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Affordable local ingredients for fish feeds in low-income contexts:

A social and gender risk and opportunity analysis

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Affordable local ingredients for fish feeds in low-income contexts: A social and gender risk and opportunity analysis

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Table of contents

Executive summary 1

1. Introduction 4

1.1. Background and objectives of this review 4

1.2. Review methodology 5

1.3. Key gender concepts and framework 8

2. Findings 11

2.1. Potential social and gender risks and opportunities from the use of new local ingredients for fish feeds 11

2.2. Emerging gender-inclusive business and livelihood opportunities, entry points and strategies associated with using local ingredients for fish feed 16

3. Design features for gender and socially integrated alternative fish feed risk assessment 18

4. Conclusion 21

Notes 23

References 24

Annex 1. Key terms of the fish and animal feed review 30

Annex 2. Summary of fish/animal feed ingredients by country and feed role 32

Annex 3. Studies on potential social and gender risks associated with fish feeds in low-income countries 34

Annex 4. Mapping ingredient studies and methodologies 36

Annex 5. Publications reviewed in the final stage of the systematic literature review 38

Executive summary

Aquaculture's contribution to food and nutrition security and also poverty reduction can be viewed in three ways: (1) as a direct source of food, including protein and essential micronutrients, (2) as a source of employment or entrepreneurship that supports people involved in earning income, which enables them to buy food, and (3) as a multiplier effect in the secondary economy by increasing economic activities in communities (Kaunda 2015).

Fish feeds are a fundamental resource for aquaculture. Yet the high costs of standard feeds limit returns for fish farmers, as they represent 40–70 percent of total production costs for small-scale aquaculturists (Enyidi et al. 2017; Singh et al. 2018). To reduce costs, especially in low-income countries, alternative affordable and nutritious fish feeds need to be found. However, introducing new ingredients could create competition or strain other aspects of small-scale aquaculture production or livelihood systems. For example, women may feed local ingredients such as peels to small livestock or use them in other types of livelihood activities they depend on for their own (only) income. Redirecting these ingredients to fish feed may inadvertently undermine women's control over assets or cause household tension. Because of this, there is a need for alternative local ingredients that can mitigate the escalating cost of traditional fish feeds, without incurring perverse consequences. However, the risks—and opportunities—associated with fish and animal feed ingredients in low-income countries have not been adequately studied or solved. This systematic literature review helps address this gap. The three objectives of this review are to identify

1. potential social and gender risks and opportunities associated with using local ingredients for fish feed instead of for preexisting local uses;
2. emerging gender-inclusive business and livelihood opportunities, entry points and strategies associated with using local ingredients for fish feed;
3. methods used to empirically assess these issues for designing potential future fieldwork.

In terms of methodology, the study applied a three-stage systematic technique. The first stage was identifying peer-reviewed, unpublished and grey literature using a tailored inclusion/exclusion criteria matrix. The second stage analyzed the selected literature centered on the objectives. The third stage was developing methodologies to provide recommendations for potential WorldFish empirical research. These methodologies were informed by insights from the literature review.

Findings

Potential social and gender risks and opportunities associated with using local ingredients for fish feeds and their competitive use

The first key finding is that there is a dearth of literature that specifically addresses gender and social risks in relation to feeds. This gap needs to be addressed for the field to move forward sustainably.

Given the lack of feed-specific data, in order to understand potential social and gender risks, we examined the literature in terms of three key dimensions of gender in relation to smallholder aquaculture overall. Based on these broader patterns, we then extrapolated the risks identified to feed. The key risks in the three areas are identified as follows:

1. Gender and social norms in aquaculture

   There are four key risks associated with gender and social norms in relation to local feed ingredients:

   - Extension services relating to feed innovations could reach, engage with and respond only or predominantly to men's needs and preferences. As a result, women might be constrained by a relative lack of access to knowledge, information, markets, etc.
   - Feed innovations could be designed to respond to men's needs and preferences, so technologies might not meet the needs of women.
   - Time and unpaid labor burdens associated with new feeds might fall disproportionately to women.
   - Women could be left out of opportunities arising from the use of local ingredients for affordable and nutritious fish feeds, such as starting fish feed businesses.

2. Division of labor and aquaculture

   There are three key risks associated with gendered division of labor:

   - Alternative fish feed-related innovations could add to women's unpaid labor burdens.
   - Reflecting broader gender imbalances in voice in the sector, women might be underrepresented in projects and policies related to fish feed initiatives.
   - Women's invisible unpaid work could widen the gender pay gap further and motivate women not to take up local feeds as business opportunities.

3. Access to and control over aquaculture assets and resources

   There are six key risks associated with access to and control over assets and resources:

   - Women might be excluded from engaging and benefitting as business owners if alternative fish feeds spark emerging business opportunities for small and medium enterprises.
   - Women's agency is limited in terms of deciding how and when to use the resources as an input into the aquaculture value chain or to allocate them to other uses.
   - Most women in the Global South do not have the kind of resources required to continuously invest in fishponds. Because of this, it is more likely men will benefit from any cost savings.
   - Women's lack of control over technologies and innovations, combined with their lower educational attainment in some contexts, means they are overlooked by extension and training opportunities. This reproduces gender asymmetries in information and technical capabilities and lowers their opportunities to be economically independent and have agency or decision-making power over new technologies.
   - Women are left behind in the use of technologies. They are often excluded from large-scale production and so are shut out of opportunities to increase income and move up the value chain.
   - New local feeds might divert ingredients that women already rely on (e.g. peels for chicken feeds) for the assets they control (e.g. small livestock). If the peels go to fish feed, how will women feed their small livestock and maintain the income they control?

Overall, the available broader literature revealed well-evidenced gender patterns, barriers and risks in aquaculture—and there are no reasons to anticipate that these would not also hold true in relation to local feed ingredient innovations. Extrapolating from these existing aquaculture patterns to fish feed suggests that if feed ingredient innovations are not managed carefully then they could lower women's opportunities to be economically independent and have agency over the resources. In other words, without factoring in women's roles, norms and needs, new opportunities for fish feeds might disadvantage women or exclude them completely.

Identify emerging business or livelihood opportunities that may be associated with local ingredients for fish feed

Generally, the business or livelihood opportunities associated with different fish feed ingredients have not been adequately explored. There is a shortage of literature on current and potential opportunities for women in aquaculture, especially arising from the use of local ingredients for affordable and nutritious fish feeds. However, there are a number of opportunities that can be associated with developing local markets for fish feed ingredients. These include developing fish feed for individual household ponds, specific contractual relations and mechanisms that aim to integrate poor people into the supply chain or distribution chain of a larger business (inclusive business models). Norms can shape spheres of innovation, and including women in the innovation can overcome some norms that run along gender lines. Recent scholarship on gender in aquaculture asserts that applying a gender lens in interventions is vital for assessing gendered power structures, division of labor, welfare effects and empowerment (Monfort 2015a).

Identify methods used to empirically assess social and gender risks and opportunities for designing potential future fieldwork

Approaches available in the literature reviews range from studying fish feeds via quantitative on-station research studies using full randomized design to qualitative analysis of fish feed ingredients. However, the review found that the scope of feed assessments or research to date has primarily focused on components of fish feeds and their nutritional value, not on social and gender risks or opportunities. As such, the approaches found in the literature have limited use for social and gender risk and opportunities. This includes the fact that none of the studies in the review used mixed methods designs.

To address this methodological gap, the review extrapolates from available literature to create some potential design features to show how to conduct a study on gender and social risks associated with the competitive use of fish feed ingredients. For example, there is a need to integrate mixed methods in future empirical studies that adopt components of qualitative initiatives such as GENNOVATE, complemented with quantitative methods. The methodological blueprint focuses on the key insights emergent from the literature, the extent to which knowledge already exists for the proposed regions, and how this existing knowledge should influence a new methodology that is "fit for purpose" for informing future work by WorldFish.

The review indicates that as fish feeds are likely to evolve in the near future, there is limited time to fill information gaps on gender and social risks in using affordable local ingredients for fish feeds and associated opportunities. The methodology proposed in this paper could provide a useful foundation for this. In particular, it can help orient research for development investments toward the kind of mixed-method, gender-integrated and context-sensitive approach needed.

Moreover, there is potential to promote women's enterprises or employment in affordable local fish feed markets. This work should aim to improve the competitiveness of women, as well as the fish feed industries, in an environmentally responsible and socially inclusive manner. If women are equipped with essential skills, training and workshops on fish production techniques, owning ponds and joining cooperatives, then this can lead to positive impacts on their well-being, sense of community and empowerment.

The review underscores that the aquaculture sector's burning challenge to innovate regarding feed is not only a technical challenge—it is very much also a social and gender challenge. To avoid harm and to benefit women and men equitably, the technical and social dimensions need to be tackled in an integrated way.

1. Introduction

1.1. Background and objectives of this review

Aquaculture has the potential to significantly alleviate poverty in low-income countries. Fish farming has been described as a creative and economic practice for transforming rural livelihoods (Shava and Gunhidzirai 2017). Fish is the primary source of animal protein in several countries and is a crucial nutritional resource for food-insecure populations (De Graaf and Garibaldi 2014; FAO 2018). Fish consumption is growing because of higher incomes and recognition of its health and nutritional benefits (Anderson et al. 2017).

Globally, fish farming is trending toward intensification. Successful intensification of aquaculture depends on a nutritionally balanced diet for fish and low costs of production (Bharathi et al. 2019). This can create a critical challenge for aquaculturalists, as fish feed accounts for 40–80 percent of total production costs in intensive systems (Enyidi et al. 2017; Singh et al. 2018). Despite this, aquaculture and the fish industry remain a central livelihood strategy in many countries (Ayoola 2010; Singh et al. 2018; Rahman et al. 2019). As such, finding cost-effective, locally produced fish feed alternatives is required as a pro-poor food security measure (Hasan and New 2013; Bhilave 2018).

Feeding fish waste to fish is common and cheap but comes with risks (Kim et al. 2019). For example, using tuna by-products as a protein source is expected to reduce the cost of feed with other fishmeal substitutes in tilapia aquaculture. However, using tuna by-products as fish feed was prohibited in the Republic of Korea, and sales were recalled by the government in July 2018, as the threshold for mercury in the fish bodies had exceeded acceptable limits (0.6–0.8 mg kg−1) (Kim et al. 2019). Replacing fishmeal and fish oil as feed for fish with alternative ingredients derived mainly from agricultural resource crops is an important emerging trend (Kwasek et al. 2020). Consequently, the search is mainly on for high protein ingredients of plant origin that can be used in fish feed formulation programs (Annex 2).

Cognizant of these challenges, research and development organizations are exploring the possibility of using local feed ingredients as a low-cost gateway to sustainable fish feed in low-income nations (Hasan and New 2013; Agboola et al. 2019). Various local ingredients may be nutritionally viable and available. However, diverting these into fish feeds presents potential and unassessed risks, such as the influence on human health and disease (Hajra et al. 2013; Rahman et al. 2019) and impacts on women's workload (Waithanji et al. 2019).

Similarly, potential local ingredients for fish feeds might already be allocated for other purposes, such as providing feed for chickens or goats, on which women rely heavily for their own income (FAO 2018; Onsongo et al. 2018; Adesehinwa et al. 2019). Conversely, growth in this area offers potential for expanding gender-inclusive local enterprise opportunities. Therefore, it is important that low-cost local fish feed innovation and investments have and apply current information regarding potential social and gender risks—and opportunities—associated with diverting these ingredients into fish feeds.

To address this, this review was designed to identify related gender risks, social risks, and opportunities in specific settings in relation to inexpensive local ingredients for fish feeds. This is in order to ultimately inform gender-responsible and socially responsible and responsive innovation regarding low-cost, local fish feed ingredients. The specific objectives of this review are to identify

1. potential social and gender risks and opportunities associated with using local ingredients for fish feeds and their competitive use;
2. emerging gender-inclusive business and livelihood opportunities, entry points and strategies associated with using local ingredients for fish feed;

3. relevant methods that aquaculture sector agencies can use to empirically assess gender risk and opportunities in relation to alternative fish feeds options.

1.2. Review methodology

This study applied a systematic literature review methodology to understand the potential social and gender risks and opportunities in using local ingredients for fish feeds. The rationale for the review is presented in Box 1 and the methodology is described in detail below.

Box 1. Why a systematic literature review?

Traditional literature reviews have long been practiced and are regarded as one of the best ways to situate a study within the existing knowledge. These reviews, however, have been criticized for too often being restricted to literature already known to the authors or literature that is found by doing little more than cursory searches. This means that the same studies are frequently cited, which introduces a persistent bias to literature reviews. Systematic reviews help reduce implicit researcher bias (Mallett et al. 2012). Higgins et al. (2011) defines a systematic literature review as a way to comprehensively locate and synthesize related research using organized, transparent and replicable procedures at each step in the process.

Mohamed Shaffril et al. (2020a) outline seven steps for a systematic literature review: guided by source, formulation of research/review questions, systematic searching strategies, appraisal of quality, data extraction, data synthesis and data demonstration. For the current study, the systematic literature review followed four steps adapted from Mohamed Shaffril et al. (2020a):

Step 1: Guided by source

The first step included identifying and assembling peer-reviewed, unpublished and grey literature based on a search of the following databases: Google Scholar, Research Gate,[1] the International Aquaculture Feed Formulation Database, the Food and Agriculture Organization's (FAO) INFOODS databases, Scopus certified, and peer-reviewed papers. Google Scholar is considered an important and among the most popular databases for systematic literature reviews (Haddaway et al. 2015; Gusenbauer 2019). To maximize the list of literature, we also did manual searches, such as backward tracking ("reference searching"), forward tracking ("citation searching"), citation and reference tracking ("snowballing").

Step 2: Formulating the research/review question

Formulating the research question for this study was based on PICo, a tool that helps authors develop suitable research questions for the review. It is based on three main concepts: population or problem, interest and context (Mohamed Shaffril et al. 2020b). Based on these concepts, we have included three main aspects in the review: (1) people involved in aquaculture (population), (2) gender and social risks, and opportunities in relation to inexpensive local ingredients for fish feeds (interest) and (3) low-income countries (context). This then guided us to formulate the main research question: "What are the potential social and gender risks and emerging gender-inclusive business and livelihood opportunities associated with using local ingredients for fish feeds in low-income countries?"

Step 3: Systematic searching strategies

Systematic searching strategies can be further divided into three sub-steps: identification, screening and eligibility.

1 – identification
The keywords are developed based on the research question. The identification process relied on keywords used by previous studies and suggested by both Scopus and experts.

Step 1: Terms only: fish feed and fish feed ingredients
Step 2: Terms combined with geography: fish feed and low-income countries
Step 3: Terms combined with gender and geography: fish feed and gender low-income countries
Step 4: Terms combined with women and livelihood: fish feed ingredients AND women livelihoods
Step 5: Terms combined with geography, women and livelihood: fish feed ingredients and women livelihood Africa OR fish feed ingredients and women livelihood Asia

Table 1. Key terms and steps of the review (fish feed).

Step 1: Terms only: animal feed and animal feed ingredients
Step 2: Terms combined with geography: animal feed and low-income countries
Step 3: Terms combined with gender and geography: animal feed and gender low-income countries
Step 4: Terms combined with women and livelihood: animal feed ingredients AND women livelihoods
Step 5: Terms combined with geography, women and livelihood: animal feed ingredients, women livelihood Africa OR animal feed ingredients, and women livelihood Asia

Table 2. Key terms and steps of the review (animal feed).

The following search strings were entered into search boxes within databases and combined in low-income settings for a publication web search:
A: Terms for *fish feed*
B: Terms for *fish feed ingredients*
C: Terms for *fish dependent livelihood*
D: Terms for *fish feed ingredients and low-income countries.*

To exclude studies in high- and middle-income countries, we used the World Bank categorization of low-, medium- and high-income countries (Fantom and Serajuddin 2016). Besides non-fish feed ingredients or animal feed research of ingredients and non-fish feed, specific search strings were extended to human research and research designs. We also included five additional criteria (Table 3) in selecting the most relevant articles and grey literature.

The following terms were excluded from the review:
E: Terms for developed countries or either high- or middle-income countries according to the World Bank
F: Terms for study types and designs
G: Terms for non-fish and/or animal studies.

1. Similar feed types or repetitive feed types (focused on the unique feed types)
2. Similar feed methodologies or methodologies used in the feed research (focused on unique feed methodologies compared to commonly used ones)
3. Similar feed types or repetitive feed types by different authors in the same country (selected relevant literature for the annotations)
4. Similar feed types or ingredients at different times (focused on the most recent studies under 10 years old)
5. Journal reputability (selected journals relevant to the field, such as *Aquaculture, Marine Policy, Reviews of Aquaculture* and others, while considering the relevant grey literature).

Table 3. Additional screening criteria for final annotations.

2 – Screening

The second step was analyzing the selected literature based on the objectives/review questions. These 243 publications were reduced to 60 published and unpublished papers, using the inclusion and exclusion requirements set for review.

Criteria	Inclusion	Exclusion
Research contexts	Low-income countries	Developed countries or either middle- or high-income countries
Study methodology	Quantitative, qualitative and mixed	
Study target population	Women and men of different socioeconomic groups, including the most vulnerable	Non-vulnerable groups, children or youths
Study setting	Smallholders in rural, peri-urban and urban settings	Large-scale commercial fish farming in urban settings
Case study areas	Fish dependent rural livelihoods	Non-fish dependent livelihoods
Data sources	Published reports/articles, books, book chapters, annual reports, technical reports, grey data/unpublished reports (e.g. unpublished reports from specific target countries where research on fish feed may be limited)	
Time	Recent publications (<10 years)	Publications >10 years
Research topic	Fish feed ingredients and livelihood and women: Risks and opportunities including well-being	
Research type	Empirical	Non-empirical
Research perspective	Gender lens and social analysis, with a focus on risks and opportunities of innovation for women and vulnerable groups	

Table 4. Inclusion and exclusion criteria for the review.

3 - Eligibility

The process of selecting literature for the review report is outlined in three distinct stages. In phase one, a maximum number of 243 published and unpublished articles was produced using 67 search terms and then grouped into six main themes.[2] In phase two, these articles were reduced to 60 published and unpublished papers, using the inclusion and exclusion requirements set for review (Table 4). In phase three, we found 40 articles that were published and unpublished using six specific screening criteria (Table 5).

Articles/grey literature type	1st round screening results	2nd round screening results	3rd round screening results	Literature reviewed
Fish feed ingredients	60	11	8	Akter et al. 2019, Bhaskar et al. 2015, Daniel 2016, Daniel et al. 2016, Dorothy et al. 2018, Jumini 2017, Singh et al. 2018, Zulfahmi et al. 2019.
Low-cost fish feed	16	8	4	Das et al. 2016, Fayose and Ogunlowo 2015, Rodrigo and Perera 2018, Sahito et al. 2015.
Fish feed types	43	11	9	Bharathi et al. 2019, Bhosale et al. 2010, Bhuyain et al. 2019, Hajra et al. 2013, Kim et al. 2019, Mo at al. 2018, Nunes et al. 2014, Pandey 2013, Wong et al. 2016.
Potential social/ gender risks	28	13	10	Aregu et al. 2018b, FarmAfrica 2016, Farquhar et al. 2019, Kruijssen et al. 2016a, Kruijssen et al. 2016b, Monfort 2015a, Rajaratnam et al. 2016, Razafindrabe et al. 2019, Weeratunge et al. 2010, Weeratunge and Pant 2011.
Risks and livelihoods	79	7	3	El-Sayed et al. 2015, Rahman et al. 2019, Waithanji et al. 2019
Fish feed methodologies	17	10	6	Bhandari et al. 2019a, Das and Biswas 2019, Gowsalya and Kumar 2018, Musyoka et al. 2019, Okike et al. 2015, Sayed et al. 2018.
Total	**243**	**60**	**403**	

Table 5. Screening criteria and process of articles/grey literature reviewed.

Step 4: Data extraction and analysis

The study followed an analysis cycle that included thematic analysis using three key techniques:

1. Organization and preparation of data: The articles were read and reread, noting down initial ideas.
2. Searching for themes: Six themes (Table 5) were used as screening criteria. These were further used to gather all data relevant to each theme.
3. Detailed analysis and data interpretation: This was the final opportunity for analysis. It included selecting vivid and compelling extract examples, final analysis of selected extracts, relating the analysis back to the research question and literature, and producing a scholarly report of the analysis.

1.3. Key gender concepts and framework

Gender is the central conceptual theme in this review. It refers to the roles, behaviors, activities and attributes that a given society at a given time considers appropriate for men and women. In addition, gender, as a concept, embodies the relationships between women and men and girls and boys. These attributes, opportunities and relationships are socially constructed and are learned through socialization processes. They are context or time-specific and changeable. Gender determines what is expected, allowed

and valued in a woman or a man in a given context. In most societies, there are differences and inequalities between women and men in responsibilities assigned, activities undertaken, access to and control over resources, and decision-making opportunities.

Moreover, as part of the broader sociocultural context, gender interacts with other important socioeconomic characteristics and is mediated by them. These include class, race, poverty level, ethnic group, sexual orientation, age, etc.[4] Assessing this intersection of gender and these other characteristics is referred to as intersectionality.

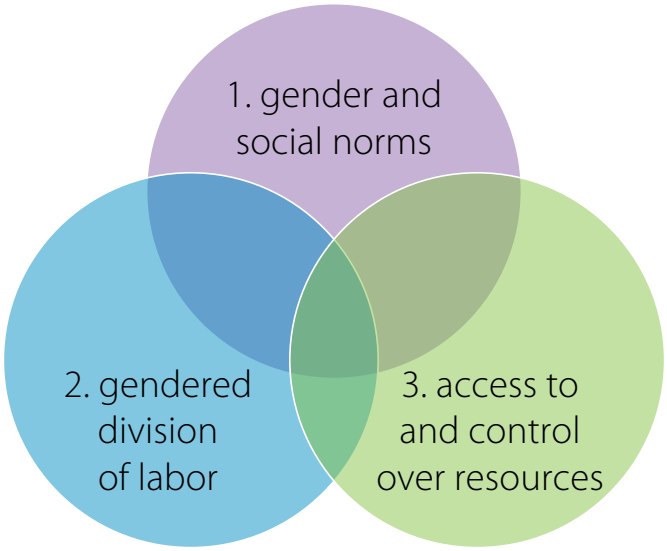

Figure 1. The review's gender framework focuses on three key dimensions of gender.

Given the scarcity of gender-focused aquaculture literature, identifying the potential social and gender risks to women and men in the use of, and competition for, local ingredients for fish feed, we chose these three dimensions to dive deep into androcentrism.

1. Gender and social norms

To fully comprehend the objectives of the review, one must understand "social norms." These can shape who is included and excluded in a community.

Social norms are the unwritten rules that underpin a society and govern how people behave. Bicchieri (2006) wrote, "one expects people to follow a certain norm in a certain situation because he/she has observed people doing just that over a long period of time." People often do not question why they act one way in society and a different way when they are home. Gender norms can be constraining, leading to inequities and discrimination. For example, gender norms in Bangladesh and other contexts limit women's mobility outside the homestead and place a disproportionate burden of unpaid domestic and care work on women, while imposing neither on men. These in turn limit women's ability to earn their own income, which reinforces a gendered hierarchy in the household.

2. Gendered division of labor

This is an important concept in basic gender analysis that helps deepen understanding about social relations as an entry point to sustainable change through development. The division of labor refers to the way each society divides work among men and women, boys and girls, according to socially established gender roles or what is considered suitable and valuable for each sex. Anyone planning a community intervention needs to know and understand the division of labor and allocation of assets on a sex-and-age disaggregated basis for every community affected by development interventions. Within the division of labor, there are several types of roles:

- **Productive roles:** Activities carried out by men and women to produce goods and services for sale, exchange or to meet the subsistence needs of the family.
- **Reproductive roles:** Activities needed to ensure the reproduction of society's labor force. They include housework like cleaning, cooking, childbearing, rearing, and caring for family members. Women do most of these tasks.
- **Community managing role:** Activities done primarily by women at the community level, as an extension of their reproductive role, to provide and maintain scarce resources of collective consumption, such as water, healthcare and education. This is voluntary unpaid work performed during "free" time.
- **Community politics role:** Activities done primarily by men at the community level, often within the framework of national politics. This officially recognized leadership role may be paid directly or result in increased power or status.
- **Triple roles:** This refers to the fact that women tend to work longer and more fragmented days than men as they are usually involved in three different roles: reproductive, productive and community work.[4]

3. Access to and control over resources

This concept has three parts: resources, access and control. The first refers to means and goods, including economic (household income) or productive means (land, equipment, tools, work, credit), political means (capability for leadership, information and organization), and time. Access and control have slightly different meanings. Access refers to the ability to use and benefit from specific resources (material, financial, human, social, political, etc.) whereas control over resources also entails being able to make decisions over the use of that resource. For example, women's control over land means that they can access and use land, own land as the legal titleholders, and make decisions about whether to sell or rent the land. Access and control over resources is a key element of women's empowerment and, by extension, the achievement of gender equality.[4]

Fish smoking near the Tonle Sap lake in Siem Reap, Cambodia.

2. Findings

2.1. Potential social and gender risks and opportunities from the use of new local ingredients for fish feeds

Although increasing, gender scholarship in aquaculture is limited (FAO 2016; Kruijssen et al. 2018). This is significant because failure to integrate gender is likely to result in sub-optimal outcomes for women specifically, and for the sector as a whole (Kruijssen et al. 2016b; Pyburn and Eerdewijik 2016).

Specifically, the review found 10 articles on social and gender risks and opportunities. Although only two focus on any fish feeds or ingredients, it still gives an overview of gender in aquaculture. Table 6 provides an overview of knowledge gaps identified in the literature, and it frames each in relation to a gender-based critique.

Next, we examine social and gender risks and opportunities through the lens of the gender conceptual framework.

Critique	Knowledge gaps
Using synonyms: "fishers" as men and "fisher wives" as women	Fish farming has long been perceived as a male sphere because of the perception that men engage in all fishing activities while women do not (Weeratunge et al. 2010). This is problematic because it obscures the contribution of women in aquaculture and fish feed interventions.
Limited studies on gendered preferences, needs and participation in the use of fish feeds	At the production level, there is limited knowledge about gendered preferences and needs for fish feed and breeding programs as well as impacts of genetically improved fish feeds and disease prevention practices (FAO 2016; Kruijssen et al. 2016b). There is also limited evidence of women's participation and gender relations in input sectors in general (feed and fish feed), including limited understanding of policies that result in gendered and social inclusion or exclusion (FAO 2013; Kruijssen et al. 2018).
Gender-blind aquaculture studies	Many aquaculture studies are gender-blind because they do not consider the differential impact of the aquaculture sector on men and women. As a result, programs may unwittingly exacerbate women's unpaid workloads, reduce women's control over resources, lower their decision-making power or contribute to inequitable distributions of income in aquaculture (Rajaratnam et al. 2016).
Lack of robust sex-disaggregated data	The lack of robust sex-disaggregated datasets impedes gender analysis in fish feed research, which can form a basis for developing gender-sensitive policies and planning (Kruijssen et al. 2018).
Limited analyses on gender and social norms	Analyses on gender and social norms are only starting to emerge in aquaculture research (Weeratunge et al. 2010). In most cases, these may be outside the scope, timeframe or budgets of programs, or the skills of the project staff (du Preez 2018).
Informal institutions are crucial to women's advancement	In rural contexts, informal institutions are more powerful, overriding constitutions and legislation, especially in the case of ownership of assets and resources for aquaculture (Monfort 2015a; Aregu et al. 2018b). Informal institutions do not embrace access and ownership of assets and aquatic resources by women (Weeratunge-Starkloff and Pant 2011), even if land inheritance statutory laws change (World Bank et al. 2009).
Limited evidence on the effects of degradation and depletion of aquatic resources on women's livelihoods	Ecological degradation and depletion of aquatic resources further limit women's and men's access to resources for fish feeds, and climate change compounds the situation by threatening to exacerbate the condition for women (Weeratunge et al. 2010). There is no evidence of the gender and social risks posed by these challenges on the livelihoods of men and women who depend on aquaculture.

Table 6. Knowledge gaps and critiques of social and gender risks and opportunities relating to feeds in aquaculture.

Gender and social norms in aquaculture

Men's and women's roles and responsibilities, access to assets and resources, and decision-making power are all influenced by social and gender norms (Alesina et al. 2013). In terms of risks, an opportunity for more profit might not encourage women to engage in a new intervention on fish feeds if a social norm will constrain them or deliver negative consequences. For example, while legal restrictions on women's mobility may be rare, social norms governing women's subordination, modesty and caregiving roles could effectively restrict women's movement (Kruijssen et al. 2018). Women's unpaid care roles often keep them housebound and busy. Even where appropriate policies and laws exist, social norms and social sanctions can constrain women's agency and prevent them from taking opportunities available to them (Ferrant and Nowacka 2015). Similarly, a study by Kruijssen et al. (2016b) on gender in farmed fish value chains in Bangladesh found that the level of support from husbands and in-laws for women to stretch norms by taking on nonconforming roles is key to determining the extent to which women are able to participate in aquaculture value chains. This emphasizes the need for research for development to identify and work to address constraining gender norms that exclude and subordinate women.

The review revealed existing gender constraints in relation to norms in aquaculture and then identified potential risks associated with each in relation to a shift to local fish feeds. These are presented in Table 7.

Gender division of labor

Multiple factors influence both paid and unpaid participation and agency in particular tasks in aquaculture value chains. These include gendered allocation of education, healthcare, childcare, control over income and social networks, among others (Weeratunge et al. 2010). Despite the many roles women play in aquaculture at all stages—pre-harvest, harvest and post-harvest—they are often not accepted as "fishers" by the communities (EMEDO 2017).

Gender issues related to constraining norms	Key risks
Norms frame men as (fish) farmers and "household heads," and women as helpers and subordinates (Petesch et al. 2017[5]; Aregu et al. 2018a). Thus, agro-advisory services or private sector actors often overlook women as knowledgeable decision-makers and clients (Manfre et al. 2013).	Extension services relating to feed innovations might reach, engage and respond only or predominantly to men's needs and preferences (Waithanji et al. 2019).
Technologies tend to be associated with men, who are perceived as farmers and innovators while women are not (Aregu et al. 2018a).	Feed innovations may be designed to respond to men's needs and preferences, so available technologies in some cases may not meet the needs of women (Waithanji et al. 2019).
Women as caregivers (Kabeer 2011). Neglecting unpaid care work leads to incorrect inferences about levels and changes in individuals' well-being and the value of time.	Time and unpaid labor burdens associated with new feeds may fall disproportionately to women.
Men's networks are usually wider than women's because they move around more frequently and freely, while women face greater mobility constraints, relating to norms, work burdens and other factors (Surendran et al. 2016; Kruijssen et al. 2018).	Men will hear and learn about and take advantage of any new opportunities arising from the use of local ingredients for affordable and nutritious fish feeds before women. The risk is that women could be further marginalized and miss out on opportunities for income growth and control.
Market information and access to inputs, such as fingerlings and fish feeds and credit, are less available to women than men (Kruijssen et al. 2018; Nunan and Cepic 2020) because women have less mobility outside home and less time due to unpaid work.	Women might have to take greater risks with more limited information at hand than men if they want to start fish feed businesses. Consequently, their chances of success are diminished without targeted assistance.

Table 7. Gender and social norms and associated key risks relating to the shift to local fish feed ingredients in aquaculture.

Gendered division of labor is particularly critical to understanding the risks related to the "identity" of the women fishers and recognition of the paid and unpaid tasks that women perform, which in turn affect their agency and empowerment. Intertwined with and stemming from norms, behaviors around gendered division of labor can cause many indirect disadvantages for women.

The review found some similar division of labor patterns across the diverse contexts in Africa, Asia and the Pacific in which work such as pond preparation, stocking, liming[6] and the purchase of fish feeds is done mostly by men (Weeratunge et al. 2010; Kruijssen et al. 2018). Women are mostly involved in the post-production nodes. These include post-harvest handling (sorting, cleaning and grading) and processing and trading (Weeratunge et al. 2010; Kruijssen et al. 2018). However, at the processing level it is difficult to differentiate between processing fish from captured sources and farmed fish (Weeratunge et al. 2010; Pyburn and Eerdewijik 2016). Women's level and nature of participation in aquaculture is significantly shaped by their workloads in both productive and reproductive roles, as well as the proximity of ponds, cages and fishery reservoirs.

While the literature does reveal these common patterns, the available literature on the gender division of labor relies on generalizations or limited data and analysis. Additionally, the limited information available on gendered labor in aquaculture value chains varies between sources (Weeratunge et al. 2010; FAO 2016; Pyburn and Eerdewijik 2016). For example, some studies suggest gender roles and responsibilities limit women's ability to participate in income-generating economic activities (Haylock et al. 2016; Read-Hamilton and Marsh 2016), while others show that women contribute significantly but are underrecognized (FAO 2017).[7] Even though women are present in all segments of the industry, they remain invisible. They are efficient yet often underpaid, and they are less equipped to face adverse external events (Monfort 2015a).

For Weeratunge et al. (2010), women contribute significantly to income-generating activities by performing many unpaid pre- and post-harvesting tasks and are outnumbering men in processing and trading fish. In Nigeria and Myanmar, women are highly engaged in the fish value

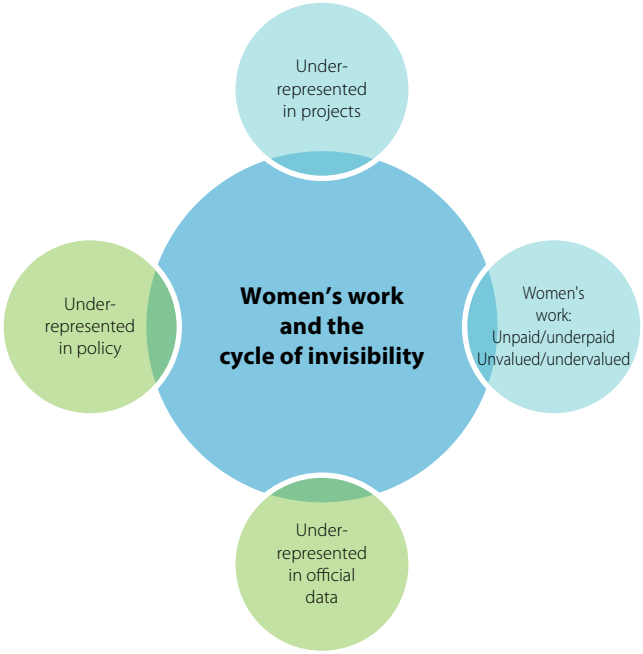

Figure 2. Women's work and the cycle of invisibility.

chain, but they still face barriers that limit their engagement and returns and are unrecognized in statistics. For example, Weeratunge et al. (2010) explain that women are more likely to sell in informal markets and men in formal markets and so women are underrepresented in statistics about aquaculture that focus on the formal sector. In addition to these challenges, women also take on a disproportionate share of unpaid care, which further limits their opportunities to engage in markets.

The review found that the gender division of labor was emphasized in a number of publications. As such, in this review we tried to identify associated potential risks related to each. These are presented in Table 8.

Access to and control over aquaculture assets and resources

Deep-rooted gender disparities in social, cultural and economic spheres reduce women's access to and control over aquaculture assets and resources (Weeratunge-Starkloff and Pant 2011). Without control, women are unable to choose how and when to use assets and resources as an input into the aquaculture value chain or allocate them to other uses. Scholarship on access to assets and resources in aquaculture posits that asset distribution is gendered, with women being disadvantaged in ownership and control of assets, both in terms of the number

Gender division of labor	Key risks
Women are burdened by reproductive responsibilities, related to household and child care, that men do not necessarily face (Weeratunge et al. 2010).	Alternative fish feed-related livelihood opportunities may add to women's already higher burdens. In other works, they lead to women's triple burden and perpetuate women's subordination and prevent them from realizing their full potential.
Women's unpaid labor contribution is unrecognized in society and also in statistics (FAO 2017).	Women may get underrepresented in projects and policies related to fish feed initiatives (FAO 2017) and may not get the benefit of better extension services, policies and institutional practices directed at women.
In the gender division of labor in fish value chains, women are underpaid and undervalued. They often hold the lowest-paying jobs in the fish value chain and remain excluded from large-scale production except as local processors (Monfort 2015a; Kruijssen et al. 2018).	Women's invisible unpaid work could widen the gender pay gap further. They might only have limited opportunities to move up the value chain, and this may reduce their motivation to take up local feeds as business opportunities.

Table 8. Gender division of labor in aquaculture and associated key risks relating to the shift to local fish feed ingredients.

owned and their value (Meinzen-Dick et al. 2011; Doss et al. 2014; Doss et al. 2018). For example, in Bangladesh women own less than two percent of ponds (Kruijssen et al. 2016). A recent study by FarmAfrica (2016) in 11 countries revealed that, out of all survey participants, the highest female control over ponds was in Kenya, at 20 percent. However, complementing qualitative data confirmed that men were de facto owners of most of these ponds. Aquaculture is a capital-intensive enterprise, especially in the beginning because of the need to purchase fingerlings and to feed the fish and clean pond dikes in order to maintain the fish for at least 6 months before any income is earned. Given that many rural women, particularly in the Global South, do not have control over assets, they do not have the kind of resources required to continuously invest in ponds, especially during the setup phase (FarmAfrica 2016). Decisions about investing in aquaculture or using funds for other purposes are not usually a women's domain (FAO 2017).

The review also found that women's access to appropriate technology is limited. The fact that men own most of the equipment constrains women from participating in fish processing (Monfort 2015a). In some cases, strongly held beliefs that women cannot operate fish processing machinery permeate the entire country of Bangladesh (Kruijssen et al. 2018). In other examples, project designers, researchers and implementers target women for technologies that they assume will benefit women when this is not the reality (Kantor et al. 2015). The full range of factors shaping how women and men adopt and use aquaculture innovations is understudied (Kantor et al. 2015).

Gender disparities compound and multiply. As an example, women rarely have land in their name. This leads to less collateral and more limited access to formal credit (FAO 2019). Moreover, women's control over income derived from aquaculture is lower than men's. For example, a study among women involved in aquaculture in five regions in Bangladesh showed that 78 percent of the women interviewed had limited or no control over the incomes derived from aquaculture (Kruijssen et al. 2018). Collectively, these disparities result in extension workers overlooking women as knowledgeable actors. This means women have less access to specialized knowledge and skills, as well as extension services required for fish farming, hatchery or nursery management, or marketing (Weeratunge et al. 2010).[8] In turn, this means the barriers to entry for women in aquaculture are higher than for men, and in many cases this risk may be too high to bear.

The review found that social networks also contribute to differential access to various resources, such as formal and informal credit as well as market information, and also access to inputs like fingerlings and fish feeds (Kruijssen et al. 2018; Nunan and Cepic 2020). Other issues for women include restricted mobility and lack of consent of family members for women's engagement

in income-earning opportunities and decision-making (Farquhar et al. 2019). Women's restricted mobility affects their access to markets and aquaculture ponds and limits their involvement in value chain contexts (Kruijssen et al. 2018).

The review found existing challenges regarding access to and control over aquaculture assets and resources, and then identified associated potential risks related to each. These are presented in Table 9.

Access to and control over aquaculture assets and resources	Key risks
Aquaculture farm and pond ownership is generally low among women (Kruijssen et al. 2016).	If alternative fish feed emerges as an opportunity for small and medium enterprises, then women might be excluded from engaging and benefitting as business owners.
Regardless of the asset or resource, women are disproportionately excluded from control and ownership in aquaculture because of deep-rooted gender disparities (Weeratunge-Starkloff and Pant 2011).	Gender imbalances in power mean that women lack agency regarding how and when to use resources as inputs into the aquaculture value chain or to allocate them to other uses.
Aquaculture is a capital-intensive enterprise (Farm Africa 2016).	Most women in the Global South do not have the kind of resources required to continuously invest in fishponds (Farm Africa 2016). Men could give priority to fish feeds over terrestrial nutrition, especially poultry, which is regarded as a woman's enterprise (Orr et al. 2016).
Gendered imbalances are generally low when it comes to control over income in terms of exercising agency on how it is spent and whether to invest it in aquaculture or use it for other purposes (Weeratunge et al. 2010; Kruijssen et al. 2016).	If mostly men own fish farms and control income, then they will more likely benefit from any cost savings.
Gender inequities exist in access to and control over technologies (Weeratunge et al. 2010).	Women's lack of control over technologies and other innovations, combined with their lower educational attainment in some contexts, means extension and training opportunities often overlook them. The risk is that this reproduces gender asymmetries in information and technical capabilities and lowers their opportunities to be economically independent and have agency/decision-making power over new technologies.
Technologies are not designed in a gender-responsive way to take into consideration women's needs and preferences.	The risk is that if the trend of gender-blind design extends to fish feeds, then the technology gender gap will extend here as well. And if women have fewer fit-for-user technologies, and less access and control over them, they are also likely to risk being excluded from scaling up production to larger scales, and so could be shut out of opportunities to increase income and move up the value chain (Weeratunge et al. 2010).
Decisions made by men as "household heads" are more likely to benefit the livelihoods they themselves control and benefit from (Ferrant and Nowacka 2015).	The risk is that in situations where women have access but not control over resources, the competition for ingredients will favor men's enterprises and benefit. Moreover, new local feeds might divert ingredients that women already rely on (e.g. peels or insects for chicken feeds) for the assets they do control (e.g. small livestock/chickens) (Waithanji et al. 2019), which undermines women's livelihoods and resilience.

Table 9. Gendered patterns regarding access to and control over aquaculture assets and resources and associated risks.

2.2. Emerging gender-inclusive business and livelihood opportunities, entry points and strategies associated with using local ingredients for fish feed

Aquaculture has been introduced into many parts of the world, particularly in Africa and Asia, as a way of improving living standards and of escaping poverty among rural communities (FAO 2012; Mwaijande and Lugendo 2015; FAO 2018). Livelihood outcomes from the aquaculture sector include income, potential for employment generation, people's food and nutrition security, family well-being, promoting socioeconomic growth and alleviating poverty (Belton et al. 2014; Ottinger et al. 2016; FAO 2018; Mangeni and Mhlanga 2019; Razafindrabe et al. 2019; Nasr-Allah et al. 2020). Although underreported, women are engaged in aquaculture in a myriad of ways and contribute significantly to the overall well-being of households. The aquaculture sector is too diverse to state that this is an all-encompassing aquaculture value chain (FAO 2013; Monfort 2015a; Kruijssen et al. 2016b; Razafindrabe et al. 2019). Nonetheless, ways in which gender inequities in aquaculture value chains and livelihoods occur include the following:

- Low-quality jobs frequently are linked to certain gender roles, particularly women's positions. Jobs with lower remuneration typically involve more women (Kruijssen et al. 2018).
- Women are often excluded from large-scale production and so are shut out of opportunities to increase income and move up the value chain (Weeratunge et al. 2010).
- Women are disproportionately represented in less profitable and less secure nodes of aquaculture value chains (Weeratunge-starkloff and Pant 2011; Rajaratnam et al. 2016; Kruijssen et al. 2018).
- Women are a key element in aquaculture industries, yet they are often invisible along the value chain and in statistics and are underpaid (Monfort 2015a). As such, they are less able to cope with adverse external events, and they do not receive institutional support in the same way men do (Monfort 2015a).

Leverage points for increasing women's engagement in, and benefit from, aquaculture business opportunities that would be relevant to local fish feed gender inclusive businesses

Men and women of different ages do not participate in aquaculture value chains in the same way, and the derived benefits from increased incomes are not evenly distributed (Monfort 2015a; Farquhar et al. 2019). For example, women smallholder farmers, in theory, can expand their farming activities through aquaculture. Yet, due to gender imbalances in technical knowledge, lack of capital, exclusion and invisibility, they are unable to benefit from opportunities to the same extent as men (Tonye and Francis 2014). While these gender barriers persist, the review also identified several leverage points. We suggest that these may be relevant not only to aquaculture value chains in general, but also potentially useful to inform gender-responsive fish feed sector development. The following are promising areas:

- Access to credit: Microfinance institutions seek to serve those excluded from the formal banking sector and give them access to financial markets as a key strategy of poverty reduction (Moger and Dhananjaya 2017). Access to these facilities is seen as a way of providing the poor with opportunities to take an active role in their economy through entrepreneurship, providing them with income and bargaining power and building up social empowerment for poor women and men in the communities. These can help women move up along the value chain and even take initiatives to start fish feed businesses using local ingredients.
- Collective action: Small-scale fishers and fishing communities frequently suffer under the domination of influential players inside and outside the fisheries sector who control fisheries governance policies (FAO 2016). By working together, small-scale fish farmers become stronger and gain market power and better prices. However, efforts to organize women into collectives are hindered because of inadequate knowledge on how to form cooperatives, poor leadership skills, little awareness of the importance of collectives, inaccessibility of establishment guidelines for cooperatives, and a lack of capacity-building programs to support women's initiatives

(EMEDO 2017). Collectives can be a good entry point for women entrepreneurs to start fish feed businesses in their communities. Women can leverage this network to find buyers and customers without risking individuals' money or breaking with restrictive gender norms.

- Gender-transformative approaches: These have been successfully used in agriculture and fisheries programs to change the unequal gender norms that underlie many of the constraints identified. These norms may also interfere with the successful implementation of many leverage points if not addressed. These approaches can be built into research designs.[9]
- Inclusive business models (IBMs): IBMs are specific contractual relations and mechanisms that aim to integrate poor people into the supply/distribution chain of a larger business. Extensive tilapia or seaweed farming in Africa could benefit from IBMs established by cooperatives and links to local agribusiness, while shrimp farming in South Asia could require larger contract farming models with more semi-intensive smallholders able to meet export market standards. One major risk with these models, however, is that without carefully enacting social protections in the makeup of the associations or businesses, they might replicate inequalities that exist at the local level, such as gender inequalities or unequal land distribution. There is little evidence in the reviewed papers where social upgrading actively responded to, for example, the needs of women or youths. In many cases, external stakeholders such as government and nongovernmental organizations were responsible for making IBMs more socially equitable, as opposed to the businesses themselves actively making such efforts (Kaminski et al. 2020). According to Murekezi et al. (2018), aquaculture is well suited for contract farming because it is labor intensive and aquaculture products are perishable and have a high value-to-weight ratio.

Photo credit: Netsayi Noris Mudege/WorldFish

WorldFish scientist Mary Lundeba feeding broodstock at Chomba Chileshe's farm in the Fisonge area of Luwingu, Zambia.

3. Design features for gender and socially integrated alternative fish feed risk assessment

This section presents the need for new methodologies as well as improving existing ones to ensure they capture the specific context of gender and aquaculture.

The integration of gender or social lenses into any study on fish feeds, whether qualitative or quantitative, is currently missing. In terms of quantitative studies, two examples are found. Using quantitative methods, Bhaskar et al. (2015) examines the use of poultry waste to replace fishmeal in India, while Akter et al. (2019) identifies potatoes in Bangladesh as a potential alternative plant protein. The latter study applied on-station quantitative research and experimental design using complete randomized design and treatments. The methods involved collecting and storing samples, feed preparation, feeding and analysis of experimental tilapia fish fry, proximate composition analysis (moisture, ash, crude proteins and lipids), growth parameters and water quality parameters, and glucose monitoring (Akter et al. 2019).

In terms of qualitative studies, three literature reviews were found. Daniel et al. (2016) completed one on the importance of microalgae as a fish feed ingredient, while Dorothy et al. (2018) also completed another on narratives and data from journal articles on plant leaves as potential feed ingredients (terrestrial and aquatic leaf meals).

Only two articles were found regarding mixed methods[10] studies associated with fish feed: Jumini (2017) and Singh et al. (2018). Jumini (2017) tests manure and feathers from chickens in Indonesia as potential locally sourced fish feed ingredients. The study used descriptive statistics as well as qualitative data. The qualitative analyses included feedback interview data collected from seminar workshops and training sessions with community members. Singh et al. (2018) studies brewery waste, ghee residue, cassava waste, jute, subabul, raintree, spirulina and moringa in India. Data from evaluations was used to categorize the potential of nonconventional ingredients for fish feeds, and the chemical properties were reviewed. Community engagement was also included.

Moreover, sex-disaggregated data is essential for understanding the differential impacts of development and the value chain on women and men. However, such data in aquaculture is lacking in most countries, and the data that is available is far from sufficient for policymakers to design gender-equitable fisheries and aquaculture policies.

A notable exception to all these limitations is WorldFish's Women's Empowerment in Fisheries Index (WEFI). This methodology has been modified from the Women's in Agriculture Index, combined with the Gender Equitable Men's Scale, and is being used to assess changes in women's empowerment in relation to interventions in aquaculture and fisheries.

Annex 4 further documents the methods used.

To understand the social and gender risks associated with using specific (potential) fish feed ingredients, certain methodological design features emerge from the literature.[11] The literature reviewed suggests that there is a high potential to exacerbate gender inequalities for women in any new industry, such as fish feeds. However, it points to some key opportunities for gender equal and socially relevant methodologies:

- **Undertake assessments using tools that can track changes in empowerment in relation to innovations and interventions**. For example, a collaborative effort will ensure results at scale, such as that already done with WEFI, so that the research for development is not done in silos.
- **Develop a gender-integrated theory of change (TOC) regarding the inclusive development and scaling of local feed ingredients using a rigorous yet participatory planning process**. Moving from one ingredient to another and from an exclusive market structure and normative framework (rules of the game) to something more inclusive requires a participatory planning process. All new feed innovations

(including technology innovations) and investments come with risks and opportunities. The opportunities for advancement and positive change appear higher for men than women. Conversely, for women, especially if single or widowed, the risks of changing feed ingredients and models may be higher because women are already disadvantaged compared with men. Partners and all stakeholders, across aquaculture, gender and both small and medium enterprises, should articulate their short-, medium- and long-term goals. They should also identify the conditions and investments or interventions they believe have to unfold for those goals to be met in a transparent way. This will involve conceptualizing an enabling environment for fish feed business opportunities and then working back to develop strategies to overcome the systemic drivers of gender and social risks. This will also involve mapping country-level gender policies and aiming to shift the scales from gender-blind to gender-transformative policies and institutions.

- **Integrate context-sensitive and intersectional approaches**. This refers to applying a lens throughout that not only considers gender, but assesses all dimensions in relation to other, interconnected key social characteristics that affect power and vulnerability in given contexts, such as age, wealth, ethnicity, legal status, disability and occupation. Among low-income and at-risk people, there are different categories of men, women and youths. Many are consistently excluded, while others want to innovate differently but the conditions that would encourage them to take risks are not in place. Different identities have different historical experiences. They may have different aspirations and may likely require varying strategies for equitable engagement and returns, including risk management.
- **Design comparative case studies of local feed businesses**. Investigate the experiences and views of diverse women and men in relation to the affordability, quality and competition of standard commercial fish feed. Document local innovations and focus on lessons learned and people's own interpretation of these experiences of success and failure. Gender and social norms can be a positive or negative force for change, but the evidence around how to make these changes positive is scant. The literature reviewed suggests that a deep endogenous understanding of local gender norms would be required to avoid undermining women's goals and strategies. Comparative case studies can be one way to illuminate these goals and strategies before introducing new feed ingredients.
- **Develop and use mixed method studies and establish a baseline**. This should be done before any intervention to provide empirical evidence on how social networks, social capital and the local political economy in communities affect livelihood strategies and opportunities in aquaculture. With this knowledge, the use of fish feed ingredients can also be mapped, along with household contestation for ingredients, specifically assessing risk in relation to local feed enterprises. Data collection should aim at building sex-disaggregated panel databases as part of the evidence and thematic catalogue of studies. This will assist in measuring changes and adverse consequences over time. As a result, there is a need to assess risk in relation to local feed enterprises, as well as ingredients.
- **Test various scenarios**. Scenario testing is a research method from behavioral economics that tries to understand how different people would respond to hypothetical situations of change, known as "what-if scenarios," such as "what would happen if something were the case." For example, if an organization supported the commercial production of local fish feed ingredients and promoted women's employment with producers, how would this affect home-based enterprises and women's livelihood strategies? If cassava was promoted as a cost-effective and nutritious fish feed alternative and started being used to feed fish instead of chickens or pigs, what would the chickens or pigs eat, and would this cause any change in women's income, or in household relations (e.g. conflict)?[12]
- **Use agent-based modeling and ensure gender norm datasets like GENNOVATE are put into it**. This can allow for the combination of livelihood strategies, natural resource management, sociocultural and

political-economic data and model scenarios based on existing data. According to Edmonds and Meyer (2013, 7) "agent-based modelling does not require high levels of mathematical skill and thus is more accessible to social scientists." Agent-based modeling allows for a visual representation of the data and enables planners, policymakers and development partners to see the potential impact of their proposed efforts in terms of household, farm and community trade-offs and conflict.[13]

- **Use the evidence to generate policies that sustainably address gender and social risks.** For example, these should advocate for policy reforms that back equitable ownership and use of property and resources.

Photo credit: Jairo Lajtrado/WorldFish

Fish caught from the rice field system support the livelihoods of many Cambodian communities. Selling fish at home has a direct impact on a family's ability to generate income (Tramper CFR, main pond, Pursat).

4. Conclusion

The systematic review of the literature on fish feeds explored three key areas:

1. social and gender risks associated with the use of local ingredients for fish feed
2. emerging gender-inclusive business and livelihood opportunities, entry points and strategies associated with using local ingredients for fish feed
3. methods used to empirically assess these issues to help design potential future fieldwork.

In the first area, the key finding was that there is a significant gap in the available literature. Moreover, in the studies that do exist, not all of them collected sex-disaggregated data, which makes it difficult to draw robust conclusions between men and women, let alone gender. Women's contributions to aquaculture production in general can be overlooked in statistics and available literature. Therefore, there is a risk that any negative changes brought about by introducing new ingredients could be born disproportionately by women and go unnoticed by men. Moreover, the potential risks that came out of the review were related to gender norms, division of labor and access to and control over resources. These can hold women back from taking advantage of new opportunities, inflame any existing inequalities and restrict women's ability to voice their concerns over any competitive use or negative consequences.

In the second area of inquiry, emerging business and livelihood opportunities were explored that may be associated with local ingredients for fish feed. There is an established body of literature on how expensive fish feed is to the detriment of the productivity and profitability of the aquaculture sector as a whole. As such, finding solutions to this conundrum is needed. New feed ingredients have been trialed, especially from agricultural or animal waste, as an affordable option. In the majority of situations, according to the sources reviewed, women have access to but no control over feed ingredients. This inevitably favors men's enterprises in competition for ingredients. As such, judiciously planned interventions that integrate gender and social lenses in fisheries and aquaculture development policies will effectively improve women's livelihoods, well-being and the environment they depend on. Some successful examples of women's increased involvement in, and benefit from, fish feeds and aquaculture were found. These included collective action work, access to credit and inclusive business models.

The third and final area of inquiry related to documenting the methods currently used in fish feed research. Sex-disaggregated datasets are lacking, as laboratory experiments and qualitative reviews take precedence. However, very few of these studies discuss risks outside of nutrition for humans and financial costs. Consequently, the review finds that new questions about risk, and especially gender and social risks, need to be asked during fish feed studies, along with new or different methods used. This lack of data impedes gender analysis, which is the basis for developing gender-sensitive policies and planning (Weeratunge et al. 2010). The current methodologies used in empirical studies for fish feed ingredients across low-income countries can be categorized as quantitative on-station research trials using full randomized design and treatments, and some qualitative reviews. There is a need to integrate mixed methods into future empirical studies that adopt components of qualitative initiatives such as GENNOVATE, complemented with quantitative methods.

The full range of factors shaping how women and men adopt and use aquaculture innovations is understudied—particularly the surrounding gender power relations and dynamics (Kantor et al. 2015). There is some information on access to and control over aquaculture assets that reveals the disadvantaged position women are in. The role of gender and social norms is alluded to in many studies and is usually considered a barrier to women's equitable advancement. However, the pockets of literature do not add up to offering the specific context required. What is known is that gender and social norms can be a positive or negative force for change, so they are worthy of study. The literature reviewed suggests that a deep

endogenous understanding of local gender norms would be required to avoid undermining women's goals and strategies. Methodologies extrapolated from available literature to create some potential design features have been developed to assist WorldFish in planning future fish feed studies that are gender equitable and socially inclusive, and in identifying the opportunities in aquaculture value chains while also examining risks.

Photo credit: Samuel Stacey/WorldFish

Women fish sellers, Fayoum, Egypt.

Notes

[1] https:/www.researchgate.net

[2] See Annex 1 for the complete list of major terminology used in the study of fish and animal feeds.

[3] There was additional literature brought in from literature outside the scope of the review after the third screening (i.e. the literature available was too small to create meaningful findings).

[4] UN Women 2011–2017.

[5] Both references come from the GENNOVATE study.

[6] Liming is the application of acid-neutralizing compounds of calcium, and/or calcium and magnesium. This is done to enhance the effect of fertilization (Wurts and Masser 2014).

[7] Weeratunge et al. (2010, 1) write, "If gleaning, trading, processing and fish farming were enumerated in addition to fishing, the fisheries/aquaculture sector might well turn out to be a female sphere."

[8] In some cultures, women are limited from interacting with male extension workers, and there are only a few female extension workers (Kiumbuku and Mutinda 2013).

[9] For some examples of gender-transformative approaches see: https://www.cimmyt.org/wp-content/uploads/2017/10/Ethiopia-GENDER02-.pdf

[10] Mixed methods is a procedure for collecting, analyzing and mixing or integrating both qualitative and quantitative data at different stages of the research process.

[11] While this section focuses on the risks, the complete literature review covers opportunities as well.

[12] For more information on scenario testing: Marengo L and Pasquali C. 2003. How to construct and share a meaning for social interactions? *In* Conventions et Institutions: Approfondissements the 'oriques et Contributions au De'bat Politique, Paris; Dray A, Perez P, Le Page C, D'Aquino P and White I. 2006b. Atoll Game: A companion modelling experience in the pacific. *In* Perez P and Batten D, eds. Complex science for a complex world: Exploring human ecosystems with agents. Canberra, Australia: ANU E Press. 255–80.

[13] Edmonds B and Meyer R, eds. 2013. Simulating social complexity: A handbook. Springer Heidelberg.

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Annex 1. Key terms of the fish and animal feed review

1. Fish feeds
2. Fish feed ingredients
3. Cassava peels + animal feeds + women + risks
4. Cassava peels + fish feeds + women + risks
5. Types fish feed
6. Indigenous fish feed
7. Low cost fish feed
8. Fish feed AND Asia (Bangladesh, Myanmar and Malaysia)
9. Fish feed AND Africa (Egypt, Nigeria and Zambia)
10. Affordable fish feed
11. Small-scale aquaculture AND women
12. Small-scale aquaculture AND low-income countries
13. Fish feed ingredient AND Asia (Bangladesh, Myanmar and Malaysia)
14. Fish inputs
15. Fish feed ingredient AND Africa (Egypt, Nigeria and Zambia)
16. Fish feed AND women low-income countries
17. Positive impacts AND/OR fish feed
18. Negative impacts AND/OR fish feed
19. Fish feed impacts AND/OR gender low-income countries
20. Fish feed impacts AND Asia (Bangladesh, Myanmar and Malaysia)
21. Fish feed impacts AND/OR Africa (Egypt, Nigeria and Zambia)
22. Fish feed AND/OR livelihood Asia (Bangladesh, Myanmar and Malaysia)
23. Fish feed AND/OR livelihood Africa (Egypt, Nigeria and Zambia)
24. Nutritional fish feed
25. Nutritional fish feed AND/OR low-income countries
26. Viable fish feed AND/OR low-income countries
27. Potential fish feed AND/OR low-income countries
28. Fish feed and social risks
29. Fish feed and economic risks
30. Fish feed and environmental risks
31. Fish feed risks and low-income countries
32. Fish feed challenges

33. Fish feed challenges AND low-income countries
34. Fish feed opportunities
35. Fish feed opportunities AND low-income countries
36. Social and gender risk analysis and fish feeds
37. Social and gender risk analysis and animal feeds
38. Gender and animal feeds
39. Women and animal feeds
40. Women, feed ingredients, risk, and livelihoods
41. Competition between fish and animal feed
42. Fish research methodologies (gender and social analysis)
43. Determinants fish feed AND low-income countries
44. Unconventional fish feeds plant origin AND low-income countries
45. Unconventional fish feeds animal origin AND low-income countries
46. Commercial fish feeds animal origin and AND-income countries
47. Commercial fish feeds plant origin and AND-income countries
48. Breeding and genetics available fish feeds AND low-income countries
49. Management fish feeds AND low-income countries
50. Ecological and environmental print fish feeds AND low-income countries
51. Fish feed ingredients AND women livelihood
52. Fish feed ingredients AND smallholders well-being low-income countries
53. Animal feeds, women and risk
54. Animal feeds, women and opportunities
55. Gender norms AND fish feed low-income countries
56. Fish feed as livelihood AND women empowerment low-income countries
57. Feeds and competition
58. Feeds and equity
59. Fish feeds and competition
60. Fish feeds and equity
61. ("Fish feed" AND "animal feed ") AND (women livelihood OR gender norms OR low-income countries)
62. Gender and access to assets to aquaculture resources
63. Gender and division of labor in aquaculture
64. Gender and shared benefits in aquaculture
65. Gender and social structure in aquaculture
66. Gender and social norms in aquaculture
67. Gender and participation in aquaculture

Annex 2. Summary of fish/animal feed ingredients by country and feed role

Country	Fish/animal feed type (ingredients)	Fish feed role/status	Sources
Myanmar	• Rice bran • Wheat bran • Peanut oil cake • Sesame oil cake • Cotton seed cake • Mustard oil cake	Commonly and widely used	CGIAR 2018.
	• Soybean meal • Fishmeal • Rapeseed meal • Corn gluten meal • Feather meal • Fish oil • Premix	Supplementary feed ingredients	
India	Neem seed cake	Alternative feed	Daniel 2016.
Bangladesh	Use of potato	Alternative (cost-effective)	Akter et al. 2019.
	Rice bran	Commonly and widely used	
	Mustard oil cake Soybean oil cake Wheat bran	Commonly used and low-cost feed ingredients	Bhuyain et al. 2019
Tropical countries	Palm kernel meal (by-product of palm oil processing)	Potential for milkfish feed	Zulfahmi et al. 2019.
Review/setting not specified	Distillers' dried grain solubles, brewery waste, ghee residue agricultural plant materials: • Leucaena leucocephala (Subabul) • Samanea saman (Raintree pod) • Moringa oleifera (Drumstick) • Manihot esculenta (Cassava)	Potential of new feed ingredients used as supplementary feed ingredients	Singh et al. 2018.
Review/setting not specified	Terrestrial plant leaves: turi, drumstick, ipil-ipil, alfalfa mulberry, sweet potato, cassava, cucumber, squash, broad bean, papaya, white cowpea, green mung bean, jackfruit, Mexican fire plant, cocoyam, blackjack, banana, akee Aquatic plant leaves: water hyacinth, azolla, duckweeds, water lettuce, Indian stargrass, white snowflake, duck lettuce, bur-reed, water fern	Possible alternative feed	Dorothy et al. 2018.

Country	Fish/animal feed type (ingredients)	Fish feed role/status	Sources
Indonesia	Chicken feathers (quill)	Alternative fish feed ingredients	Jumini 2017.
India	Poultry viscera	Potential feed	Bhaskar et al. 2015.
Egypt	Soybean meal Fishmeal	Main protein sources (locally available)	El-Sayed et al. 2015.
Sri Lanka	Papaya peel	Low-cost feed	Rodrigo and Perera 2018.
Northeast India	Agro-based wastes	Low-cost feed	Das et al. 2016.
Nepal	• Fishmeal • Crop grain • Blood and innards of poultry and animal • Kitchen leftovers • Maize powder	Supplementary fish feeds	Bhandari et al. 2019a.
Nepal	• Rice bran • Mustard oil cake mixture	Commonly used fish feed ingredients	Bharathi et al. 2019.
Pakistan	Non-conventional plant sources: • Bermuda grass • Nursery grass (sages) • Typha • Maize spike	Low-cost feed	Sahito et al. 2015.
Nigeria	Cassava	Affordable fish feed ingredient	Fayose and Ogunlowo 2015.
Nigeria	Cassava peels	Potential fish feed	Okike et al. 2015.
China	Trash fish	Alternative fish feed ingredient	Mo et al. 2018.
China	Food waste: • Herbivores (grass carp) • Omnivores (grey mullet)	Alternative fish feed	Wong et al. 2016.
India	Soybean (*Glycine max*)	Alternative ingredients	Bhosale et al. 2010.
A review, context not defined	Earthworm (*Eisenia fetida*)	Alternative protein source	Musyoka et al. 2019.

Annex 3. Studies on potential social and gender risks associated with fish feeds in low-income countries

Key search terms	Fish/feed ingredient	Potential social and gender risks	Setting	Target group	Sources
Gender norms AND fish feed low-income countries	• It does not focus on any fish feeds or ingredients, rather it gives an overview of gender in aquaculture in a market-led program	• Limited participation of women in aquaculture • Inadequate access to quality fingerlings and fish feeds • Inadequate capital to invest in commercial aquaculture • Low levels of skills and knowledge aquaculture	Kenya	Both men and women	FarmAfrica 2016. Kiumbuku et al. 2013.
Women, feed ingredients, risk and livelihoods	• No specific fish feed or ingredients mentioned	• Limits women's equal engagement and returns • Gender inequity on value chain performance	A review, context not defined	Both men and women	Kruijssen et al. 2018.
Fish feed ingredients AND women's livelihood	• No specific fish feed or ingredients mentioned	• Major differences in the levels of participation • Division of labor • Access to and control over resources • Benefits from aquaculture • Levels of decision-making power	Bangladesh	Both men and women	Kruijssen et al. 2016b.
Gender norms AND fish feed low-income countries	• No fish feed ingredients discussed	• Limited decision-making power • Reciprocal and iterative relationship with norms and innovation. The report provides insights on how interactions between gender norms, agency and other contextual factors shape access to, adoption of and benefits from agricultural innovations in aquaculture in Bangladesh and the Philippines	Bangladesh and the Philippines	Both men and women	Aregu et al. 2018b.
Fish feeds and equity	• Mustard oil cake, rice bran, rice, banana leaves, corn meal, pellet feed, pig manure and wheat bran	• Limited availability and access to fingerlings • Costly transportation • Fish losses due to bird predation and diseases	Nepal	Women	Farquhar et al. 2019.
Fish feeds and equity	• No fish feed ingredients mentioned • The main focus is on gender roles in fish farming and the importance of involving women in aquaculture	• Male-dominated	Bangladesh	Women	Rahman et al. 2019.

Key search terms	Fish/feed ingredient	Potential social and gender risks	Setting	Target group	Sources
Social and gender risk analysis and fish feeds	• No fish feed ingredients mentioned • The main focus is on legal frameworks and policies that can improve aquaculture in Egypt	• Poor legal and policy environment • Limited access to training and credit • Seasonal production cycle • Lack of quality control and inspection • Limited access to agro-advisory services and capacity building opportunities	Egypt	Both men and women	El-Sayed et al. 2015.
Social and gender risk analysis and fish feeds	• No ingredients mentioned • The main focus is on aquaculture or improving family welfare • Opportunities for income generation and improvement of overall socioeconomic conditions of the local actors	• Increase the family income • Family nutrition • Opportunity for self-employment • Uplifted their overall socioeconomic condition	Bangladesh	Women	Farquhar et al. 2019.
Fish feed ingredients AND smallholder's well-being low-income countries	• No fish feed and ingredients mentioned • The article focuses on the Women in Aquaculture fish farming project, which targeted women with migrant husbands in Nepal	• Community empowerment • Fight against malnutrition • Food and nutrition security • Economic empowerment • Self-confidence and enhanced sense of community	Nepal	Women	Farquhar et al. 2019.
Gender norms AND fish feed low-income countries	• Gendered comparison of knowledge attitudes and practices in poultry and fish farming, and the use of insects as alternative feeds for fish and poultry	• Workload on women • Differences in decision-making • Gender knowledge gap • Gender inequality in ownership of land	Kenya	Both men and women	Waithanji et al. 2019.
Fish feed AND/ OR livelihood Africa (Egypt, Nigeria, Zambia)	• Value chain analysis focusing on activities around fish feed manufacturing of pelleted and extruded fish feeds	• Value addition • Employment • Profitability • Improved efficiency of feed mills	Egypt	Both men and women	El-Sayed et al. 2015.

Annex 4. Mapping ingredient studies and methodologies

Sources	Ingredients	Methods	Tools	Contexts	Strengths	Weaknesses	Critiques
Akter et al. 2019.	Potato as a potential alternative plant protein	Quantitative on-station research, experimental design using complete randomized design and treatments	Feed formulation, feeding and sampling on experimental tilapia fry, growth parameters, water quality parameters, glucose tests	Bangladesh	Controlled experiment, rigorous, replicable, enabled use of complex laboratory equipment, less expensive and saves time	Only involves biophysical methods; does not integrate indigenous knowledge of fishers; may rely on generalizations despite the diversity of contexts	Top-down approach that needs context-specific information on participation of farmers and other stakeholders such as extension staff for effective adoption of potato as an alternative plant protein
Bhaskar et al. 2015.	Poultry waste to replace fishmeal	Quantitative laboratory research, experimental design using randomized design and treatments	Collection and storage of samples, proximate composition analysis (moisture, ash, crude proteins and lipids), growth parameters	India	Controlled experiment, rigorous replicability of findings possible if they are found to be significant, enabled use of complex laboratory equipment, less expensive and saves time	Only involves biophysical methods; findings rely on biophysical scientific inferences and may not fit the diversity of contexts for adoption	Top-down approach that needs context-specific participation of farmers and other stakeholders such as extension staff for effective adoption of poultry waste as an ingredient
Daniel et al. 2016.	Microalgae as a fish feed ingredient	Qualitative	Literature review from different sources on the importance of microalgae	No context mentioned	Gives a historical review on use of microalgae as fish feed; this can provide a benchmark for other future studies	Not comprehensive enough and does not explicitly present the methodology used and articles reviewed	A need for more comprehensive literature review on microalgae as a fish feed ingredient
Dorothy et al. 2018.	Plant leaves as potential feed ingredients (terrestrial and aquatic leaf meals)	Qualitative	Literature review of narratives and data from journal articles	No specific context mentioned	Shows a good attempt at highlighting plant leaves as potential ingredients; differentiates between terrestrial and aquatic leaves	The methodology for review is not clear and does not explain the number of articles reviewed and the scope	Clarity in the methodology used is lacking and this is important for future studies that may need to review plant leaves as feed ingredients

Sources	Ingredients	Methods	Tools	Contexts	Strengths	Weaknesses	Critiques
Jumini 2017.	Chicken manure and feathers	Qualitative with some descriptive statistics	Analysis of qualitative data with some descriptive, seminars, workshops and training sessions with community members	Indonesia	Bases implementation of the intervention on situation analysis; participation of the community in the project	Attempts to integrate mixed methods design though it leans more to the qualitative; complementarity of the analyses is weak	Participation of beneficiaries in the project does not show acceptance and ownership by the community as whole
Singh et al. 2018.	Brewery waste, ghee residue, cassava waste, jute, subabul, raintree, spirulina, moringa	Qualitative	Literature review of studies that have evaluated the potential of the aforementioned fish feeds ingredients	India	Categorization of potential non-conventional ingredients for fish feeds; comprehensive review on each of the chemical properties and use of ingredients for fish feed	The methodology for review is not clear and does not explain the number of articles reviewed and the scope	A better and explicit methodology on the review process is needed; the systematic process of the review is not presented
Sissener et al. 2011.	Genetically modified (GM) plants (soybean, Bacillus thuringiensis maize, GM cotton, Roundup Ready canola)	Qualitative	Literature review of limited trials in GM crops	No specific context mentioned	Reveals the scepticism of using GM crops in fish feed; provides details of attempted feed trials; outlines limitations and challenges in fish feed trails with GM plants	The methodology for the review is not clear and does not explain the number of articles reviewed and the scope	A better and explicit methodology on the review process is needed; the systematic process of the review is not presented

Annex 5. Publications reviewed in the final stage of the systematic literature review

Akter et al. 2019.

Aregu et al. 2018b.

Bhandari et al. 2019b.

Bharathi et al. 2019.

Bhaskar et al. 2015.

Bhosale et al. 2010.

Bhuyain et al. 2019.

Daniel 2016.

Daniel et al. 2016.

Das et al. 2016.

Das and Biswas 2019.

Dorothy et al. 2018.

El-Sayed et al. 2015.

FarmAfrica 2016.

Farquhar et al. 2019.

Fayose and Ogunlowo 2015.

Gowsalya and Kumar 2018.

Hajra et al. 2013.

Jumini et al. 2017.

Kim et al. 2019.

Kruijssen et al. 2016b.

Kruijssen et al. 2016c.

Mo et al. 2018.

Monfort 2015b.

Musyoka et al. 2019.

Nunes et al. 2014.

Okike et al. 2015.

Pandey 2013.

Rahman et al. 2019.

Rajaratnam et al. 2016.

Razafindrabe et al. 2019

Rodrigo and Perera 2018.

Sahito et al. 2015.

Sayed et al. 2018.

Singh et al. 2018.

Waithanji et al. 2019.

Weeratunge et al. 2010.

Weeratunge-Starkloff and Pant 2011.

Wong et al. 2016.

Zulfahmi et al. 2019.

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