A systematic review of the impact of post-harvest aquatic food processing technology on gender equality and social justice

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**Editor’s summary**

Fisheries and aquaculture production are key to livelihoods, food and nutrition. Yet over one third of global aquatic harvest is lost or waste. The post-harvest sector, key to reducing these losses, and dominated by women workers, is not well understood. This systematic review synthesizes evidence on equity and equality outcomes of post-harvest practices and technologies aimed at reducing loss and waste in the fisheries sector.

**Abstract**

Post-harvest practices and technologies are key to reducing global aquatic harvest loss. The lives of post-harvest fisheries workers, over half of them women, are deeply affected by these technologies, but their equity and equality outcomes are poorly understood. This systematic review synthesizes evidence of post-harvest aquatic food processing technology outcomes, showing that persistent inequalities in social structure and norms disadvantage women across a range of technologies, both traditional and improved, especially regarding control over resources. We found that improved technologies bring enhanced productivity and possibly income for workers, yet contracts are often precarious due to pre-existing social inequities. Whilst power and control of resources is more unequal in factory settings, it is not necessarily equal in traditional contexts either, despite offering greater flexibility. More rigorous comparative research, including voices of diverse actors, is key to understand the impacts of different technologies on gender equality and social justice and inform policymaking.

1. **Main**

Fisheries and aquaculture are an important source of livelihood, food and nutrition for many of the world’s poorest, supporting worldwide about 67 million people directly and about 492 million people indirectly 1,2. Fisheries and aquaculture provide about 17% of animal-source protein for human consumption3, yet over a third of global fisheries and aquaculture harvest is lost or wasted 4,2. Appropriate post-harvest practices and associated technologies are crucial to reducing loss and waste across the value chain (from handling to storage, processing, packing and sale) 2, improving quality and food safety, extending the shelf life of aquatic foods and improving year-round availability 5,6. They are also critical for the sustainability of aquatic food systems, making them both more resilient and equitable 7.

Historically, fisheries data has focused on the primary sectors of fish catch and production, where women comprise only about 15% of the workforce 6.However, women constitute around 50% of the total workforce in post-harvest fisheries and aquaculture, varying by activity, with proportionally much greater involvement in fish processing and trade 1,2. Despite significant contributions to post-harvest fisheries, women often remain invisible, are unpaid or underpaid, their work seen as an extension of household work 8,9. Improvements in technology are making these processes increasingly complex, shaped additionally by the flow of migrant workers, changing youth aspirations, and concerns around violence and the reproductive and care burdens of women. While this has resulted in the recognition of and emphasis on considering gender alongside other identities in agricultural research and practice 10–13, to date little attention has been given to aquatic food systems, and post-harvest processes in particular, or to the socio-economic and equity impacts on populations involved in the sector14–18.

Equity, equality, diversity and inclusion are concepts that are now discussed widely in global fora, building on a long history of feminist research and advocacy on gender equality19. Although these concepts reference diverse social groups, women remain a key concern in relation to the post-harvest sector 20. The United Nations’ Food and Agriculture Organisation 21 defines gender equality as “women and men enjoying equal rights, opportunities and entitlements in civil and political life”, while equity refers to the underlying principles of “fairness and impartiality in the treatment of women and men, their rights, benefits, obligations and opportunities”. In this review, we seek to identify differences and nuances in the experience of women and other marginalised groups, depending on whether they are young or old, migrant or resident, poor or with access to some resources, alongside wider issues of social justice based on race or nationality. We ask: ‘What do we know about social justice (equity and equality, alongside health and livelihood) concerns related to different types and technologies of aquatic food post-harvest processing; and how does this differ by age, gender, race, nationality, migrant status and other cultural differences?’

We systematically reviewed available evidence on post-harvest technologies in the fisheries sector, to analyse associated social justice concerns and signpost where future research and policy development needs improvement. Locating this review within a food systems framework, focusing specifically on technology as a driver of food system change, we compare insights across processing types and highlight equity and justice issues associated with both improved and traditional technologies.

1. **Conceptual Framework**

Post-harvest processing includes (but is not limited to) canning, drying, smoking, salt curing, freezing, cooling and cold storage, and for each of these processes a range of technologies are available 22–25. For example, in addition to simple sun-drying techniques, drying devices include solar, convective and rotary dryers22,25. Innovation and improved technologies, including mechanisation, have been a major driver of change within the history of agriculture and food systems. Within development settings, definitions of technology focus on the tools, techniques, products and processes by which human capability is extended 26, more recently broadening beyond physical devices to consider the knowledge, piloting and procedures involved, and human engagement and agency within these 27.

Given the high perishability of fresh fish, manual non-mechanised technologies have been used for many centuries to extend its shelf life and retain its freshness and quality. ‘Improved’ technologies of the last 60 years or so aim to enhance aspects of processing efficiency, food quality through reducing deterioration, safety through controlling pathogen growth, and environmental sustainability 28. Improvements in these technologies often combine manual processes with enhancement of existing physical technologies, sometimes involving the creation of mechanised and systematised processes and environments. Some of these improved technologies can be practiced at home or on a small-scale such as sun-drying, wind-drying and brining, while highly mechanised, automated processes require controlled, factory settings.

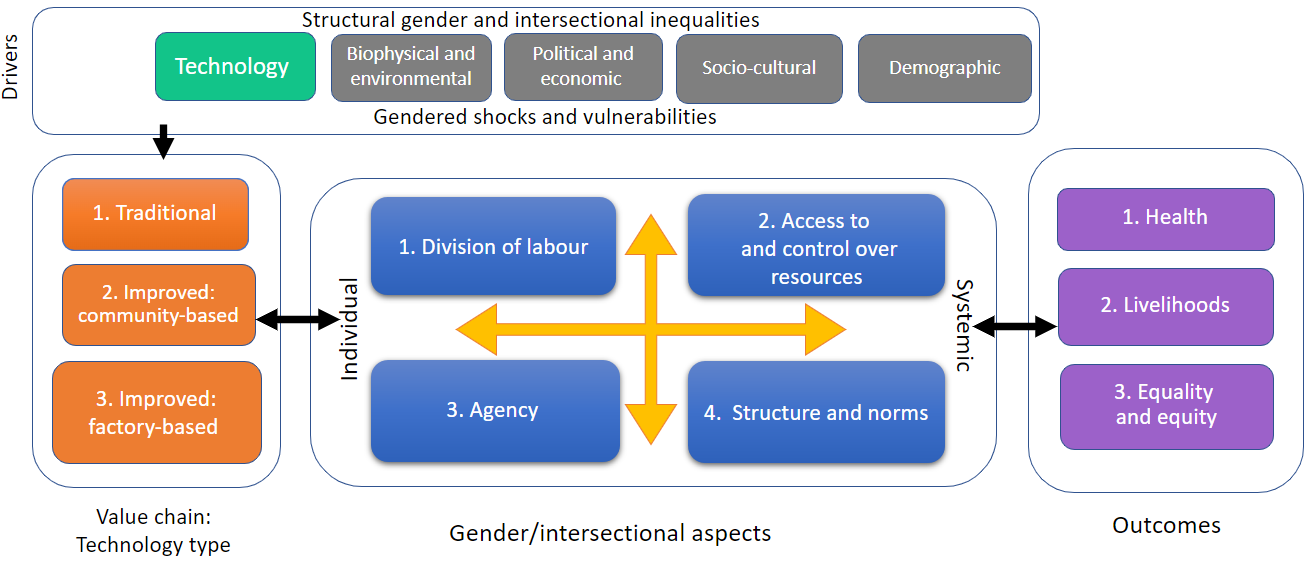
In this review, to accommodate these differences in both the type and scale of the technology used, we categorise these technologies as **‘**traditional’ - i.e., home-based, long-standing techniques that have been in place for generations or ‘improved’ – i.e., an innovation or technological change within the last 60 years. The ‘improved’ category can be split into two groups: first, ‘home- or community-based’, small-scale technological improvements that may be more incremental within existing production systems and second, ‘factory-based’, larger volume production systems that may encompass manual processing through to full automation techniques (Table 1).

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| --- | --- | --- |
| **Traditional** | **Improved: home/community-based** | **Improved: factory-based** |
| Manual cleaning  Simple sun drying  Smoking  Salting (curing)  Wind drying  Simple convective dryer  Traditional mud kilns  Rafter ovens  Basic drum oven | Fish-drying machine  Raised racks for sun drying  *Closed banda, chorkor, ahotor, cinderblock* and similar fish smoking ovens  Gas-fuelled fish smoker  Small cold storage (with electricity)  Improved drum oven  FAO *FFT-Thiaroye* improved kiln  Solar tent | Automated cleaning  Mechanised processing  Mechanised packaging |

***Table* 1: Traditional and improved technologies used for fish processing.** Improved closed *banda* ovens add walls to the traditional large smoking *banda* platforms, retaining heat, controlling the process and improving fish quality. *Chorkor* ovens are a basic improvement to a traditional fish oven, adding walls and removeable trays to stack fish for smoking. The *ahotor* oven modifies the *chorkor* oven with a grate in the oven for fuelwood, which is energy efficient and reduces smoke emission. The *cinderblock* oven’s mesh grate on top allows vertical laying of fish for smoking. The improved drum oven has a double-walled insulated kiln and can use lower-emission biomass briquettes rather than charcoal. The FAO *FFT Thiaroye* oven is fully closed and reduces smoke emissions significantly compared to all others. The solar tent is a large ‘greenhouse’ wrapped in polythene plastic used for drying fish naturally and improves quality of dried fish.

The adoption and use of diverse technologies, however, are likely to have differential outcomes, contingent on the social institutions within the particular contexts in which they are introduced 29. To understand equity and equality outcomes more broadly, and specifically in relation to health and livelihoods, we explore different dimensions of gender relations which are likely to influence these outcomes. We examine the gender divisions of labour and individual agency as factors that function at the household level, and the access to and control over assets and resources (including credit and capital) as well as social norms and expectations at the systemic level 30-32. These dimensions provide insights into both individual and systemic (dis)advantages, as well as the scope for institutions to be flexible in the face of new opportunities, together contributing to either positive or negative outcomes 33-35. Further, our analysis draws on an intersectional lens, seeing gender as embedded within other social identities of class, ethnicity, race, etc.

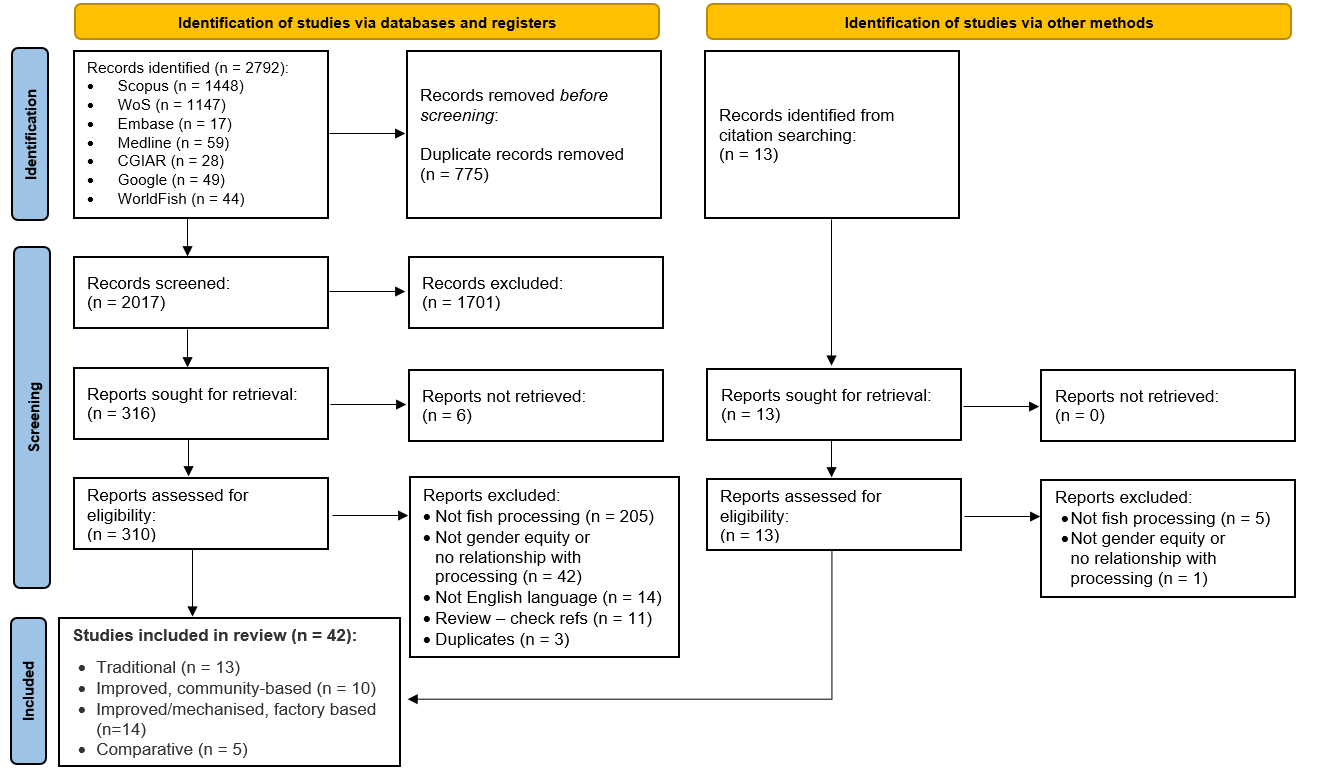
Figure 1 summarises the conceptual framework we use to examine the impact of post-harvest aquatic food processes and technology, both traditional and improved, across a range of settings, from the home to the community and factory on three sets of outcomes – health, livelihoods, and equality and equity – for women and other marginalised groups. We have adapted previous attempts to analyse gender relations within food systems to enable us to understand the mediating factors that could explain these particular outcomes.



***Figure 1: Impact of gender and intersectional inequalities on health, livelihood and equity outcomes of fish processing technologies*** (adapted from 31,36). Drawing on a food systems framework, this conceptual framework focuses on the impact of technology as a driver of food system change.

1. **Results**

Electronic searches retrieved 2792 results and 2017 titles and abstracts were screened (Figure 2). Of the 310 full texts retrieved, 205 were excluded for not relating to aquatic food processing, 42 for not relating processing with equity, 14 for not being in English, and 3 were duplicates. The 11 reviews were checked for references, and as a result 13 additional primary studies were assessed. A total of 42 studies were included in the systematic review. These include 13 studies focussing on traditional processing technologies, 10 on improved, home/community-based processing technologies, 14 on improved/mechanised, factory-based technologies, and five studies comparing a combination of technologies (see Supplementary Information Table 1 for characteristics of included studies).



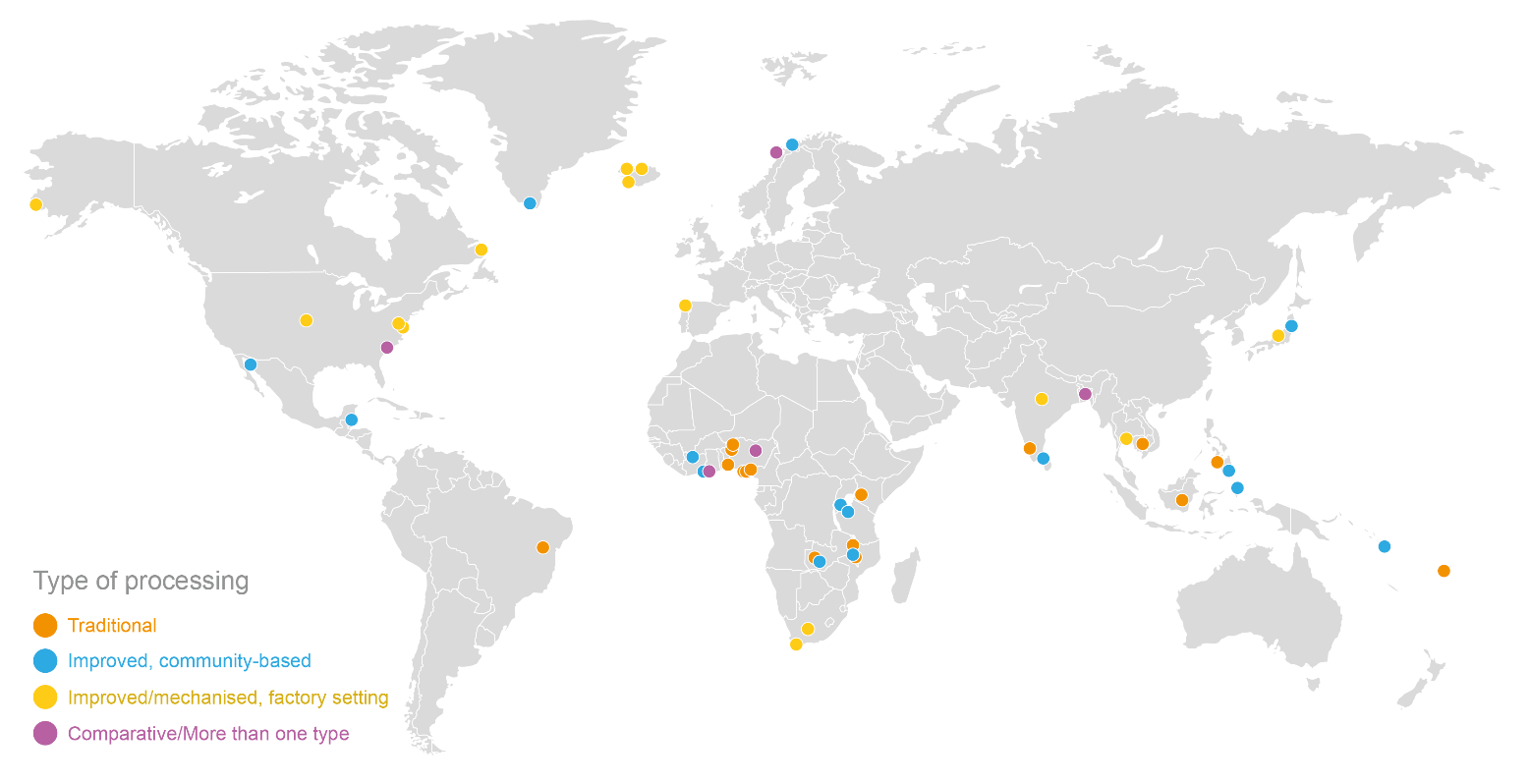
***Figure 2. PRISMA Diagram reporting review results.*** The diagram indicates the process of search and screening of evidence, indicating the number of articles included at each phase of the review.*Adapted from* 37.

**3.1 Risk of Bias for Included Literature**

Our risk of bias considers the degree of risk that relationships found between technology and equity outcomes in the included studies may be inaccurate due to quality of research conceptualisation, design and methodological reporting. Limited methodological information in some studies made assessment of rigour more difficult; where not described we assumed risk of bias to be higher, placing many studies in a ‘moderate’ risk category. Across the 42 included studies, there was moderate risk of bias overall (average 7.2 out of 12). Individually, it was gauged as low in 14 studies (33%), moderate in 24 (57%), and high in four (10%). We focus predominantly on the 38 studies (90% of total) with ‘low or moderate risk of bias (Supplementary Information Table 2).

**3.2 Range, Timeline and Focus of Literature**

Four key points arise in basic analysis of the studies. Firstly, while widely distributed geographically, there remain significant geographical gaps in data, even accounting for publishing language limitations, such as Australasia, much of South and Central America and the Middle East (Figure 3). See Supplementary Information Table 3 for location details.



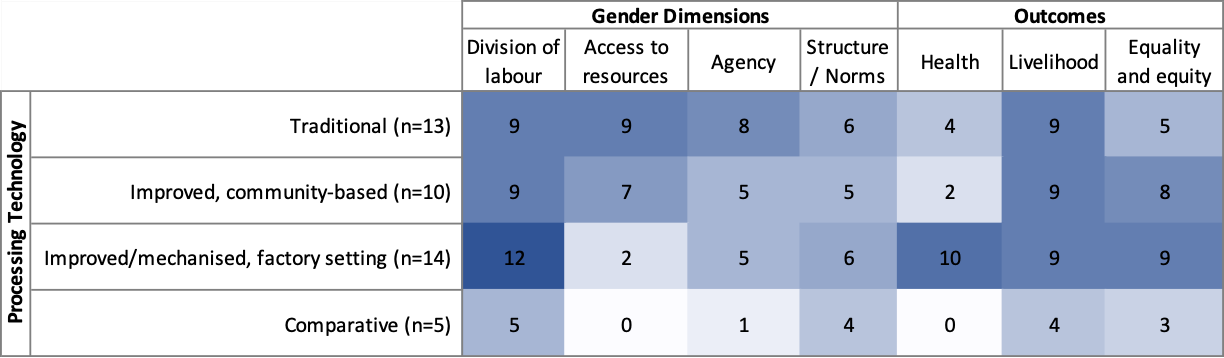
***Figure 3: Geographic spread of the 42 included studies***. The markers are approximate as many studies omitted precise locations. Where studies reported country-wide findings, markers are placed centrally.

Secondly, whilst the overall number of studies appears low relative to the sector’s livelihood importance, the historical timespan shows a growing focus (Figure 4). Apart from one early outlier study (1987), most are published since 2000, increasing significantly since 2015, along similar timelines to the increasing focus more broadly on gender and inclusive approaches fostered within the global Sustainable Development Agenda of ‘leaving no one behind’ 38 and the growing emphasis on gender inclusion in research, policy and practice in the sector following the adoption of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in 2014 39.

Thirdly, studies have shifted in focus from predominantly larger scale, factory-based improved technologies before 2010 to assessment of traditional and smaller scale technologies and comparisons between them over the last 13 years, recognising the diversity of the sector (Figure 4).

***Figure 4: Publication dates of included studies by year, grouped by processing type.*** Studies post-2010 are more diverse, covering a range of different technologies.

Finally, studies examining the impacts of different technologies on a range of social inequities and inequalities were limited (Figure 5). Gender was the best represented issue, with 60% of studies comparing men and women. One fifth (21%) focused only on women, and similar proportions (19%) had no gender lens. Other intersectionalities were poorly reported: 17% of studies included an ethnicity or migrant component and only two studies (5%) reported on youth. In terms of outcomes, 74% reported livelihood outcomes, 38% reported health outcomes and 60% mentioned social outcomes, with some papers reporting combinations of these.



***Figure 5: Gender dimensions and social justice outcomes assessed in the included literature, by processing technology.*** *Shading reflects number of studies.*

**4. Equity Outcomes of Technologies**

**4.1 Health Outcomes**

Eighteen studies (40-57; four with low risk of bias, 12 moderate and two high) revealed negative impacts of post-harvest processing on a range of health outcomes, though only six of them presented quantifiable data (41, 46-48, 51, 56, two with low risk of bias, the remainder moderate).

Eleven out of 14 factory-based studies reported on health outcomes (44-52,55,57; four with low risk of bias, seven medium and one high). Women had more workplace asthma, while men had higher rates of airway obstruction. This was attributed to women’s seasonal contracts reducing their risk of developing progressive deterioration of lung function, exacerbated by cigarette smoking among male factory workers 48. Airway obstruction caused by smoking fish often led to chronic obstructive pulmonary disease (COPD) 52. Workplace incidents related to chemical exposure such as ammonia, used for freezing seafood, were reported only in factory-settings 42,50. Various respiratory problems associated with poor ventilation were noted in factory 48,51,52, and some community settings 43,54,58. Factories with high levels of mechanisation also reported poor mental health outcomes, due to psychosocial stressors such as long working hours 55, monotonous work, low cheerfulness 45, and low ‘healthfulness’ as subjectively rated by workers 53. Interestingly, female Polish workers rated the ‘healthfulness’ of their jobs more negatively than Filipino workers in the same factory-setting in Iceland, highlighting the differential experiences at the intersection of gender and race or migration status 53. Only four of the 13 papers discussing traditional processing focused on health outcomes 40,41,56,58. Malaria was associated with lack of protection from mosquito bites and poor sanitation 58. Allergies and skin problems, such as cuts and lacerations, occurred in both traditional 41, and factory settings 44,46,48,50,57, though skin burns occurred in traditional settings only 41.

Two health-related issues common to all processing settings, including an article comparing two different settings 54, were musculoskeletal problems 41,46,47,49,56 and sexual exploitation of women 42,44,50,60. Women reported higher rates of upper limb symptoms compared to men in factory settings in one study 47, connected to the physically monotonous nature of their work 45. Ocular irritation such as red, itchy or swollen eyes was reported across settings, associated with smoking in traditional 56, and community settings 43, and steam vapor in a canning factory 48. While there is limited evidence of positive health outcomes in the papers reviewed, regular employment in factories may provide the potential for benefits such as health insurance 54. Further gender disaggregated data is required to understand the proportion of women who actually receive these benefits.

**4.2 Livelihood Outcomes**

Twenty-nine studies, four of them comparative, concerned livelihood outcomes including differential opportunities for women and men, skill acquisition/training, wage gaps, social expectations around women’s unpaid domestic labour, and working conditions. Nine papers 58,60-67 (five at low risk of bias, four moderate) specifically considered traditional technologies. These highlight that traditional processing is one of the most important livelihood opportunities for women. Given their immense knowledge and skill, women play a vital role in decision-making at different stages of the value chain 58,63, gaining access to resources, including savings and credit 63,66. However, women using traditional technologies also appear to suffer from higher product losses 60,65,68, while retaining total responsibility for childcare and household management 61,63. Comparing the traditional technologies with work in factory settings, traditional activities were perceived as less physically demanding, and hence given less social value 55.

Education appears to play a key role in the adoption of improved or mechanised technologies, yet the absence of sex-disaggregated data makes it difficult to explore systematically the role of education in male and female technology use 68. Home/community-based processing improved women’s income 43,69,75 (of eight studies, two had low risk of bias, five moderate and one high), though low fishing assets and low investment capacity limited women’s earning potential 70,71. Mobilising women into collectives and training in technology and marketing helped strengthen their livelihoods in one West African case 43, yet capacity-building programmes did not necessarily lead to significant changes in their incomes 75, with unequal pay and regularity of work 73 depending on domicile, marital status 74 and age 72. Structural-systemic factors played a part, with household financial needs, family well-being 69, safety concerns 55, and social norms potentially driving technology choice. The adoption of improved processing technologies increased where men were involved, as in the case of Nigeria 65 and Cote D’Ivoire 43.

Eight papers looked exclusively at factory settings 44-46,49-51,53,59; two at low risk of bias, five moderate and one high. While jobs were relatively more stable, gendered differences were visible in work, contract, and pay 52,53. Women had high-paced 45 menial jobs at low wages 59,76, daily work contracts and poor working conditions 44,51. Migrant workers' experiences of the gender division of labour and job satisfaction were dependent on gender, nationality, and education 53, and while on irregular contracts 50 and working in poor conditions, most migrant women workers valued this work due to the relatively stable income, increased technical skills, social confidence, and feared losing their jobs 74.

Three papers (moderate risk of bias) compared improved home/community-based and factory-based processing 55,77,78. The seasonal nature of catch led to fluctuations in labour requirements in both settings 77. While work using the improved home/community-based skills of slaughtering, filleting, and cleaning was also required in factories, this often went to migrant workers on temporary and lower-paid contracts, as in Norway, driven by a clear hierarchy of jobs in the eyes of employers. Stable jobs in management generally went to the local population 78. In a similar vein, women predominated in lower-status, lower-paid jobs in factory settings in a Bangladesh case study, though deploying skills used in smaller-scale processing, while men gained more influential, higher-paid employment 55.

**4.3 Equality and Equity Outcomes**

Of the 25 papers examining equity and equality outcomes, 10 articles, two home/community-based 71,72, six traditional 58,60,61,63,67,79 one factory-based 50, and one comparative 54, highlighted the benefits for women in terms of ownership and management of these businesses, the ability to sell at profitable market prices, and the flexibility to combine work with child-care (five at low risk of bias, five moderate). Two studies identified men supporting women by carrying out the labour-intensive tasks 58,60. Most, however, highlighted the persistent discrimination encountered by women in incomes, spending choices, access to insurance and other employment benefits, membership in unions or cooperatives, and representation in public decision-making 42, 63, 69, 73, 80.

Kinship ties to fishermen meant that women in the family often provided unpaid labour in the context of home/community-based seafood processing across contexts, from the United States 77 to Zambia 69 and Mexico 73, leading to an undercounting of their contributions. The six papers relating to traditional settings found women having control over their incomes and decision-making (58,60,61,63,72,79, three at low risk of bias, three moderate), though also critiquing traditional fish drying for perpetuating culturally discriminatory practices 74,79. Restrictions on women’s economic activities and their lower access to resources 70 had a negative impact on their willingness to pay for technology, leading to a higher level of fish losses 58,60.

Some equality/equity impacts were discussed in nine papers focusing on large-scale factory-based fish processing (44,46,49,50,51,52,53,59,76 6 at low risk of bias, 1 moderate, 2 high) and four comparative papers 54,55,77,78. While providing employment to a large number of women, only a limited number received social security 50,54,77. Yet, factory-based women processors, especially migrant workers, and those belonging to discriminated ethnicities, while experiencing long working hours, monotonous labour, poor living conditions, inadequate sleep and increased psychosocial and physical strain 50,55,69, also noted a sense of social connectedness 53,74. Another issue noted was sexual harassment 50,76, or sexual utilisation to procure affiliations with trade networks (Tanzania 74). While migrant women performed intensive manual labour, managerial and key positions were occupied by native female workers 53,78, who in turn held lower positions than their male counterparts 55,76. Factory-settings revealed inequities 46,47,51,59, yet the financial freedom and purchasing power gained by women contributed to greater decision-making power within their households, but not outside the domestic arena 48,55.

**5. Social Organisation of Post-harvest Fish Processing Technologies**

In line with our conceptual framework (Figure 1), we turn to the possible social and gender mediators that might explain the outcomes of post-harvest processing and use of technology discussed above.

**5.1 Divisions of labour**

Nine studies focusing on small-scale operations that supply local markets within traditional systems displayed a variety of gendered engagement (three with a low risk of bias and six moderate), including women preparing and selling shrimps (Brazil 61), harvesting and processing seaweed (Philippines 62), drying fish (Malawi and Zambia 40,60,63), and smoking fish (Cambodia, Kenya, and Nigeria 58,41,64). The small-scale and flexible nature of the work allows women to simultaneously fulfil multiple roles, including childcare 41, and managing the household 63. In the Nigerian case, while women and youth prepare and smoke fish in traditional ovens, men supply firewood and help arrange fish on racks 65. Here the situation demonstrates greater potential mutuality in terms of labour contributions, wages and sources of revenue.

Nine studies considered improvements to small-scale processing technologies, seven of them in the Global South. There was low risk of bias for three, moderate for five and high for one. All noted women’s predominance in this sector, demonstrating knowledge and skills to manage a range of activities including salting and frying 42, racks 80, or solar drying 69,70, smoking 43,71, and packaging 72. However, since these activities are carried out alongside caregiving and domestic work, processing work created an additional time burden on women 73 and disguised their processing work within extended household labour activities 69. Any wages received tended to be lower than those of men 74.

Larger scale, mechanised technologies were slightly more common in the Global North (seven of the twelve studies, including one comparing North and South). Risk of bias was low in four, moderate in seven and high in one. Several of them found that technological advancements and automated techniques reduced the numbers of jobs involving cutting, cleaning and packing, generally assigned to women, whilst increasing pressure to attain production targets 44,45. Fewer jobs meant higher demands on the remaining workers, increasing physical and psychosocial stress 46,47. With jobs, such as preparing fish for canning or smoking, culturally perceived as women’s work, women typically held subordinate positions in the labour hierarchies, with disparities in wages and types of contracts offered 59. Seafood processing factories, in particular, offered women short-term employment contracts, involved monotonous and long work, and were associated with work-related injury 48,50,76 and illness 51,52. One also reported additional issues of child exploitation (Bangladesh 76). Migrant workers in these jobs were often labelled as ‘trainees’ to enable payment of lower wages 53. Higher-level management roles within large-scale fish processing industries required training and skills, harder for women workers to access, perpetuating the gender differentials 59.

Five studies compared more than one technology, with three assessing gender relations 54,55,68, and two exploring perceived differences in work aptitudes relating to migrant status, race or nationality 77,78; one scored low risk of bias; the remainder scored moderate. Friberg studied people from four ethnic groups engaged in fish processing factories in Norway, revealing how labour hierarchies changed over time with the introduction of new waves of migrants into the workforce, with some ethnicities superseding others. Ethnicity was perceived to reflect certain strengths favouring manual work or front office roles, with non-natives considered to be harder working than native workers 78.

**5.2 Access to and control over resources**

All the studies considering resource allocation took a gendered perspective. Within the traditional technologies, many factors contributed to women’s limited access to, and control over, resources (nine studies, seven with medium risk of bias, one high and one low). Fisheries policies favoured the male-dominated production sector (Nigeria, Malawi, Zambia and Cambodia; 40,56,58,60,64), rather than post-harvest, causing women ‘three times more physical [fish] losses than men’ 60. The organisation of male and female groups in fishing camps enabled women to engage in processing and trading, yet did not necessarily facilitate their control over assets (Zambia 60). Women were not formally paid (Philippines 62), and they were marginalised by low educational attainment or lack of access to information regarding new technologies (Nigeria; 56,79). Yet in two cases, despite gender differentiated responsibilities, women had an equal share of assets, resulting in increased wellbeing (Nigeria and Indonesia; 65,66). Some women owned their businesses, either solely, or jointly with their husbands, given specific efforts to improve their access to resources to create profitable businesses (Cambodia 58).

Seven studies focused on improved, home/community-based technologies especially for drying and smoking (two had low risk of bias, four moderate and one high). These included drying yards 74, solar dryers 70 and drum or *chorkor* kilns for smoking 71,43. Some approaches encompassed both drying and smoking 69,73, incorporating additional techniques for salting and frying 42. Women often suffered economically through lack of access to credit or capital (Tanzania, Ghana, West Africa; 42,71). In one example 88% of women used traditional ovens because they lacked resources to invest in upgrades (Cote D’Ivoire; 43), resulting in constrained economic decision-making 69,70,73. However, the introduction of improved modern equipment could shift resource control towards men, depending on the level of investment and complexity of the technology development 43.

Two studies explored improved mechanised facilities, one on the intersection of gender and migration and the other the intersections of age, gender, and educational attainment (moderate and high risk of bias). Both showed that even as post-harvest work was formalised and mechanised, social hierarchies prevailed, limiting the access to resources for women, more specifically, migrant women (Japan 81, US and Canada 51).

**5.3 Agency**

Using traditional technologies for smoking 58,64,79 and drying 58,79,66, and processing more generally 40,63, eight studies (five low risk of bias, three moderate) noted women having agency in decision-making around their work and business, enabling them to secure improved economic opportunities through informal social networks in local markets. For home/community-based improved technologies, five studies provided evidence of this being beneficial to women, yet in one case there was an issue with uptake at management level (West Africa; 43). To overcome barriers to women’s agency, capacity development programmes to enhance women’s skills were organised, yet they did not necessarily increase women’s welfare (e.g. Indonesia; 75). In some places, age emerged as a critical factor shaping agency, with some older women having more authority and influence than the younger generations due to recognition of their proficient skillset (Alaska; 72), but in others, older women’s decision-making agency was constrained (Zambia and Mexico; 69,73).

In the five factory settings, women workers reported physical and mental pain from conducting repetitive tasks (45,49-51,53; two with low risk of bias, three moderate). Despite this, women in one case were content with formal employment as it increased their agency at home 50. While migrant workers employed in processing factories suffered from ailments and physical exhaustion, and were unable to change their work context, they might appreciate their employment for the earnings it brought them, improving the lives of their families (e.g. Iceland; 53). Women in some factory work had higher aspirations for their children and some reporting more equitable employment roles in the factory, including earning more than men (e.g. Bangladesh; 55).

**5.4 Structure and norms**

Six papers considering traditional technologies discussed social norms around the value of women’s work, including those related to institutions, finances, and culture, creating obstacles to women’s full participation in the fisheries sector (40,41,60,63,65,79; four scoring low risk of bias, two moderate). Social norms restricted access to resources for most women, yet those who could access credit had greater leverage within their households 40. Structural norms and gendered responsibilities left women with little decision-making power or influence to effect change in many cases (Malawi, Nigeria, Zambia; 40,56,58,60). The five studies exploring improved, home/community-based technologies (one scoring low risk of bias, one high and three moderate) highlighted the impacts of women’s exclusion from policy, limited access to credit, and decision-making authority on quality of life, negatively affecting their wellbeing (Japan, Nigeria, Ghana, Mexico, Zambia; 65,69,71,73,80).

All six papers from factory settings reported the monotonous repetitive nature of work, and the experience of the factory environment, such as cold temperatures (44,49,50,57,59,81; all at moderate risk of bias). The Global North studies reported migrant women workers having particularly vulnerable positions 44,59,57,81. The four papers comparing traditional and improved technologies across contexts (54,55,77,78; one scoring low risk of bias, the others moderate) confirmed the prevalence of physical repetitive work and long hours in factories, driven sometimes by harvest perishability, and the intersecting nature of social disadvantage, with outcomes worse for migrant women workers. Women were often unable to access the social protection benefits on offer including minimum wages, health insurance, housing and transport, due to their concentration at the lower levels of the labour hierarchy 54).

**6. Discussion**

This review demonstrates that the experiences and outcomes of different technologies in fish processing, both traditional and improved, are more nuanced than the pre-existing narratives and evidence indicate. Some aspects remain poorly understood and reported. Divisions of labour (and related position of power or greater earnings) appear unfavourable to women in most situations. Whilst resource control and agency are variable within traditional and improved settings, factory settings remain largely male-dominated. However, perceptions of the attractiveness of the factory work environment vary according to the background of the group, and the social positionality of the worker.

Previous studies of mechanisation show that women frequently report less agency and lower equity outcomes as enterprises expand and adopt more capital-intensive technologies, due to a combination of resource constraints, individual characteristics such as education, social norms and care responsibilities 6,11,12,13,82.Traditional technologies are practicable within smaller-scale operations, requiring less capital and management, allowing greater flexibility in working times and social relationships. While sometimes less productive, these technologies usually allow greater agency for women. Here one confronts a trade-off between enhanced productivity, income, and gender equality as seen in women’s control over resources and decision-making agency 9,83. Yet our review demonstrates a more nuanced and complicated picture emerging, as women in some community settings also find their labour undervalued, and there are few comparative studies between relative earnings for similar skills-based work in these different settings. Social norms and wider structures are the most intransigent and remain difficult to address across the board.

Several important issues emerge from this review. First, while literature focusing on social justice in post-harvest fisheries technologies is growing, there remains a substantial lack of robust comparative analysis across fish processing technologies and their influence on social equity and wellbeing outcomes 30,39,84. These outcomes should be understood better and considered in investments and discussions of the future of the fisheries and aquatic food sector due to the importance of the sector for millions of people. Related, despite others’ calls for action, we noted a significant lack of even the most basic sex-disaggregated and gender-specific data 3,17,85. Such disaggregation is a first step in highlighting the nature of gendered specialisation that marginalises women in what is largely production-centric fisheries’ policymaking 12,83,86. In the studies included in our review, youth, the elderly and migrant workers were rarely mentioned, despite being intersectional groupings with significantly different lived experiences and engagement in the sector. There is growing recognition that these ‘other factors’ form a critical gap in the understanding of policy and action across the aquatic food sector. A few studies have started adopting intersectional approaches 87,88, drawing on work in other sectors (e.g. psychology 89 and agriculture 90), with potential to incorporate newer issues of environmental and climate justice 91. A second step in applying a more nuanced gender lens is to understand its different dimensions including shifts in divisions of labour, access to resources, agency and wider structures in the context of technology change and choice.

Second, while scale and nature of the technology used are important drivers of outcomes, we find common patterns across the studies. In the larger-scale, factory-based settings using advanced technologies, women and migrant workers tend to have lower status, often temporary, lower-paid jobs that are culturally stereotyped as ‘women’s work’, experiencing gender pay gaps, lack of access to worker rights and managerial roles, and exposure to occupational health hazards 92. Labour divisions are stark, reinforced by social norms. Yet, factory settings provided options for young school leavers, potentially offering greater financial freedom and decision-making power. While women appear to have greater flexibility, control and agency in smaller scale processing operations, this doesn’t necessarily contribute to significant equality or income gains. Extension services and capacity-building programmes are central to ensuring gender equality, improving women’s access to both resources and skills, and challenging the devaluation of their work as ‘unskilled’ 54. While these interventions often focus on the material outcome of reducing loss and waste rather than also ensuring social equity and justice 93, nevertheless the improved home/community-based sector appears to be more dynamic than larger-scale factory-based processing, with technological improvements driving reductions in loss and waste, and in turn, a rise in incomes.

Third, while robust evidence on health, livelihood and wider equality outcomes detailed in the conceptual framework (Figure 1) is limited, it does reveal that, whether traditional or improved processing, health outcomes are generally negative and include musculoskeletal symptoms, issues with skin, eyes and respiratory systems, with poor sanitation causing additional problems. For livelihoods, however, there was a contrast between traditional and improved settings. While traditional processing technologies allowed for greater flexibility, potentially forming a lucrative additional home-based activity, it lacked the regular income and security of factory-based employment. Improved, home/community-based technologies demonstrated the potential to deliver positive outcomes, yet fuller assessments of their economic, social and technical costs and benefits are needed. The focus to date in analysis of the effect of these technologies has been on their functional efficiency and productivity, rather than their social, gendered and intersectional impacts, including health and wellbeing outcomes.

Technology is a critical driver of food system change and has been central to the growth and transformation of the fisheries and aquaculture sectors. Social structures and norms that place the burden of reproductive and care work on women, make women’s work invisible and constrain their participation in decision-making processes around technology. Yet technological change does influence women’s social and economic position (and that of other intersectional groupings), either through exclusion or inclusion on unequal terms 88. It is hence important to highlight the ways in which the experience and impact of technology is gendered, and how gender and technology shape each other 94, in order to ‘minimise the negative effects that marginalise women and other vulnerable groups of people and maximise the emancipatory potentials’ 39. Addressing the interactions between social and technical systems with a gendered lens, exploring how they impact on power relations between actors and institutions 84, could help develop strategies that can enable equitable transitions in the face of rapid change.

7. **Final Reflections**

Given the large number of people, in particular women, engaged in post-harvest activities globally, this review sought to better understand how processing technology and technical change, a key driver of food systems transformation, has impacted those engaged in this sector, and how labour, resources, power and decision making are influenced and change in this process. In the context of climate change and other economic pressures, we are witnessing a rapid development of post-harvest technologies to enhance productivity and efficiency, reduce loss and waste, and ensure quality. Yet without addressing the social justice dimensions of these changes, there is a risk that this may exacerbate pre-existing and persistent inequalities. Our review brings out several recommendations for policy, research and practice.

First, we recognise and highlight important nuances and contradictions in both the techniques and processes embedded within different technologies: for example, home-based fish processing provides flexibility but also expectations of unpaid labour; factory working can provide income (and choice), and is perceived differently by different groups, but also brings hazards of physical and mental ill health for many and bars permanent or management-level employment for women and migrants. Given these nuances, we need to ensure that disaggregated data are collected and analysed across a range of socio-cultural differences, in order to clearly see the associated wellbeing outcomes for those working in the fisheries sector.

Second, the focus of fisheries’ policymaking needs to embrace the entire aquatic food system, moving beyond capture fisheries and aquaculture to post-harvest processing, storage and consumption. This shift needs to be reflected in research and investment across the system and will be most effective when framed within integrated conceptual frameworks such as ours that consider structural drivers, social institutions and livelihood, health and social justice outcomes.

Third, more rigorous and comparative research is needed to examine the impacts of a range of technologies on different groups of people including women and men, young and elderly, migrant and non-migrant, and formally consider intersectionality. Finally, and related to the above, diverse voices, especially women’s and migrant worker voices, should have a place in policymaking and investment decisions around post-harvest processes at local, national and global levels to ensure that a range of inequalities are considered and addressed in the process of developing and rolling out improved technologies.

**8. Methods**

This systematic review was carried out using Cochrane methodology, as specified in the Cochrane Handbook, to minimise bias 95, and reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria 37. Full details of inclusion criteria, search strategies, data extraction and risk of bias assessment are reported in Supplementary Information.

We included quantitative and qualitative research of any design that assessed the impact of one or more types of aquatic post-harvest processing on social justice (equality and equity), livelihood and health outcomes. Participants could include men, women and/or children of any ethnicities, socio-economic statuses or age-groups, involved in (or affected by) aquatic food post-harvest processing technology. Studies had to be accessible in English and could be fully or partially published, come from any part of the world, and be published in any year. Reviews were not included but their reference lists were checked for additional studies.

Searches of the format [fish or other aquatic food] AND [equity] AND [processing] were developed using text and indexing terms, and appropriate Boolean operators used for each of the seven selected databases: Scopus, Web of Science, Google Scholar, Embase (Ovid), Medline (Ovid), CGIAR gender impact platform and WorldFish Repository. Searches were run in October 2022.

Titles and abstracts then full texts were loaded into Rayyan software 96 and assessed for inclusion independently in duplicate and differences in opinion discussed between two reviewers or within virtual meetings of the full review group of co-authors. Duplicates were identified and excluded, and multiple reports of the same study collated. Reasons for excluding ineligible studies were recorded. The selection process was recorded in sufficient detail to complete the PRISMA flow diagram (Figure 2).

Data extraction was carried out by one reviewer and checked by another. Tabulated data included bibliographic information, study location, design, characteristics of participants, processing type and outcomes, plus risk of bias score. Full texts were re-read and key elements of context, findings and concepts extracted and coded to identify meaningful patterns and relationships.

Risk of bias was initially assessed during data extraction using the Newcastle-Ottawa tool for non-randomised studies 97.This, however, did not fully capture risk of bias in the qualitative studies, so we changed to an adaptation for the social sciences allowing for qualitative studies to have equal chance of assessment of their quality as that for quantitative studies 98. Studies were assessed independently in duplicate for research design, explicitly building on previous research, description of methodology, representativeness of the target community, comparability of cohorts, appropriate and consistent use of indicators for outcome assessment, adequacy of follow-up and discussion of limitations and conclusions; points (more points equating to lower risk of bias) were allocated to each study on this basis. With a maximum score of 12, risk of bias was considered low with 9-12, medium with 5-8 and high with 0-4 points (Table 2, Supplementary Information).

Conclusions were based on thematic synthesis of the included studies, ensuring transparency and rigour in the process of generating analytical themes 99. Meta-analysis was not possible as quantitative data were too diverse. However, we drew on elements of meta-ethnography, to present a higher-order interpretation that goes beyond the individual studies, aiming to provide new insights and theories emerging from the collective evidence 100.

**Data availability:** The data that support the findings of this study are available from the corresponding author upon request. The DOIs of the studies included in the systematic review are presented in Supplementary InformationTable 1.

**References**

1. Food and Agriculture Organization (FAO), Duke University & WorldFish. *Illuminating Hidden Harvests*. doi.org/10.4060/cc4576en (FAO, Rome, 2023).
2. WorldFish. *WorldFish Annual Report 2021*. https://hdl.handle.net/20.500.12348/5284 (Penang, Malaysia 2022).
3. Food and Agriculture Organization (FAO). *The State of World Fisheries and Aquaculture (SOFIA)*. [doi.org/10.4060/ca9229en](https://doi.org/10.4060/ca9229en) (FAO, Rome, 2020).
4. Agarwal, M., Agarwal, S. A., Subia Singh & Ruchika Jayahari, K. M. *Food Loss and Waste in India: The Knowns and the Unknowns*. www.wri.org/publication/food-loss-and-waste-in-india. (World Resources Institute, Washington, 2021).
5. Stathers, T. *et al.* A scoping review of interventions for crop postharvest loss reduction in sub-Saharan Africa and South Asia. *Nat Sustain* **3**, 821–835 (2020).
6. Gopal, N., Hapke, H. M., Kusakabe, K., Rajaratnam, S. & Williams, M. J. Expanding the horizons for women in fisheries and aquaculture. *Gender, Technology and Development* **24**, 1–9 (2020).
7. HLPE. *Food Security and Nutrition: building a global narrative towards 2030*. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security https://www.fao.org/3/ca9731en/ca9731en.pdf (Committee on World Food Security, Rome, 2020).
8. Bennet, E. Gender, fisheries and development. *Mar Policy* **29**, 451–459 (2005).
9. Gustavsson, M. Women’s changing productive practices, gender relations and identities in fishing through a critical feminisation perspective. *J Rural Stud* **78**, 36–46 (2020).
10. Bryceson, D. F. & McCall, M. K. Lightening the load on rural women: How appropriate is the technology directed towards Africa? *Gend Technol Dev* **1**, 23-45. (1997).
11. Basu, P. & Scholten, B. A. Technological and social dimensions of the Green Revolution: connecting pasts and futures. *Int J Agric Sustain* **10**, 109–116 (2012).
12. Gopal, N., Edwin, L. & Meenakumari, B. *Transformation in Gender Roles with Changes in Traditional Fisheries in Kerala, India*. *Asian fisheries science* vol. 27 (2014).
13. Rola‐Rubzen, M. F., Paris, T., Hawkins, J. & Sapkota, B. Improving gender participation in agricultural technology adoption in Asia: from rhetoric to practical action. *Appl Econ Perspect Policy* **42**, 113–125 (2020).
14. Bennett, N. J. Mainstreaming Equity and Justice in the Ocean. *Front Mar Sci* **9**, 1–6 (2022).
15. Hicks, C. C. *et al.* Rights and representation support justice across aquatic food systems. *Nat Food* **3**, 851–861 (2022).
16. Issifu I, Dahmouni I, Deﬀor E. W. & Sumaila U. R. Diversity, equity, and inclusion in the Blue Economy: Why they matter and how do we achieve them? *Front Polit Sci* 1–11 (2023).
17. Food and Agriculture Organization (FAO). *The State of Food and Agriculture 2013*. <https://www.fao.org/3/i3300e/i3300e00.htm> (FAO, Rome, 2013).
18. Food and Agriculture Organization (FAO). *The State of World Fisheries and Aquaculture (SOFIA)*. [doi.org/10.4060/cc0461en](https://doi.org/10.4060/cc0461en) (FAO, Rome, 2022).
19. Kabeer, N. *Mainstreaming Gender Equality in Poverty Eradication and the Millennium Development Goals: Handbook for Policy Makers*. (Commonwealth Secretariat, London, 2003).
20. Gopal, N., Williams, M. J., Porter, M. & Kusakabe, K. Gender in Aquaculture and Fisheries. The long journey to equality. *Asian Fisheries Science* **29S**, 1–246 (2016).
21. Food and Agriculture Organization (FAO). *Training Module - How to Integrate Gender Issues in Climate-Smart Agriculture Projects*. <https://www.fao.org/documents/card/en?details=45d93533-c024-%2f> (FAO, Rome, 2017).
22. Komlatsky, V. I., Podoinitsyna, T. A., Verkhoturov, V. V & Kozub, Y. A. Automation technologies for fish processing and production of fish products. *J Phys Conf Ser* **1399**, 044050 (2019).
23. Turan, H. & Erkoyuncu, İ. Salting technology in fish processing. In *Progress in food preservation* (eds. Bhat, R., Alias, A. K. & Paliyath, G.) 297–313 (2012).
24. Tokur, B. & Korkmaz, K. Novel thermal sterilization technologies in seafood processing. Eds Ozogul, Y. in *Innovative Technologies in Seafood Processing* pp. 303–322 (CRC Press, Boca Raton, 2019).
25. Kamarulzaman, A., Hasanuzzaman, M. & Rahim, N. A. Global advancement of solar drying technologies and its future prospects: A review. *Solar Energy* **221**, 559–582 (2021).
26. Harwood, S. & Eaves, S. Conceptualising technology, its development and future: The six genres of technology. *Technol Forecast Soc Change* **160**, 120174 (2020).
27. Dosi, G. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Res Policy* **11**, 147–162 (1982).
28. Mamat, H. & Bhandari, B. R. Special Issue on Innovative Food Products and Processing. *Applied Sciences* **13**, 8542 (2023).
29. Kabeer, N. *Reversed Realities: Gender Hierarchies in Development Thought*. (Verso, London, 1994).
30. Kruijssen, F., McDougall, C. L. & van Asseldonk, I. J. M. Gender and aquaculture value chains: A review of key issues and implications for research. *Aquaculture* **493**, 328–337 (2018).
31. Njuki, J.*,* Eissler, S, Malapit, H.,Meinzen-Dick, R., Bryan, E., and Quisumbing, A. *A Review of Evidence on Gender Equality, Women’s Empowerment, and Food Systems*. https://ebrary.ifpri.org/digital/collection/p15738coll2/id/134469 (International Food Policy Research Institute Discussion Paper, 2021).
32. Moser, C. Gender planning in the third world: Meeting practical and strategic gender needs. *World Dev* **17**, 1799–1825 (1989). [doi.org/10.1016/0305-750X(89)90201-5](https://doi.org/10.1016/0305-750X(89)90201-5)
33. Giddens, A. *The Constitution of Society: Outline of the Theory of Structuration*. (Polity, London, 1986).
34. Rao, N., Mishra, A., Prakash, A., Singh, C., Qaisrani, A., Poonacha, P., Vincent, K., and Bedelian, C. A qualitative comparative analysis of women’s agency and adaptive capacity in climate change hotspots in Asia and Africa. *Nat Clim Chang* **9**, 964–971 (2019).
35. McDougall, C., Kruijssen, F., Sproule, K., Serfilippi, E., Rajaratnam, S., Newton, J. and Adam, R. *Women’s Empowerment in Fisheries and Aquaculture Index (WEFI): Guidance Notes*. <https://hdl.handle.net/20.500.12348/5107> (WorldFish, Penang, Malaysia 2022).
36. De Brauw, A., Van Den Berg, M., Brouwer, Inge D., Snoek, H., Vignola, R., Vignola, R., Melesse M., Lochetti G., Van Wagenberg, C., Lundy, M., Maitre D'hotel. E., Ruben, R. and Ruben, R., *Food System Innovations for Healthier Diets in Low and Middle-Income Countries*. (2019).
37. Page MJ *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *PLoS Med* **18**, (2021).
38. UNDP. *What does It mean to leave no one behind? A UNDP Discussion Paper and Framework for Implementation.* https://www.undp.org/publications/what-does-it-mean-leave-no-one-behind (United Nations Development Programme, 2018).
39. Doneys, P., Kusakabe, K., Wamboye, E.F., Wamboye, Evelyn F., Chib, A and Chatterjee, J.S. Gender, technology and development: reflections on the past, and provocations for the future. *Gend Technol Dev* **26**, 285–294 (2022). Quotation p.292.
40. Nagoli, J., Binauli, L. & Chijere, A. Inclusive ecosystems? Women’s participation in the aquatic ecosystem of Lake Malawi. *Environments - MDPI* **6**, 1–13 (2019).
41. Ngaruiya, F. W., Ogendi, G. M. & Mokua, M. A. Occupational health risks and hazards among the fisherfolk in Kampi Samaki, Lake Baringo, Kenya. *Environ Health Insights* **13**, 1–11 (2019).
42. Environmental Management and Economic Development Organization (EMEDO). *Women’s Role, Struggles and Strategies across the Fisheries Value Chain the Case of Lake Victoria-Tanzania*. www.icsf.net (Socio Economics and Extension Services Division, National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, 2017).
43. Zelasney, J., Ford, A., Westlund, L., Ward, A. & Riego Peñarubia, O. Securing Sustainable Small-Scale Fisheries. Securing sustainable small-scale fisheries – Showcasing applied practices in value chains, post-harvest operations and trade. Case Study 3: The FAO-Thiaroye processing technique: facilitating social organization, empowering women and creating market access opportunities in West Africa.Authors Ford, A., Randriananroandre A. and Penarubia, O. R*.*  doi:10.4060/ca8402en. (FAO, Rome, 2020).
44. American University Washington College of Law International Human Rights Law Clinic and Centro de los Derechos del Migrante (AUWCL). *Picked Apart the Hidden Struggles of Migrant Worker Women in the Maryland Crab Industry*. (AUWCL, USA, 2010).
45. Rafnsdottir, G. L. and Gudmundsdottir, M. L. New technology and its impact on well-being. *Work* **22**(1)31-39 (2004). https://www.researchgate.net/publication/8890376.
46. Aasmoe, L., Bang, B., Andorsen, G.S., Evans, R., Gram, I.T. and Løchen, M. L. Skin symptoms in the seafood-processing industry in north Norway. *Contact Dermatitis* **52**, 102–107 (2005).
47. Aasmoe, L., Bang, B., Egeness, C. & Løchen, M. L. Musculoskeletal symptoms among seafood production workers in North Norway. *Occup Med (Chic Ill)* **58**, 64–70 (2008).
48. Jeebhay, M. F., Robins, T.G., Miller, M.E., Bateman, E., Smuts, M., Baatjies, R. and Lopata, A.L. Occupational allergy and asthma among salt water fish processing workers. *Am J Ind Med* **51**, 899–910 (2008).
49. Tomita, S., Lopata, Andreas L., Muto, T., Koetkhlai, K., Naing, S.S. and Chaikittiporn, C. Introduction Prevalence and Risk Factors of Low Back Pain among Thai and Myanmar Migrant Seafood Processing Factory Workers in Samut Sakorn Province, Thailand. *Industrial Health* **48**, 283–291 (2010).
50. Shobhana Warrier, M. V. Women at work: Migrant women in fish processing industry. *Econ Polit Wkly* **36**, 3554–3562 (2001).
51. Howse, D., Gautrin, D., Gautrin, D., Cartier, A., Horth-Susin, L., Jong, M. and Swanson, M.C. Gender and snow crab occupational asthma in Newfoundland and Labrador, Canada. *Environ Res* **101**, 163–174 (2006).
52. Howse, D., Jeebhay, M. F. & Neis, B. The changing political economy of occupational health and safety in fisheries: Lessons from Eastern Canada and South Africa. *Journal of Agrarian Change* **12**, 344–363 (2012).
53. Yingst, A. & Skaptadóttir, U. D. Gendered labor in the Icelandic fish processing industry. *Maritime Studies* **17**, 125–132 (2018).
54. Barclay, K. M., Satapornvanit, A. N., Syddall, V. M. & Williams, M. J. Tuna is women’s business too: Applying a gender lens to four cases in the Western and Central Pacific. *Fish and Fisheries* **23**, 584–600 (2022).
55. Choudhury, A., McDougall, C., Rajaratnam S & Mi Young Park, C. Women’s Empowerment in Aquaculture: Two Case Studies from Bangladesh. (FAO, Rome, 2017).
56. Ike-Obasi, J. & Ogubunka, S. O. The roles of women in fish processing activities in some local government areas of Rivers State, Nigeria. *Agricultural Extension Journal* **3**, 73–77 (2019).
57. Sangaramoorthy, T. Liminal living: Everyday injury, disability, and instability among migrant Mexican women in Maryland’s seafood industry. *Med Anthropol Q* **33**, 557–578 (2019).
58. United Nations Industrial Development Organization (UNIDO). *Gender Analysis of Post-Harvest Fisheries in Cambodia*. https://downloads.unido.org/ot/26/61/26610418/Report-%20CAPFish\_Profiling%20of%20Post-harvest%20Fishery%20Value%20Chains%20&%20Market%20System%20Analysis.pdf (CAPFish/PHFD/Technical Report 10, Cambodia, 2021).
59. Abeledo, L. M. Labour segmentation in the Spanish fish-canning industry: A historical perspective, 1880-1960. *Contin Chang* **21**, 475–501 (2006).
60. Kaminski, A. M. Cole, S.M., Al Haddad, R., Kefi, A., Chilala, A., Chisule, G., Mukuka, K.N., Longley, C., Teoh, S. and Ward, A. Fish losses for whom? A gendered assessment of post-harvest losses in the Barotse Floodplain fishery, Zambia. *Sustainability (Switzerland)* **12**, 1–20 (2020). Quotation is p.15.
61. Santos, A. N. Fisheries as a way of life: Gendered livelihoods, identities and perspectives of artisanal fisheries in eastern Brazil. *Mar Policy* **62**, 279–288 (2015).
62. Ramirez, P. J. B., Narvaez, T. A. & Santos-Ramirez, E. J. Gender-inclusive value chains: the case of seaweed farming in Zamboanga Peninsula, Philippines. *Gend Technol Dev* **24**, 110–130 (2020).
63. Torell, E., Manyungwa-Pasani, C., Bilecki, D., Gumulira, I. & Yiwombe, G. Assessing and advancing gender equity in Lake Malawi’s small-scale fisheries sector. *Sustainability (Switzerland)* **13**, 1–17 (2021).
64. Nwabeze, G.O., Ifejika, P. I., Tafida, A.A., Ayanda, J.O., Erie, A. P. and Belonwu, N.E. *Gender and Fisheries of Lake Kainji, Nigeria: A Review*. *Fisheries Society of Nigeria* http://hdl.handle.net/1834/38238 (Fisheries Society of Nigeria, Lagos, 2012).
65. Omeje, J. E., Anthonia Ifeyinwa, A., Samuel Preye, J. & Queen Mercy, M. Economics of Smoked Farmed Catfish in Kainji Lake Basin, Nigeria. *Journal of Agricultural Extension* **26**, 1–14 (2022).
66. Larson, S., Stoeckl, N., Rimmer, M. A. & Paul, N. A. Understanding feedback relationships between resources, functionings and well-being: A case study of seaweed farming and artisanal processing in Indonesia. *Ambio* **51**, 914–925 (2022).
67. Salim, S. S. & Geetha, R. Empowerment of fisherwomen in Kerala-an assessment. *Indian Journal of Fisheries* **60**, 73–80 (2013).
68. Davies, R. M. & Davis O.A. Traditional and improved fish processing technologies in Bayelsa State, Nigeria. *European Journal of Scientific Research* **26** 539–548 (2009).
69. Cole, S.M., McDougall, C., Kaminski, A.M., Kefi, A.S., Chiala, A. and Chisule, G. Postharvest fish losses and unequal gender relations: Drivers of the social-ecological trap in the Barotse Floodplain fishery, Zambia. *Ecology and Society* **23**, 1–18 (2018).
70. Chiwaula, L. S., Chirwa, G. C., Binauli, L. S., Banda, J. & Nagoli, J. Gender differences in willingness to pay for capital-intensive agricultural technologies: the case of fish solar tent dryers in Malawi. *Agricultural and Food Economics* **6**, 1–15 (2018).
71. Forkuor, D., Peprah, V. & Alhassan, A. M. Assessment of the processing and sale of marine fish and its effects on the livelihood of women in Mfantseman Municipality, Ghana. *Environ Dev Sustain* **20**, 1329–1346 (2018).
72. Frink, L. The identity division of labor in Native Alaska. *Am Anthropol* **111**, 21–29 (2009).
73. Solano, N., Lopez-Ercilla, I., Fernandez-Rivera Melo, F. J. & Torre, J. Unveiling Women’s Roles and Inclusion in Mexican Small-Scale Fisheries (SSF). *Front Mar Sci* **7**, 1–14 (2021).
74. Galappaththi, M., Collins, A. M., Armitage, D. & Nayak, P. K. Linking social wellbeing and intersectionality to understand gender relations in dried fish value chains. *Maritime Studies* **20**, 355–370 (2021).
75. Hasniati, Yunus, R. & Hamsinah. The empowerment of coastal women through capacity improvement of seaweed farmer groups. *Advances in Economics, Business and Management Research* **43**, 97–100 (2017).
76. Hamid, M. A. & Alauddin, M. Coming out of their homesteads? Employment for rural women in shrimp aquaculture in coastal Bangladesh. *Int J Soc Econ* **25**, 314–337 (1998).
77. Griffith, D. C. Nonmarket labor processes in an advanced capitalist economy. *Am Anthropol* **89**, 838–852 (1987).
78. Friberg, J. H. & Midtbøen, A. H. Ethnicity as skill: immigrant employment hierarchies in Norwegian low-wage labour markets. *J Ethn Migr Stud* **44**, 1463–1478 (2018).
79. Akinpelu, O.M., Ayeloja, A.A., George, F.O.A., Adebisi, G.L., and Jimoh, W.A. Gender analysis of processing activities among commercial catfish processors within Ibadan metropolis, Oyo state south-western Nigeria. *J Aquac Res Dev* **4**,1–5 (2013).
80. Delaney, A. Transition in nori cultivation: evolution of household contribution and gendered division of labor. *Cah Biol Mar* **52**, 527–533 (2011).
81. Mazumi, Y. Migration outside large cities: a comparison of the hiring of migrants for the food processing industry in the United States and Japan. *Comp Migr Stud* **9**, (2021).
82. Johnson, N. L., Kovarik, C., Meinzen-Dick, R., Njuki, J. & Quisumbing, A. Gender, Assets, and Agricultural Development: Lessons from Eight Projects. *World Dev* **83**, 296–311 (2016).
83. Thorpe, A., Pouw, N., Baio, A., Sandi, R., Ndomahina, E.T., and Lebbie, T.“Fishing na everybody business”: Women’s work and gender relations in Sierra Leone’s fisheries. *Fem Econ* **20**, 53–77 (2014).
84. Williams, M. J. & Syddall, V. Women, fisheries technology and development: toward new research approaches. *Gend Technol Dev* **26**, 357–384 (2022).
85. Neis, B., Gerrard, S. & Power, N. G. Women and children first: The gendered and generational socioecology of smaller-scale fisheries in Newfoundland and Labrador and Northern Norway. *Ecology and Society* **18**, 1–13 (2013).
86. Szaboova, L., Gustavsson, M. & Turner, R. Recognizing women’s wellbeing and contribution to social resilience in fisheries. *Society & Natural Resources* **35**, 59–74 (2022).
87. Lynch, M. & Turner, S. Rocking the boat: intersectional resistance to marine conservation policies in Wakatobi National Park, Indonesia. *Gender, Place & Culture* **29**, 1376–1398 (2022) doi:10.1080/0966369X.2021.1971630.
88. Lokuge, G. & Hilhorst, D. Outside the net: Intersectionality and inequality in the fisheries of Trincomalee, Sri Lanka. *Asian J Women Stud* **23**, 473–497 (2017).
89. Warner, L. R. A best practices guide to intersectional approaches in psychological research. *Sex Roles* **59**, 454–463 (2008).
90. Tavenner, K., Crane, T. A., Bullock, R. & Galiè, A. Intersectionality in gender and agriculture: toward an applied research design. *Gend Technol Dev* **26**, 385–403 (2022).
91. Mikulewicz, M., Caretta, M. A., Sultana, F. & J. W. Crawford, N. Intersectionality & Climate Justice: A call for synergy in climate change scholarship. *Env Polit* **32**, 1275–1286 (2023).
92. Knott, C. The rhythm of making cheaps: a case study of rhythmanalysis and qualitative labour shortages in Canadian fisheries. *Applied Mobilities* **6**, 202–219 (2021).
93. Snider, A., Adraki, P. K., Lolig, V. & McNamara, P. E. Assessing gendered impacts of post-harvest technologies in Northern Ghana: gender equity and food security. *Gend Technol Dev* (2023). doi:10.1080/09718524.2023.2273153.
94. Wajcman, J. Feminist theories of technology. *Cambridge J Econ* **34**, 143–152 (2010).
95. Higgins, J.P.T., Thomas, J., Chandler, J., Cumpston, M., Li T., Page, M.J. and Welch, V.A. *Cochrane Handbook for Systematic Reviews of Interventions Version 6.3*. (John Wiley & Sons, Chichester, 2022).
96. Ouzzani, M., Hammady, H., Fedorowicz, Z. & Elmagarmid, A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev* **5**, 1–10 (2016).
97. Wells, G.B., O’Connell, S.D., Robertson, J., Peterson, J., Welch, V., Losos, M., Tugwell. P. The Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. *Ottawa Hospital Research Institute* **2**, 1–12 (2000).
98. Yosef, S., Jones, A. D., Chakraborty, B., and Gillespie, S. Agriculture and nutrition in Bangladesh: Mapping evidence to pathways. *Food Nutr Bull* **36**, 387–404 (2015).
99. Thomas, J. & Harden, A. Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Med Res Methodol* **8**, 1–10 (2008).
100. Noblit, G. W. & Hare, R. D. *Meta-Ethnography: Synthesizing Qualitative Studies*. (Sage Publications, Newbury Park, 1988).

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# **Ethics declaration – Competing interests**

The authors declare no competing interests.

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***Contributions***

This systematic review emerged from discussions between NR, LH, JF, JB and NG. NR, NG and JF led the conceptualisation and LH led the development of the research protocol and study design. Search, screening and extraction was carried out by HG, GS, NM, ST, MH, AW, NG, JB and LZ, under the guidance of LH. NR, LH, GS, ST, NM, AW, MH and NG were responsible for writing sections of the paper based on the preliminary analysis. NR, NG, JF and JB reviewed and edited the paper. MH, NM, NG and LH created the maps, diagrams, figures and tables. HG supported referencing. All authors reviewed the final version of the paper.

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