because VAD is a public health problem with a prevalence of 32.0% in children below 5 years in this area (WHO, 2007). Moreover, cassava and maize are staple crops grown and consumed by people in this location (Oriakhi et al., 2017).

The intervention is assumed to consist of multicomponent parts interacting together, to comprise training households in home gardening (HG) of yellow cassava and orange maize, provision of cassava stems and maize seeds, nutrition education, cooking session and distribution of recipe books and posters (posters would detail the health benefit of vitamin A-rich foods). This intervention is assumed to run for one year. The comparator is the status quo: no training or HG intervention (Fig 2).

There are no data on the number of children below the age of 5 in Ovia north-east local government, Edo State. Therefore, we assumed that there are 2500 children below age 5 in a village in Ovia north-east local government and modelled these 2500 children distributed to

834 households. We assumed that 3 children below the age of 5 would belong to a household, amounting to 834 households. We used a village (of 834 households with children under 5 years) as our unit of analysis. A lifetime horizon of 80 years was used in order to capture the long-term impacts of blindness which in this case is irreversible. The model used a cycle length of one year. The WHO recommendation of 3.50% was used for discounting both costs and benefits (WHO & WorldBank, 2020). The health states were defined based on the epidemiology of vitamin A deficiency. The well state represents a child free from vitamin A deficiency. The low retinol state was set at ≤0.70micromoles per litre based on the WHO definition to represent the subclinical and clinical stages of vitamin A deficiency (WHO, 2021). The blind health state was defined as a progressed state of low retinol where a child has little or no light perception and the dead health state represents the terminal state of the condition. We assumed that the intervention is for one year and households will continue to engage in home gardening in the subsequent years by replanting from their harvest

Transition Probabilities

Table 1 shows model parameters and their distributions. Transition probabilities were derived from the most relevant available evidence (Awasthi et al., 2013; Imdad et al., 2017). A systematic literature search was conducted to identify the most recent and relevant data used in estimating the progression of the cohort across different health states. Transition probabilities from well state to low retinol state were derived from Imdad et al., 2017 (Imdad et al., 2017), as were relative risks for low retinol and death. The transition probability of moving from low retinol to well and low retinol to blind was obtained from Awasthi et al., 2013 (Awasthi et al., 2013). Probabilities were calculated from event rate as recommended by Fleurence and Hollenbeak (Fleurence & Hollenbeak, 2007). Transition probabilities for moving from well health state to dead were obtained from the Nigerian life table sourced from the WHO (WHO, 2016). An average of the male and female probability of dying was calculated from the life tables. The transition probability of progressing from blind to dead was obtained from the WHO (WHO, 2000). Efficacy of HG was assumed based on a randomised controlled trial conducted in Kenya by Talsma et al., 2016 (Talsma et al., 2016). To the best of the authors' knowledge, this is the only published study to date that has examined the effectiveness of vitamin A cassava on serum retinol. Yellow cassava caused a modest effect of 0.04mmol/L (95% CI: 0.00, 0.07 mmol/L) increase in serum retinol. A 2 by 2 table was calculated using data from Talsma et al. 2016 (Talsma et al., 2016) and the relative risk of low retinol was estimated (Appendix 1).

Valuation of resources

We adopted the societal perspective for costing which covered productivity losses, cost of intervention, revenue from sale of surplus produce and health care costs. Table 2a describes the costs captured in more details. A breakdown of cassava and maize production was gathered independently from two Agric-economist experts. Costs were in naira and were converted to international dollars at 148.69 naira = Int$1 (World Bank, 2020). A discount rate of 3.50% was applied based on the recommendation from WHO (WHO, 2008). The costs of the cooking sessions, microphones, projectors, posters and recipe books were estimated based on market prices from vendors of these goods. Resources were costed for 834 households. Sales of surplus garden produce were based on assumption and imputed into the model by subtracting their value from the total cost of intervention. Opportunity cost of households working in home gardens was not included as it is assumed that these households are already engaging in home garden. Changes in healthcare costs was not included due to lack of available data on monetary changes home food production would bring to the healthcare.

Cost of health states

Table 2b shows the costs of being in each health state and their distribution parameters. Cost of being in the well health state for the intervention and control arm was derived by making assumptions on the cost of eating vitamin A- rich foods from other sources such as beef and chicken. For the low retinol health state, cost of 3 episodes of diarrhoea in a year (WHO, 2020) and one episode of measles were estimated. Foregone monthly livelihood in caring for a blind child in a year was estimated as the cost of the blind health state. This was estimated by multiplying an average monthly income by 12 months.

Health outcomes - Disability adjusted life years (DALY)

Table 3 shows the DALYs accrued by health states per year. DALYs were chosen as the health outcome measure in this study as they are useful in quantifying disease burden in developing countries (Sassi, 2006). Disability weight for well state was ascribed 0 and death was 1. Disability weight for low retinol and blindness was obtained from the global burden of disease study 2019 (IHME, 2019). Discounted DALYs for one episode of measles was added exogenously to the total DALYs in the model. Appendix 2 shows how DALYs for measles were derived. Discount rate for DALYs was 3.50% based on WHO recommendations and the total DALYs accrued over the time horizon of the model were calculated and multiplied by 834 households.

Analysis

Probabilistic sensitivity analysis (PSA) was conducted using a Monte Carlo Simulation by ascribing distributions to the model parameters. A lognormal distribution for relative risk of low retinol and death was assumed. For the transition probabilities, a beta distribution was assumed for all the health states apart from blind-to-death where a uniform distribution was assumed with the probability lying between a minimum and maximum value of the source of data. A beta distribution was used for the disability weight of low retinol and blindness, well and dead health states. A uniform distribution (plus or minus 10%) was assumed for costs data, since the cost was based on expert opinion.

Model output, analysis and presentation

Mean cost and accrued DALYs were calculated from the PSA results using 5000 simulations for the control and intervention arm separately. Incremental costs, DALYs and incremental cost-effectiveness ratios (ICERs) were calculated for each of the 5000 PSA simulations. The Point estimate ICER for the HG intervention compared to the no HG comparator was estimated as the ratio of incremental costs and incremental DALYs averted for intervention and control arm, and reported as incremental cost per DALY averted.

Threshold (Intl$2,880) as recommended by Wood et al. 2016 (Woods et al., 2016) was used for this study. The incremental net benefit was calculated using this threshold and the probability of cost effectiveness at different thresholds was estimated. When the incremental net benefit is greater than zero, home gardening intervention is accepted as cost-effective compared to no-intervention (Edlin et al., 2015). These data were used to plot the cost effectiveness acceptability curve by plotting the probability that home gardening is cost-effective compared to no home gardening intervention at different thresholds. The cost-effectiveness plane was also represented as scatter plot showing incremental costs and DALYs. Results were expressed with a 95% credible interval

Value of information analysis

A value of information (VOI) analysis was carried out using the Sheffield Accelerated Value of Information online software (SAVI) (Strong et al., 2014). The expected value of information (EVPI), expected value of perfect parameter information (EVPPI) for single and group parameters were estimated. According to UNICEF, in Nigeria there are about 31 million children under the age of five (UNICEF, 2020). We estimated 31 million Nigerian children as the beneficial population based on the UNICEF data.

Expected value of perfect information (EVPI)

EVPI is the value of obtaining perfect information concerning all parameters of a cost-effectiveness analysis at a given threshold or willingness-to-pay. It is the monetary value of eliminating all uncertainty from a cost-effectiveness analysis. In simple terms, EVPI is the difference in monetary value between the expected net benefit with perfect information and the expected net benefit with existing evidence or information (Briggs et al., 2006). The results of the PSA were used in estimating EVPI.

In considering decision uncertainty, the expected value of perfect parameter information (EVPPI) is the value of reducing uncertainty for individual parameters included in a model. EVPPI helps decision makers to prioritise research resources. EVPPI is the difference between the expected net health benefit with existing information and the expected net benefit with perfect information for a particular parameter in the model (Briggs et al., 2006; Edlin et al., 2015). Another approach that was explored in calculating the EVPPI was by grouping parameters and estimating the value of additional research in getting perfect information for the group. Briggs et al., 2006 stated that individual EVPPI for parameters does not add up to the EVPI. In the same vein, EVPPI for a group of parameters may be different from the individual sum of the EVPPIs of those parameters (Briggs et al., 2006). The EVPPIs for individual parameters may be zero but when analysed as a group, the value of additional research may be significant (Briggs et al., 2006; Edlin et al., 2015). While it is important to calculate EVPPI for individual parameters, it is more useful to estimate EVPPI for groups of related parameters. This would point to what kind of research study that should be prioritised. Parameters that could be conducted as a study were grouped together. Appendix 3 shows the grouping of individual parameters.

Results

From the Markov model, the mean cost for 834 households is Intl$6,123.29 for the control arm and Intl$33,670.28 for the intervention arm (Table 4). Incremental cost of home gardening of yellow cassava and orange maize is Intl$27,546.98 (95% credible interval: Intl$24,887.46 - Intl$30,152.26). The mean DALY accrued for 834 households in the control arm is 14,097.45 and 14,027.71 in the intervention arm, and the mean incremental benefit for HG is 69.74 DALYs averted (95% credible interval -264.84 to 109.32). The mean ICER is Intl$395.00 per DALY averted. This means that at a cost-effectiveness acceptability threshold of Intl$2,880 per DALY averted, home gardening of yellow cassava and orange maize is likely to be cost-effective in preventing vitamin A deficiency in children below the age of 5. However, at a threshold of Intl $2,880 per DALY averted, there is uncertainty with a 72.27% likelihood (probability) that home gardening of yellow cassava and orange maize is cost-effective compared to no home gardening intervention (Illustrated in the cost-effectiveness plane Figure 3, and cost-effectiveness acceptability curve Figure 4).

Overall EVPI for home gardens

The VOI analysis showed overall EVPI as Intl$29,843.50 per person. This means that the value of gaining perfect information in adopting home gardening of yellow cassava and orange maize is Intl$29,843.50 per person that will be affected by this decision. With an annual population of 31 million Nigerian children, overall EVPI per year would be $925 billion. Given that no research study is likely to cost this amount, further research is likely to be worthwhile.

Overall EVPPI for single parameters

EVPPI was estimated for all the parameters. Only the relative risk of low retinol showed a substantial value in carrying out further research to resolve uncertainty (EVPPI per person Intl$29,854.53, EVPPI per annual prevalence Intl$925 billion). The relative risk of low retinol explains the effectiveness of HG of yellow cassava and orange maize in improving serum retinol in children. Other parameters demonstrated that carrying out additional research to eliminate associated uncertainty would not be worthwhile (Figure 5 and Appendix 4)

Group parameter EVPPI

Group EVPPI showed that only prioritising research on the relative risk of yellow cassava and orange maize on serum retinol alongside cost analysis of home gardening of yellow cassava and orange maize is worthwhile (single person EVPPI – Intl$29,851.68 and population EVPPI – Intl$925 billion). Appendix 5 shows the group of parameters and their value EVPPI.

Discussion

In this economic evaluation, we used a Markov model to predict the cost-effectiveness of home gardening of yellow cassava and orange maize in preventing vitamin A deficiency in children. Results show that HG of yellow cassava and orange maize has a 72.27% likelihood of being cost effective from a societal perspective at an acceptability threshold of Intl$2,880 with a 'best estimate' ICER of Intl$395.00 per DALY averted. This suggests that based on the best available current evidence it is likely that HG would be highly cost-effective in preventing nutritional blindness in children. However, there remains a 27.73% chance that the results may be misleading, and that wide adoption of HG would not be cost-effective. Making decisions based on uncertain results from models could be detrimental to the health of people affected by this decision and might be a waste of limited resources. Conducting more research would be a logical way of reducing uncertainty in the results of a decision model, however, the decision to gather more evidence must be worthwhile in terms of comparing the cost of that research to its intended or potential benefits in reducing uncertainty in the adoption of a new health intervention. We assessed the value of resolving the 27.73% uncertainty of HG by estimating EVPI and EVPPI.

The results of the VOI analysis showed an overall EVPI of Intl$925 billion for HG of yellow cassava and orange maize to prevent vitamin A deficiency in 31 million Nigerian children. These EVPIs have very large numbers because they represent the EVPI of a very large cumulative population that can be affected by vitamin A deficiency in Nigeria. This makes it an important research agenda because a huge number of the population are affected. The results of the single parameter EVPPI showed that, all parameters yielded no value in performing further research except relative risk of serum retinol which gave a value of Intl$925 billion. This means that further research to reduce the current uncertainty around the effect of HG in improving serum retinol would yield a good return on investment, as long as the research costs less than Intl$925 billion to undertake. However, no research study is likely to cost Intl$925 billion. This means that further research is highly likely to be worthwhile, although the expected value of sample information (EVSI) and expected net gain of sampling (ENGS) are required to confirm this. Group EVPPI showed that undertaking an effectiveness study to assess the effect of HG of yellow cassava and orange maize on serum retinol alongside a costing analysis is worthwhile. Group EVPPI differ from single EVPPI as it estimates the EVPPI of one or more parameters simultaneously. Costing of the intervention in this study was by expert consultation. This finding highlights the importance of carrying out a costing analysis to establish the cost of HG of yellow cassava and orange maize.

This study is the first that we are aware of to use VOI to explore decisions relating to the cost-effectiveness of vitamin A interventions in children. However, VOI has been used to address the usefulness in carrying out further research in other areas of major public health concerns in Africa. Kim et al. 2017 (Kim et al., 2017) carried out a VOI to understand the value of reducing uncertainty in an evidenced-based Malaria Decision Analysis Support Tool (MDAST) in East Africa. They found that obtaining perfect information to eliminate the uncertainty of the model parameters would give an increased program net benefit of 5 – 21%. In 2012, Maheswaran and Barton (Maheswaran & Barton, 2012) built an economic model to assess the cost-effectiveness of screening and treating of tuberculosis in HIV positive patients in Sub-Saharan Africa. They also carried out a VOI for future research prioritisation. Their VOI showed that research on the effectiveness of non-insecticide-based vector control will be valuable in reducing uncertainty. Also, Uthman et al. 2018 (Uthman et al., 2018) developed a Markov model and a VOI to assess the cost-effectiveness of directly administered anti-retroviral drugs and self-administered ant-retroviral drugs to people living with HIV at high risk of defaulting in self-administered anti-retroviral drugs. Their VOI analysis suggested that more research on the effectiveness of direct administered anti-retroviral drugs over self-administered anti-retroviral would be of benefit in reducing uncertainty in the model. The use of VOI is gradually gaining popularity in prioritising research in Africa especially in the face of scarce resources and an avalanche of health problems to address (Kim et al., 2017).

The results from this VOI show that though HG of yellow cassava and orange maize is likely to be highly cost-effective, carrying out additional research to resolve uncertainty surrounding its cost-effectiveness is highly likely to be worthwhile. It has also highlighted that a randomised controlled trial alongside a cost analysis will be valuable in researching the effect of home gardening of yellow cassava and orange maize on serum retinol. One limitation of this study is that the EVSI and ENGS which are important validations for the need in carrying out further research were beyond the scope of this study due to the complexity of estimating them and the time available for this study. The EVSI is the process of reducing the expected cost of uncertainty associated with additional research with a specified sample size. The EVSI indicates how much uncertainty is expected to be reduced thereby giving the value of additional research for a particular sample size. The ENGS is the difference between the expected cost from the trial and the cost of the trial (population EVSI – research cost = ENGS) (Edlin et al., 2015; Wilson, 2015). It gives the value of the return on investment in further research and therefore demonstrates that the research is worthwhile if it has a value greater than zero (Edlin et al., 2015; Wilson, 2015).

This model assumed that this intervention will be a one-off cost and households will continue with home food production after the first year and replanting from their harvests. This assumption may not be true as some households may quit the intervention as soon as support is withdrawn and may not have a viable harvest to replant. Biofortification programmes require new variety of crops that have an improved resistance to disease, pests and a more viable harvest. These assumptions may have introduced bias to the model, making it more cost-effective than it may likely be. Using transition probabilities from a vitamin A supplementation intervention may likely have a greater chance of moving people from one health state to another compared with a home gardening intervention. Vitamin A supplementation provides a high dose of vitamin A to children whereas for home gardening, households may decide to sell their produce, harvest might be poor due to environmental factors such as crop disease, drought etc. vitamin A-rich foods will supply a lower proportion of retinol compared with vitamin A supplements. This may have exaggerated the results of this cost-effectiveness analysis. Opportunity costs of households' time in gardening was not included as it is assumed that these households are already engaging in gardening activities. Changes in healthcare costs as a result of the intervention was not included due to unavailability of data. This may have impacted on the results of the cost-effectiveness analysis. The results of this cost-effectiveness analysis should be interpreted with caution bearing in mind the assumptions made in this study.

Conclusion

In conclusion, the economic evaluation and VOI analysis presented in this study has shown that although HG is likely to be highly cost-effective in preventing nutritional blindness in children in Nigeria, it is likely that undertaking further research to derive better evidence on the effect of HG of yellow cassava and orange maize on serum retinol and a costing analysis of the intervention would be worthwhile before deciding whether to recommend this intervention.

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Declaration of interest

Authors declare that they have no competing interests

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Appendix 1. Relative risk of low retinol using data from Talsma et al. (2013)

	Control	**Intervention**		
No of events (%)	30	27		
Total number	113	109		
2 by 2 table				
Control	34	79	113	0.300884956
Intervention	29	80	109	0.266055046
Relative risk	0.88424177			
Standard error	0.089052751			

Appendix 2. DALY for one episode of measles

DALYs for measles		
Deaths	817	Ibrahim et al. (2019)
Cases	131732	Ibrahim et al. (2019)
Life expectancy	52.98	Crave (2020)
Disability weight	0.152	WHO (2008)
Cases in Sokoto	284.63	Ibrahim et al. (2019)
Population	100000	Ibrahim et al. (2019)
Duration	7	WHO (2020)
Relative risk of measles	0.5	Imdad et al. (2017)
YLL	0.32858121	(Death/cases) × life expectancy
YLD	0.002915068	1 × disability weight × (duration/365)
DALY	0.331496279	YLL + YLD
DALY control arm	0.000943538	DALY × (cases In Sokoto/population)
DALY intervention arm	0.000471769	DALY control arm × relative risk
discounted DALY control arm	0.000976562	$1/(1+D)^t$ D – discount factor, t - time
discounted DALY intervention	0.013950881	

Footnote: YLD, years lived in disability; YLL, years of life lived.

Appendix 3: Group of EVPPI

Set	**Parameters**
1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead
2	relative risk of serum retinol and cost of home garden
3	well cost, low retinol cost and cost of home garden

Appendix 4: Overall EVPPI for single parameters

Parameters	**Per person EVPPI ($)**	**EVPPI for Nigeria per year (Intl$)**
TP Well to low retinol health state	0.0	0.00
TP Low retinol to 2well health state	0.0	0.00
TP Low retinol to blind health state	0.0	0.00
TP Low retinol to dead	0.0	0.00
TP Blind to dead	0.0	0.00
Relative risk of low retinol	29,854.53	925,500,000,000
Cost of well health state	0.0	0.00
Cost of low retinol health state	0.0	0.00
Cost of Blind health state	0.0	0.00
disability weight of low retinol	0.0	0.00
Cost of HFP of yellow cassava and orange maize	0.0	0.00

Footnote: TP, transition probability; HFP, home food production.

Appendix 5: EVPPI for group parameters

	Parameters	**Per person EVPPI**	**EVPPI for Nigeria Per Year (Intl$)**
Set 1	well to low retinol, low retinol to well, low retinol to blind, low retinol to dead, blind to dead	0.0	0.00000
Set 2	relative risk of serum retinol and cost of home garden	29,851.68	925,401,925,897
Set 3	well cost, low retinol cost and cost of home garden	0.0	0.00000

Table 1. Model parameters used and distribution assumptions for probabilistic sensitivity analysis

Transition probabilities	Mean	Distribution	Parameter 1	Parameter 2	Source
Well to low retinol	0.450	beta distribution	509	623	(Imdad et al., 2017)
Well to dead	Lifetable				(Organization et al., 2016)
Low retinol to well	0.060	Beta	155	2429	(Awasthi et al., 2013)
Low retinol to blind	0.035	Beta	90	2494	(Awasthi et al., 2013)
Low retinol to dead	0.026	Beta	67	2517	(Awasthi et al., 2013)
Blind to Dead	0.60	Uniform	0.1	0.9	(Organization., 2000)

Footnote: For beta distribution – parameter 1 is alpha and parameter 2 is beta. For uniform distribution – parameter 1 is the minimum and parameter 2 is the maximum

Table 2a. Costing of resources and health states (Intl$ 2020)

Home garden	Unit price (Intl$ 2020)	Quantity	Total	Source/notes
Home garden				
Maize seeds	1.14/kg (170 naira)	567.13kg (680g per family for 834 households)	647.21	Expert consultation
Cassava stems	6.72 per bundle (1000 naira)	3336 bundles (4 bundles per family)	22435.94	Expert consultation
Health education				
Microphones	100.88 (15000 naira)	1	100.88	(34)
Projector	73.97 (11000 naira)	1	73.97	(34)
Posters	3.36 (500 naira)	834	2802.24	Based on assumption
Cooking session				
Recipe book	2.01 (300 naira)	834	1676.34	Based on assumption

Personnel				
NGO staff	1008.8 (150000 naira)	4	4035.20	Expert consultation
Proceeds from sale of surplus produce	5.04 (750 naira)	834	4194.40	Based on assumption
Total			27,577.38	
Cost of health states				
Health state	Unit cost	Quantity	Total	Source/notes
Well	0	0	0	
Low retinol	Diarrhoea (3 episodes/ year) • ORS – 1.34 (200 naira) • Zinc tablet – 1.34 (200 naira) • Floranom, 4 sachets (Saccharomyces boulardii) – 4.03 (600 naira) 4 × 4.03 = 16.12 Total = 18.8	3 episodes	56.40	Expert consultation
	Measles • Vitamin C – 1.34 (200 naira) • Paracetamol – 0.67 (100 naira) • Seven keys (Calamine lotion) – 5.38 (800 naira) Total = 7.39	1 episode per year	7.39	Cost of measles was added exogenously
Blind	672.54 per month (100,000 naira)	12 months	8070.48	Based on assumption
Dead	0	0	0	

Footnote: ORS – Oral rehydration solution, NGO – Non-governmental organization

Table 2b. Unit cost of health states.

Health states	Mean	Distribution	Parameter 1	Parameter 2	Source
Well	0		0	0	
Low retinol	56.40	Uniform	50.84	62.14	Based on assumption
Blind	8070.48	Uniform	7263.43	8877.53	Based on assumption
Dead	0	Uniform	0	0	

Footnote: For a uniform distribution – parameter 1 is the minimum and parameter 2 is the maximum. Costs are in Intl$

Table 3. DALY accrued per year by health states

Health states	Distribution	Mean	Parameter 1	Parameter 2	Source/notes
Well	Constant	0	0	0	(Organization, 2008)
Low Retinol	Beta	0.184	1.315	5.836	(Evaluation, n.d.)
Blind	Constant	0.187	1.289	5.605	(Evaluation, n.d.)
Dead	Constant	1	1	1	(Fischer Walker & Black, 2007)

Footnote: For a beta distribution – parameter 1 is alpha and parameter 2 is beta. For lognormal distribution – parameter 1 is the log mean and parameter 2 is the standard error of log mean

Table 4. Results of cost-effectiveness analysis

Mean cost	Control: Intl$6,123.29
	Intervention: Intl$33,670.28
Mean DALYs averted	Control: 14,097.45
	Intervention: 14,027.71
Incremental cost	Intl$27,546.98 (95% credible interval: Intl$24,887.46 - Intl$30,152.26)

Incremental DALYs averted	69.74 DALYs averted (95% credible interval -264.84 to 109.32)
ICER	Intl$395.00 per DALY averted
Probability of cost-effectiveness at Int$15,000 threshold per DALY averted	72.27%

Figure 1. Visual conceptualization of the model

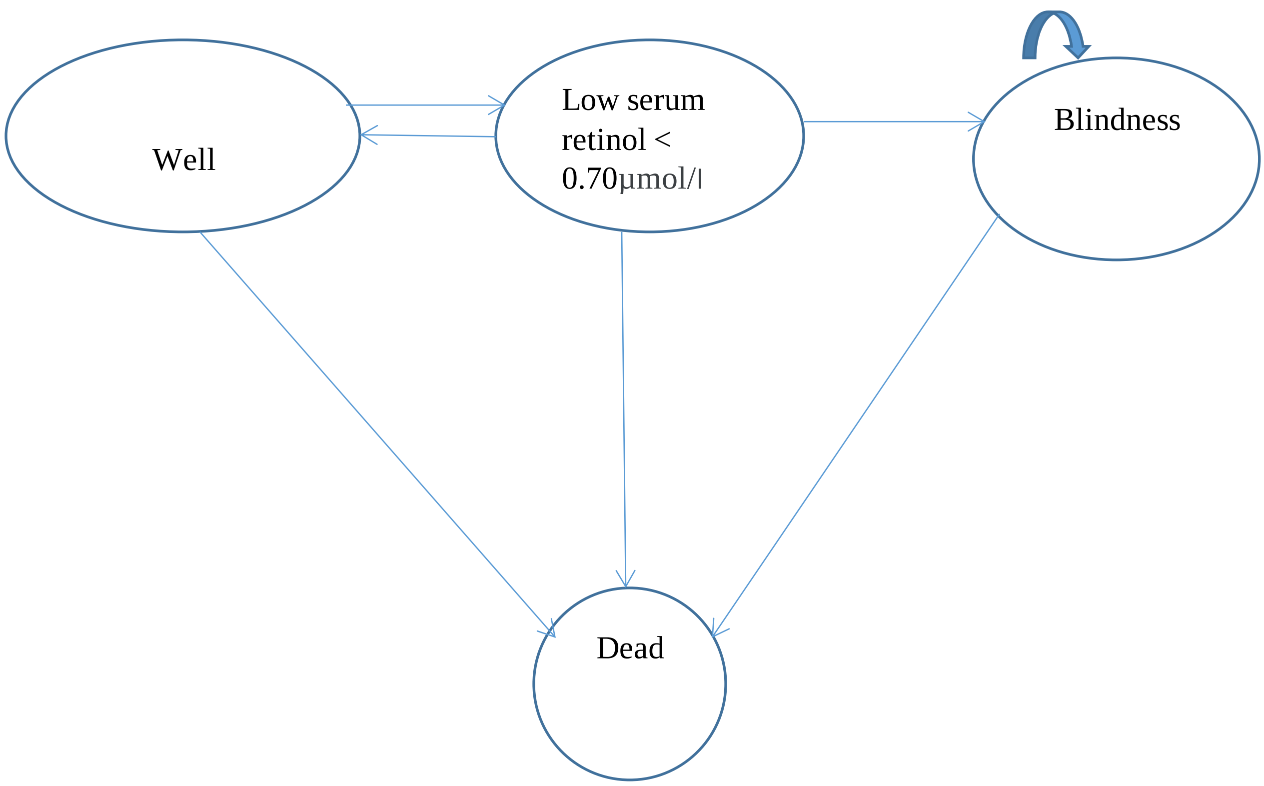


Figure 2. Diagram showing intervention and comparator

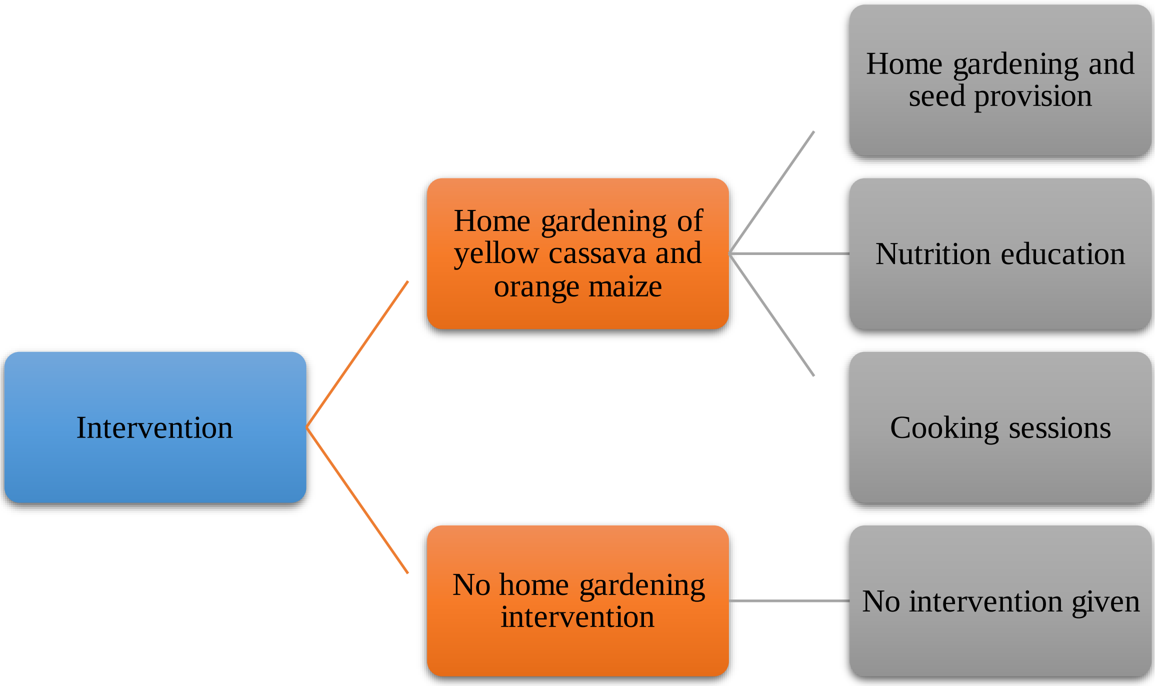
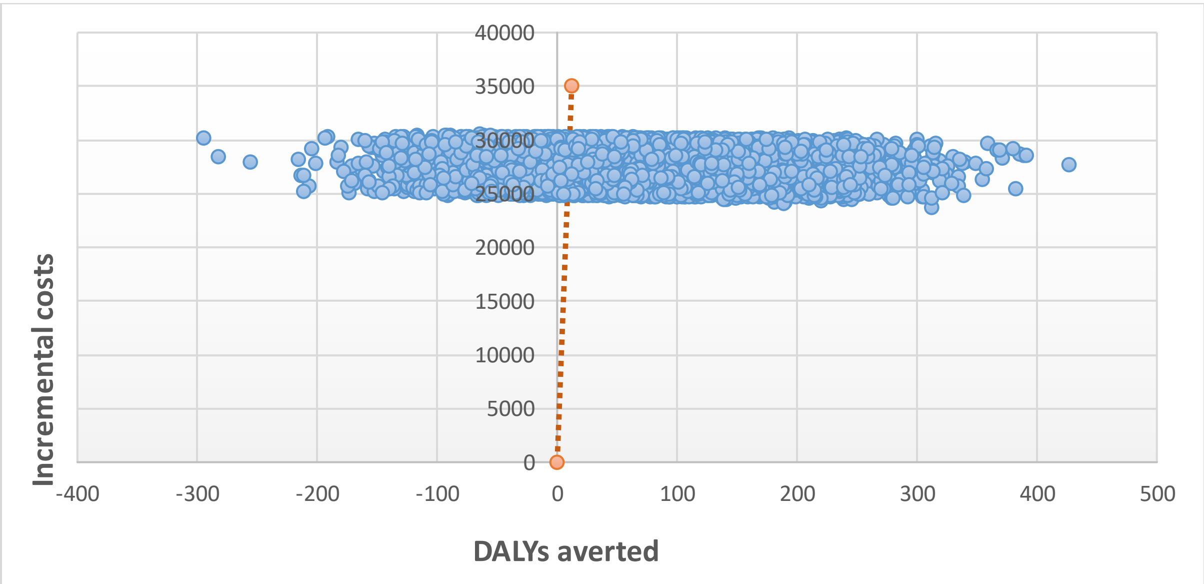


Figure 3. Cost effectiveness plane for total costs and DALYs averted for 834 households



Footnote: The orange line represents threshold line of Intl$2,880 per DALY averted

Figure 4. Cost effectiveness acceptability curve

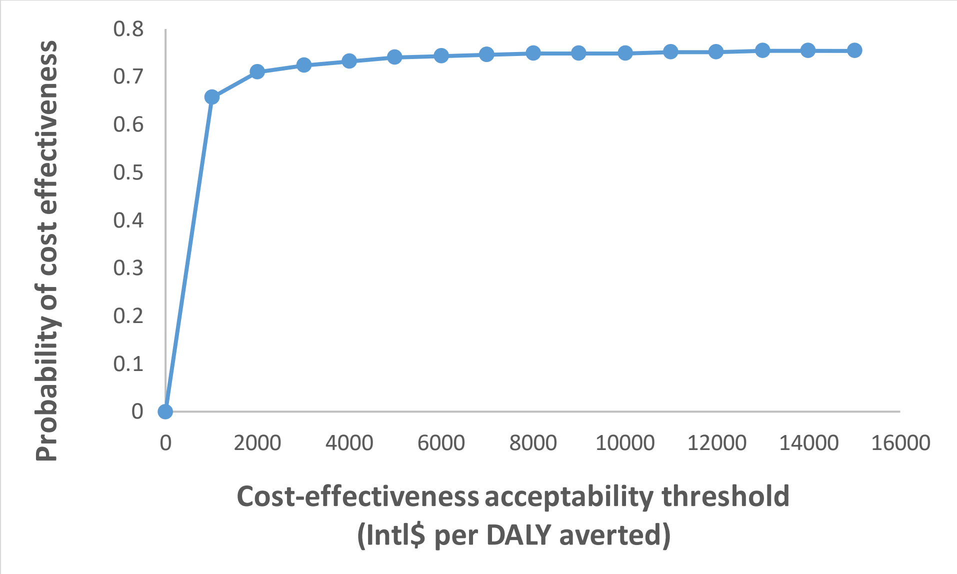
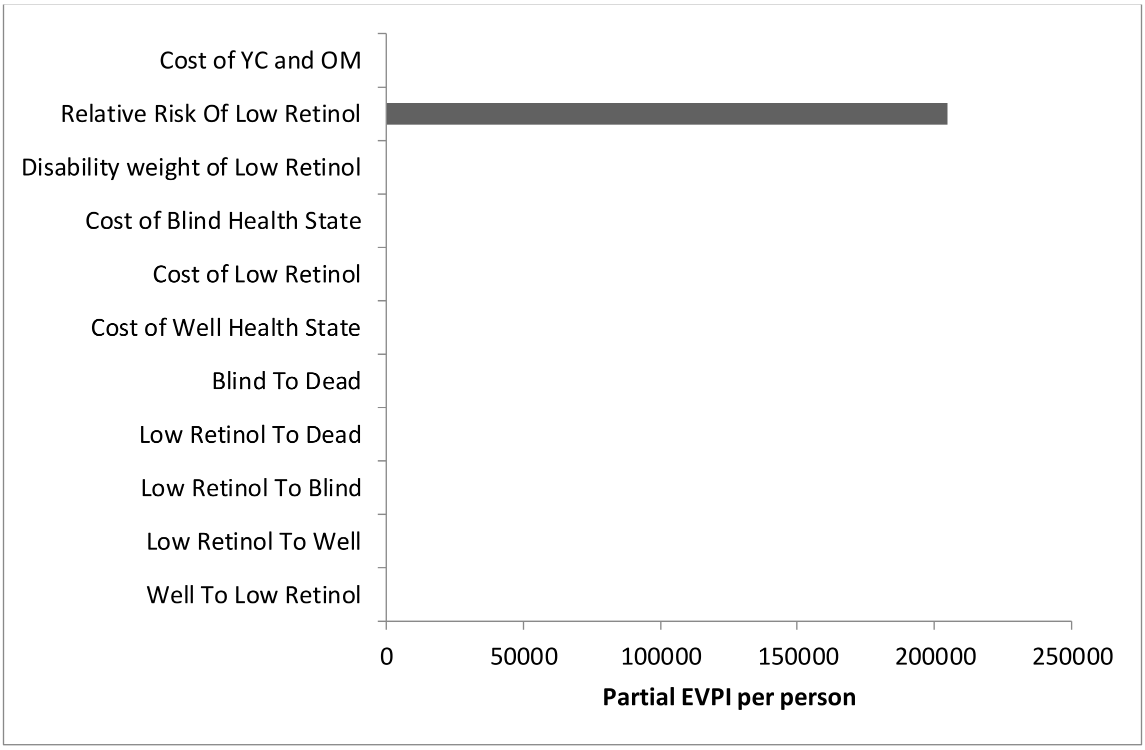


Figure 5. Single Parameter Partial EVPI per Person



Footnote: YC, yellow cassava. OM, orange maize