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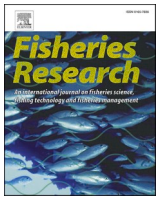

Fish consumption patterns and value chain analysis in north-western Cambodia

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ABSTRACT

This paper aims to understand the fish consumption patterns in northwestern Cambodia and to identify the key challenges in the fisheries value chain, and how to overcome these challenges for the sustainable development of Cambodia's fisheries sector. In Cambodia, fisheries resources are abundant, while value addition to fishery products is limited given that fish is a perishable food product which requires proper handling soon after harvesting. A survey was conducted with various stakeholders like fish wholesalers, retailers, consumers, government officials and processors in Battambang and Siem Reap provinces, in northwestern Cambodia. Nine key challenges within the postharvest fish supply value chain were identified as barriers posing threats to fishery products and limiting the market competitiveness of Cambodian fishery products. Technological issues -i.e. processing, packaging, preservation-, market access and raw fish supply deficiencies accounted for more than 60% of the challenges raised by respondents from the beginning of the supply chain (fishers) to consumers. Consequently, investment in infrastructure development, cost-effective technology and training, innovative solutions on processing techniques (drying, smoking and fermenting), and secure access to markets were recommended to improve the fish supply chain and increase the competitiveness of Cambodian fishery products in domestic and international markets. Further investigation on product diversification, branding and cost-effective innovative processing techniques should be carried out to create opportunities and value addition to Cambodian fishery products. A supportive policy instrument is also necessary for the sustainable growth of Cambodia's fisheries sector.

1. Introduction

The fisheries sector is crucial for economic activity, export earnings and employment in many developing countries, and is also an important source of food for mankind (Costello et al., 2020). Sustainability of the fisheries sector is strongly linked to value chains and postharvest activities (Islam and Habib, 2013; Kruijssen et al., 2018; Porras et al., 2017; Rashid and Sarkar, 2020; Tint et al., 2020; Yihang, 2020), but is often hindered by poor postharvest performance and limited value addition to fishery products, especially in developing countries and small-scale fisheries (SSF). Overcoming these issues is thus essential for improving fisheries value chains and supporting the sustainable development of the fisheries sector.

Value chain analysis is a strategic process which examines each step of the fish supply chain, from raw materials to eventual end user (De Silva, 2011). According to FAO (FAO, 2014), "sustainable food value chains focus on the integration of the multidisciplinary concepts of added value and sustainability, and on the understanding of the governance frameworks where the food system is developed". In this context, fish value chain analysis has been conducted to analyze fisheries management and co-governance systems (Barclay et al., 2017; Rosales et al., 2017; Wentink et al., 2017), and to improve market access (Jacinto and Pomeroy, 2011; Purcell et al., 2017; Pascual-Fernández et al., 2019). In addition, sustainable fish value chain analysis also needs to consider enhancement of employment and income generation opportunities in rural areas, particularly for women (FAO, 2014; Manyungwa et al., 2019).

Small-scale fisheries (SSF) support the livelihoods of millions of

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people, particularly in low-income countries (Béné et al., 2010), but several factors such as climate change, habitat destruction, and over-fishing threaten productivity (FAO, 2022). Several studies aimed to ascertain the impacts of climate change on the fish value chain, and how to increase resilience capacities of small- scale fishing communities (Kimani et al., 2020; Timmers, 2012; Fleming et al., 2014; Galappaththi et al., 2021). The impact of uncertain events like COVID-19 has also drawn much attention in recent fisheries value chain research (Bassett et al., 2022; Belton et al., 2021).

SSF value chains include many actors and involve various activities like gear making; capture, sorting, cleaning, and processing of fish; transport, marketing and selling of fish; and consumption of fresh fish and fish products (FAO, 2020). In SSF value chains many tasks are done manually, often using low-cost technologies in handling and processing fish. Challenges for sustainable management of SSF value chains include limited postharvest related facilities and infrastructure, lack of fish product quality control and certification systems, scarcity of fish for processing, lack of training facilities and poor fisheries governance systems (Jacinto and Pomeroy, 2011; Kimani et al., 2020; Rosales et al., 2017; Galappaththi et al., 2021). Sustainable postharvest technology could improve several aspects of fish and fishery products production, such as optimizing limited resources, developing value-added products, upgrading the fish processing industry, improving small-scale handling and processing knowledge, and development of new products (Ahmed, 2008; Heng and Eong, 2007).

Currently, poor postharvest activities contribute to fish losses, which represents 35% of the yearly global fish harvest (FAO, 2020). Improving postharvest activities would help directly address some of the recognized causes of fish losses, such as inadequate ice, poor handling, processing of fish during and after harvesting and extended stay (Gyan et al., 2020). To avoid these problems, fishers and fish workers need to improve their skills and to use better tools and technologies (FAO, 2020). While fish production in Southeast Asia contributed 21.9% of global fish production in 2018, postharvest loss in these countries is substantial. For example, aquaculture in Bangladesh recorded 3.14–6.36% postharvest loss (Rashid and Sarkar, 2020), whereas in the state of Tamil Nadu, India, postharvest losses were estimated to be around 15% of marine capture fisheries (Sivagnanam, 2016). However, in many countries data on postharvest loss is unavailable (Ngin, 2019).

Addressing postharvest losses has substantial biodiversity and socio-economic benefits, thereby raising the need to increase our understanding about fisheries value chains. The objectives of this research are thus to understand fish consumption patterns and map of fisheries value chains in northwestern Cambodia. This study also aims to identify the challenges within the fish value chain and the possible strategies to overcome those challenges to gain enhanced value. We carried out an empirical study in northwestern Cambodia (Battambang and Siem Reap provinces) to analyze various issues associated with the Cambodian fish value chain. The main topics studied were diversity of fishery products, consumers' preferences, fish prices, value chain actors and stakeholders, current postharvest activities, processing techniques and challenges, and policies needed to reduce postharvest loss and to increase value addition in the fishery supply chain.

Our results show that Cambodia has a wide variety of fishery products available, but these products have little added value and are sometimes of poor quality. We identify nine challenges within the postharvest sector, of which technological and market issues, and raw fish supply deficiencies are the most prominent. To overcome these problems, we propose strategies focused on infrastructure development, cost-effective technology, training, innovative solutions on processing techniques, product diversification, access to markets and strengthening the linkage of actors in the fish supply chain. These insights can be a baseline for further investigation in the value chain and be applied to similar systems worldwide, potentially leading to more sustainable management practices in the fisheries sector.

2. Material and methods

2.1. Study case: northwestern Cambodia

Cambodia is a fast growing economy with a complex and dynamic hydrological system that allows it to develop a very productive fisheries sector (Chea et al., 2017). This sector is mainly developed in inland waters, making Cambodia the world's fifth largest inland capture fisheries producer (FAO, 2020). In 2018, total annual fish production was 910,153 tons, with inland capture fisheries accounting for 59%, followed by aquaculture (28%) and marine capture fisheries (13%) (FIA, 2018). SSF are especially important as they contribute more than 60% of inland fish production (Baran and Gallego, 2015; FIA, 2018; Bann and Lieng, 2020). Cambodian freshwater fisheries also stand out for having a high diversity of species, -approximately 500 species of fishes and other aquatic animals (OAAs)-, and is listed among the top 10 countries worldwide with the highest freshwater fish diversity (So et al., 2014).

Fisheries play an important role in the Cambodian economy (MAFF, 2016) and provide the primary protein source for human consumption. The national census of 2008 reported that 64% of all rural households (over 7 million people) were engaged in full and part-time fishing activities, with a total economic value of 1 billion USD per year (FAO, 2010). Fish and fisheries contribute 76% of total animal protein intake for daily consumption, 12% of energy intake and 37% of iron intake in Cambodia (Vilain et al., 2016). However, the country faces very high risk from climate change, and the significant negative effect of climate change on fish stocks and catches may create high social and economic vulnerability (Teh et al., 2019; FAO, 2020). These conditions can be exacerbated by the lack of access to local and international markets and by trade inefficiencies and high transaction costs along the domestic value chain (Van Brakel and Ross, 2011). Processing is another challenge for the sector as many of the traditional techniques that produce fermented fish -e.g., *prahok, phaork, mom, nem* (LeGrand et al., 2020; Norng et al., 2011)-, dried-salted fish, smoked fish, and fish sauce, are not modernized, e.g. canning, and back-slopping fermentation. Thus, most processed products are consumed domestically, with only a small proportion of higher-valued, unprocessed fish being exported mainly to markets in Southeast Asia, particularly to Thailand and Vietnam, where packaging and processing technology are more advanced.

Battambang and Siem Reap provinces are the largest northwestern provinces of Cambodia. These provinces are known for their abundant fish and fishery resources (both in fresh and processed forms) and are important landing sites for freshwater fish derived from artisanal fishery activities. These two provinces are located at the north of the Tonle Sap Great Lake (TSGL), which is the heart of the Mekong River Basin (MRB) and the largest inland indiscriminate fishery in Southeast Asia. Accordingly, Battambang and Siem Reap are highly dependent on fish, and are among the most productive fishery provinces in Cambodia (Nasielski et al., 2013; Samsen and Chanboreth, 2006). At the same time, these two provinces, especially Siem Reap, also receive a significant quantity of imported fish from neighboring countries (Joffre et al., 2019). Models from Battambang and Siem Reap provinces can be applied to other provinces around the Tonle Sap Lake, as well as to other areas in Cambodia and the Mekong Region, for food security and sustainable economic development in response to rapid global change.

2.2. Data collection and survey methodology

Data used in this study were derived both from direct observations at fish markets and from a survey administered to different actors involved in the fish value chain (fish distributors, market sellers, processors, household consumers, restaurant owners, and governmental officials). Before starting the survey, an extensive literature review on fisheries resources and value chains in Cambodia and within the Mekong region, where Cambodia is one of the four riparian countries, was performed in order to: i) analyze the current state of the region's fisheries value chain,

processing technology, postharvest issues and other challenges and opportunities in the fishery sector; and ii) identify key actors and stakeholders in the fish value chain. We developed three sets of questionnaires for the following actors: (i) sellers of fish and fishery products and fish processors (wet markets, fish distribution centers, supermarkets, processors); (ii) consumers of fish and fishery products (e.g. restaurants and households); (iii) fishery sector policy makers (provincial governments) (Table 1).

The first questionnaire collected necessary information from fish sellers and processors on basic statistics of fish and fishery products such as quantity of fish sold, diversity of fish, selling prices, origin of product suppliers, species, form of selling, selling quantity, shelf life, popular species/products, processing techniques, problems and need of processors. The second questionnaire collected information from household consumers and restaurant operators on consumption preferences for fish and fishery products (quantity of consumption, type of products, frequency, food preference). The third questionnaire for policy makers aimed to understand the current statistics on inland capture fisheries, the situation of small and medium-sized enterprises (SMEs) in the fishery sector, challenges faced by consumers and processors, policy priorities in the next five years and legal frameworks to support the fish value chain.

Prior to administering the survey, both consumer and sellers' questionnaires were tested at the fish markets in Battambang city, after which some adjustments were made to improve the clarity and relevance of the questions to the research objectives. These questionnaires were then used to guide structured interviews with the respondents. Before starting the interview, the enumerator explained clearly the purpose of the interview and ensured the confidentiality of the respondents' responses. The questionnaires contained mostly open-ended questions to allow respondents to express their ideas or information, while the enumerator encouraged the respondents to provide unbiased answers based on their opinions and knowledge (Appendix A).

The survey was conducted in August 2020 by five graduate students and three researchers from the Laboratory of Freshwater Ecology of the National University of Battambang's (NUBB) research group. It started with investigations at supermarkets and wet markets on fish and fishery resources/products available at these markets, followed by interviews with local food processors to gather specific information on postharvest processing technology challenges and opportunities. The market investigation was composed of direct market observations and interviews with sellers. During market observations, the research team recorded the number of fish species, quantified the amount of fish sold and took a picture of the species. The fish species were identified to species level during the survey by the research team and verified at the laboratory for certain unclear species. The interviewees/respondents were classified into 7 groups based on their roles in the fish value chain, i.e., wet market sellers, supermarket sellers, fish distributors, home based producers/processors, restaurant owners, household consumers, and policy makers.

In total, six important wet markets at both study sites were surveyed. We conducted all surveys very early in the morning so that we could encounter the full range of diversity and abundance of fish and fishery products, and interview the key actors in the fish supply chain (fisher/retailers, middlemen, wholesalers). The wet market survey was conducted in two steps; first, market observations were conducted by the research team to obtain an overview of both diversity and quantity of fish and fishery products available. During these observations, the research team recorded the diversity of fish, fishery products, filled the observation form and took some pictures of fish and fishery products. Then the research team classified and selected on the ground fish sellers based on the variety of fish and fishery products they sold (freshwater or marine fishery, diversity of fish species, other aquatic animals (OAAs)), and the fish sellers' sales volume (number of fish tanks, area of selling ground, diversity of fishery products). The sellers were asked and confirmed whether they were retailers, middlemen or wholesalers before the interview. From market observation, fish retailers' sales volume varied within 50 kg per day, while middlemen could go up to 500 kg per day and wholesalers could sell more than 500 kg per day. However, the selling quantity varied greatly depending on the seasons, with higher sales during the peak season in December and January.

Once the sellers were identified and accepted for the interview, the second step involved interviewing the sellers, which normally took 30 min to complete. At each market, we aimed to interview at least 10% of respondents (2–3 respondents) from each actor group in the fish supply chain, i.e. retailers, middlemen, and wholesalers. Several fish sellers declined to be interviewed due to their availability, particularly the wholesalers. At least eight to nine respondents (~10% of fish sellers) were recorded in each market; we managed to interview more fish sellers in Battambang than in Siem Reap because we had more opportunities to visit wet markets there.

The processors were identified based on the guidance from the provincial Department of Industry, Science, Technology & Innovation and from visiting fish processing markets in Battambang and Siem Reap. More focus was given to processors of products important for daily consumption and trading, such as dried fish, smoked fish, salted fish, fermented fish *(prahok)*, and fish sauce. Approximately half of the processors were recommended by the Department of Industry, Science, Technology & Innovation, which provided either contacts or locations of different types of fishery product processors. The rest of the processors

Table 1
List of information collected at key locations and number of respondents. Questionnaires (i, ii & iii) referred to the survey instruments for the respective types of respondents (Appendix A).

	Types of respondents						
	Questionnaire (i)				Questionnaire (ii)		Questionnaire (iii)
Key information collected	Fish distributor	Supermarket	Wet market sellers	Processors	Household consumers	Restaurant owners	Government official
Selling price	✔	✔	✔	✔	✔	✔	
Origin (local, import, aquaculture)	✔	✔	✔	✔	✔	✔	
Supplier	✔	✔	✔	✔	✔	✔	
Species	✔	✔	✔	✔	✔	✔	
Form (live fish, chilled, processed, frozen)	✔		✔	✔	✔	✔	
Selling quantity	✔	✔	✔	✔		✔	
Popular species/product	✔	✔	✔	✔			
Shelf life		✔	✔	✔			
Detail of processing		✔	✔	✔			
Problems and needs of processor (technology, cost, market)				✔	✔	✔	✔
Potential needs, planning/ opportunities							✔
Number of respondents	**5**	**3**	**49**	**29**	**38** (30 online survey)	**10**	**4**

were identified on the ground during visits to fish processing markets at both locations. Due to time constraints and the COVID-19 situation, we tried to interview at least 3 processors of the same type of product in both locations, e.g. 3 dried fish processors, 3 smoked fish processors, etc. The interviews were based on the availability and willingness of processors to answer the survey. All processors were micro (<10 employees) or small scale processors (11 – 50 employees), or home based producers. Processors of all major product types were selected for the survey in order to reflect the key processors that are connected with the fish sellers in the value chain.

We surveyed personnel from the following government institutions: the Fishery Department (fishery cantonment) of the Fishery Administration (FiA) of Cambodia and the provincial Department of Industry, Science, Technology & Innovation, as they are the primary institutions directly involved in the fish value chain. The Fishery Department regulates the capture and primary processing of fishery products, while the provincial Department of Industry, Science, Technology & Innovation regulates the rest of the value chain, including processors' registration, inspection on processing techniques, food safety control, marketing, product certification, and policy development.

Questionnaire (i) was used to collect information from wet market sellers, processors and supermarket sellers and fish distribution centers. Questionnaire (ii) was used for household consumers and restaurant owners. Questionnaire (iii) was used specifically for government institutions. In addition to questionnaire (i), the market observation list (Appendix A) was used for direct observation during market surveys at wet markets and supermarkets. Detailed survey instruments are provided in Appendix A. For the consumer survey (questionnaire (ii)), household consumers and restaurant owners in both study sites were selected based on their availability and willingness to answer the questionnaire and be interviewed face to face (10 restaurant owners and 8 household consumers). However, because of the COVID-19 pandemic, most households around the wet markets declined to answer the survey. Thus, an online survey was conducted to gather more input from household consumers. The online questionnaire, which involved voluntary participation, was only administered in Battambang, where it was circulated in graduate student's groups (86 students) at the National University of Battambang (NUBB). To ensure the accuracy of answers, some respondents were called to interview for certain questions or to clarify the answers.

In total, a hundred thirty-eight (138) respondents were interviewed in Battambang and Siem Reap provinces, 35% (49 respondents) from wet markets, 28% (38) from households, 21% (29) from processors, 7% (10) from restaurant owners, 4% (5) from fish distribution centers, 3% (4) from policy makers (government) and 2% (3) from supermarkets (Table 1). We only kept the surveys with completed answers for the study, and excluded those with less than 50% completed answers. This resulted in the removal of six surveys from the study.

2.3. Data analyses

Basic descriptive statistics were provided to describe the fishery resources and the fish supply chain in northwestern Cambodia, while analyzing the market price of fishery products according to the type and origin of products at both survey locations (Battambang and Siem Reap). To investigate the challenges and opportunities in Cambodia's fish value chain, information from the surveys was used to develop a schematic diagram of the fish value chain. Further, a synthetic table was established to summarize key information on actors involved in the fish value chain, challenges and possible improvement strategies for postharvest activities.

3. Results

Fish market survey results from Siem Reap and Battambang provinces were grouped into three main categories: 1) Description of the status and situation of fish and fishery resources in northwestern Cambodia; 2) Analysis of the fish supply value chain; and 3) Identification of problems and potential solutions for the value chain postharvest activities and competitiveness of fish and fishery products in Cambodia(Fig. 1).

3.1. Status and situation of fish and fishery resources in northwestern Cambodia

Observations and surveys at wet markets in Battambang and Siem Reap recorded more than 37 freshwater fish species belonging to 23 fish families and 11 fish orders. Diversity of fishery resources (freshwater fish and OAAs) in Battambang was higher than in Siem Reap (species richness, i.e. the number of species per location, 22 in Battambang vs. 15 in Siem Reap). In both markets combined, carp fish from Cypriniformes, perch-like fish from Perciformes and catfish from Siluriformes were the dominant fish orders, accounting for more than 85% of the total fish species sold in the wet markets in both locations. Specifically, snakehead fish (*Channa* spp.), stripe catfish (*Pangasianodon hypophthalmus*), walking catfish (*Clarias* spp.), gourami (*Trochopodus* spp.), tilapia (*Oreochromis niloticus*) and other small fish species (*Rasbora* spp., *Parachela* spp., *Phalacronema* spp.) were the economically important fish species and primary species for daily local consumption (Fig. 2).

From the fish market surveys, freshwater fish species accounted for 79% of total daily sold products, while marine fish and OAA species accounted for 6% and 15%, respectively (Fig. 3a). In this sense, OAAs seem to play an important role in peoples' daily diet, as an important quantity of mollusk, crustacean and snakes were observed in the wet markets. Most of the fish and fishery products in wet markets, especially marine fish and OAAs such as squids, shrimps, and crabs, were sold in fresh or fresh with ice forms (63%), while the rest were processed and mainly sold as dried fish (11%), smoked (5%) and salted products (8%) and *prahok* (fermented fish paste) (7%), which are the most common traditionally processed fishery products in Cambodia (Fig. 3b).

One hundred thirty-six (136) processed fish and fishery product types were recorded from the wet markets, of which local and imported products accounted for 75% and 23%, respectively, while the remaining 2% came from unidentified sources. The majority of imported products came from neighboring countries, i.e., Thailand (60%) and Vietnam (10%); walking catfish, snakehead and tilapia were the most common imported species. These fish species were also the most popular aquaculture species in Battambang and Siem Reap.

Many *Phalacronema* fish species were kept for smoking, while gouramis were processed as salty form (considered as a luxurious product). Moreover, most of the small fish were processed into fermented salty fish (*Phaork*), and the thicklip barb (*Probarbus* spp.) was also used for fermented fish ball (*nem*) production since it is cheap and easily processed. Most processed freshwater fish species were small cyprinid species (*Henicorhynchus* spp.), which are caught in huge amounts during their annual migration from the Tonle Sap Lake to the Mekong River (Fig. 2).

Supermarket observations recorded 77 fish and fishery related products, out of which 42% were processed fish and fishery products (both freshwater and marine fish), 40% were unprocessed marine fishery related products, and 18% were unprocessed freshwater fish (Fig. 3c). Five main package forms were observed in the supermarkets, with the majority of fish and fishery products found in frozen plastic bags (36%), followed by plastic bags (26%), plates (21%), cans (12%) and bottles (5%) (Fig. 3d).

The survey of households and restaurants recorded more than 50 types of fish and fishery related foods from restaurant menus. Snakehead fish was the most consumed species (31%), followed by the bronze leatherback (15%) and butter catfish (15%), marine fish (8%), squid (8%), and shrimp (8%) (Fig. 4a). Fish and fishery related foods represented about 45% of food types in restaurants. The survey of household consumers recorded that household consumers preferred unprocessed and processed fish approximately equally. Salted fish, dried fish, smoked

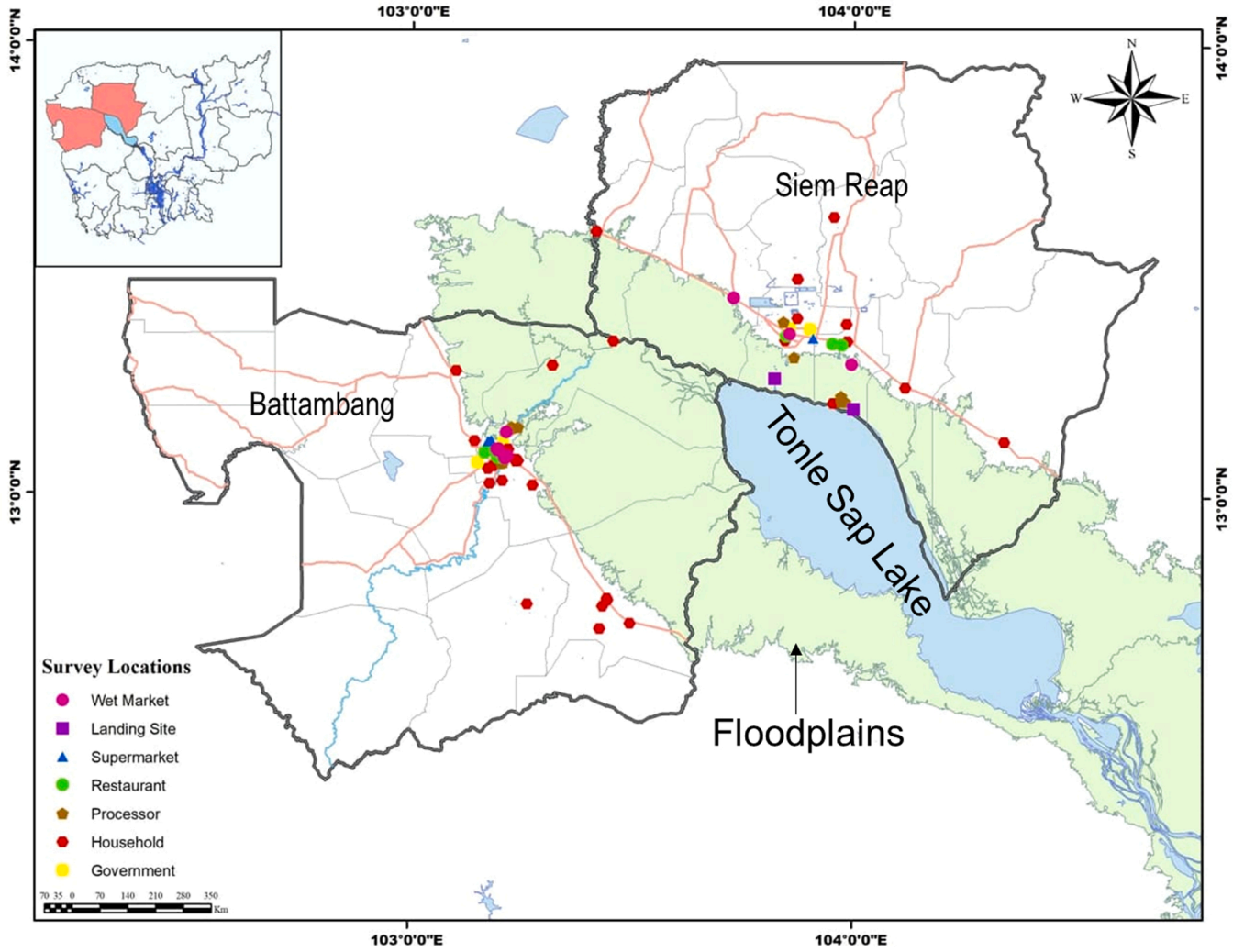

Fig. 1. Distribution of survey locations with different categories of respondents (fish market sellers, restaurant owners, supermarkets, processors, fish distributors, government officials and household consumers) in Battambang and Siem Reap provinces. The inset map (top left corner) shows Cambodia, with Battambang and Siem Reap shaded in pink.

fish, and fermented fish (*prahok)* were the four most consumed processed forms, representing 22%, 11%, 6%, and 3%, respectively, of daily fish consumption in northwestern Cambodia (Fig. 4b). The percentage of *prahok* consumption was quite low compared to daily observation; however, the result illustrated the consumption of *prahok* as main dishes, not as ingredients.

Fish market price analysis showed a significant amount of value added to processed fish and fishery related products compared to fresh form products; this comparison was made based on the average price of all types of fresh products compared to the processed ones (Fig. 5a). The average price of fresh fish was computed at 4.36 USD compared to 7 USD, the average price of processed fishery products. Thus, the minimum value added to processed products was estimated to be 1.6 times the price of fresh sold products. Besides, imported products tended to be cheaper than the local products (Fig. 5b).

3.2. Fish supply value chain in northwestern Cambodia

A preliminary schematic diagram illustrating the steps and actors involved in the fish supply value chain is presented in Fig. 6. The value chain starts from input suppliers (fish and fishery resources) and ends with domestic and international consumers. The Cambodian fish value chain is complex and multi-functional with a huge variability of products, seasonal variation in supply and demand, different type and sources of suppliers, roles and responsibilities of actors in the value chain. Each actor's position along the chain can vary and their boundaries are often blurred or overlapping. The actors along the chain interact with each other, and five main actors were defined based on the survey and field observations, i.e. (1) input suppliers, (2) collectors/wholesalers, (3) processors, (4) exporters/traders and (5) consumers. The classification of the different actors was defined based on their functions in the value chain (Fig. 6).

Input suppliers include fishers, local fish farmers and fish importers, who are the sources of fish and fishery products. Collectors collect and purchase fish from fishers, local fish famers or import and bring the fish to landing sites or fish distribution centers, and set prices with fishers depending on fish quality, supply and market demand. Collectors have their own capital for immediate cash payment to fishers and often provide credit to small-scale fishers. Wholesalers act as fish distributors by purchasing fish and fishery products and OAAs from fishers, collectors or middlemen, and re-sell the fish to retailers or other consumers, while retailers buy the fish from wholesalers, processors, or others and then re-sell in markets to consumers. Processors include home based and commercial processors who purchase fish and fishery products from fishers, collectors, wholesalers, and/or retailers and process these products into secondary or tertiary products such as fermented fish paste (*prahok*), fermented salty fish (*nem*), salted-dried fish and smoked fish. Products are then usually sold to domestic consumers, retailers and/or

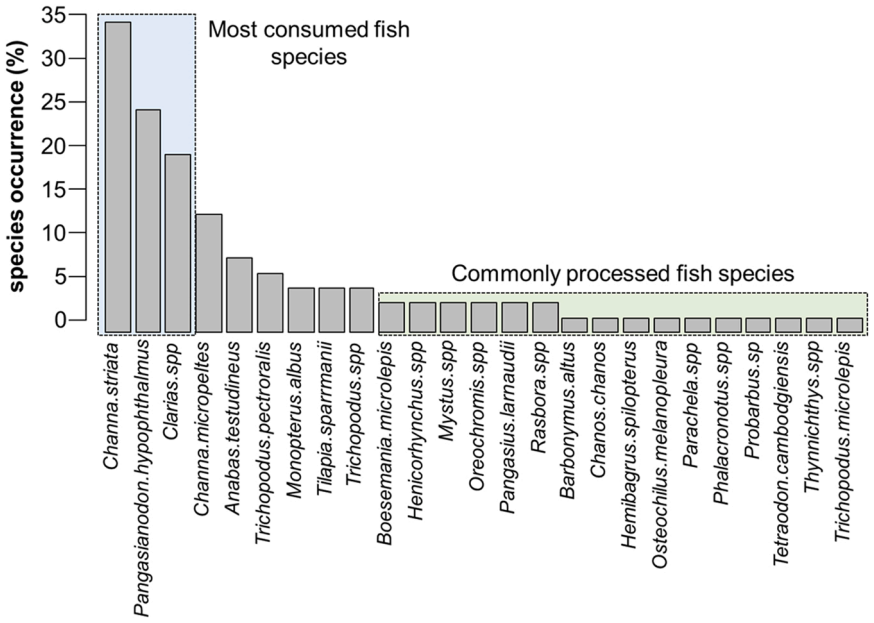

Fig. 2. Occurrences of the economically important fish species in percentages recorded from the markets in both locations (Battambang and Siem Reap) showing the local consumption preference both as fresh products or processed products.

wholesalers, or exported to international consumers.

Other actors such as the Ministry of Agriculture, Forestry and Fisheries (MAFF), Ministry of Industry, Science, Technology and Innovation (MISTI), Ministry of Commerce (MOC), local authorities (provincial government), Non-Governmental Organizations (NGOs), universities, private sector and financing agencies also play an important role in the fish supply chain by providing technical and financial support in each step of the supply chain and monitoring quality and food safety of operations. Production and collection steps are regulated by the MAFF, while processing is regulated by MISTI in line with the MOC for trading and consumption of fish and fishery products. Universities also play an essential role in knowledge and technology transfer to the fisheries sector in order to improve the quality and competitiveness of fish and fishery products at national and international markets.

3.3. Postharvest challenges in fisheries value chain

Stakeholders reported nine main categories of challenges as barriers to fishery postharvest development in northwestern Cambodia. Processing technology issues, marketing issues, and shortage of fishery resources were the most important challenges identified by respondents, and accounted for 26.4%, 19.0% and 18.2% of all challenges raised, respectively (Table 2). Processing technology issues encompassed a wide array of processing techniques in the production line such as preservation, drying, packaging, and storage techniques; preservation and drying techniques were reported to be the most important challenges faced by processors. Additionally, technical knowledge and skills on label design and product quality control (nutrition, odors and colors) were highlighted as constraints in postharvest development. Marketing issues referred to the challenges of fishery products' access to domestic and international markets because of market segmentation, price competitiveness and knowledge and means of marketing strategies. Shortage in fishery resources, defined as fluctuations in raw fish supply, was the third key challenge affecting the postharvest production line. Indeed, inland capture fisheries and local aquaculture production fluctuate seasonally, with a huge quantity of fish being captured in the rainy season while fish catch drops dramatically in the dry season.

Declining wild fish stocks, quality control and food safety, fish meat quality and production costs were reported as key postharvest development challenges and accounted for 28.5% of respondents' answers (Table 2). Declining wild fish stocks from natural systems (Tonle Sap Lake, tributaries and rice fields) result from multiple stressors driven by human activities. For instance, the shift of rice cultivation techniques in Tonle Sap floodplains, illegal fishing activities, pollution, overharvesting, hydropower development and climate change have contributed to depleting wild fish stocks. Food safety and quality control were also constraints in postharvest development, as processors had limited knowledge on food safety and hygiene, with inadequate means and facilities to ensure proper food safety and waste management in the production line. High production cost was one of the key barriers lowering competitiveness and opportunities for Cambodian fishery products in domestic and international markets. Lack of support from domestic consumers and limited number of experts in the related fields of fishery and food sciences were raised as additional challenges (2.3% of answers) slowing down development of the fishery sector (Table 2). About 5.7% of respondents were not aware of any specific challenges facing postharvest development.

For a more detailed analysis of the processors' survey, we grouped the 64 responses from 29 processors into seven categories of challenges (Fig. 7). Among processors, processing technology issues were the most frequently cited challenges (33% of responses), followed by marketing issues (29%) and production cost (14%) (Fig. 7). Specifically, within the processing technology issues, insufficient processing and drying technical knowledge were the most important problems recognized, followed by packaging technology and product certification and standards (Fig. 8a). Knowledge on modern processing technology was somewhat limited, as most of the processors applied their traditional techniques which generally lacked control over food safety hazards. Marketing issues were among the most important constraints limiting opportunities for fishery products in markets (Fig. 8b). This included the fluctuation of local market demand and prices, market segments and selling techniques; consequently, most processors failed to expand their market beyond their regular buyers, who further distribute the product to local consumers. More importantly, uncertified imported products from Vietnam or Thailand were reported to be cheaper than local Cambodian products due to lower production costs (Fig. 8b). Indeed, production cost was perceived by the processors to be relatively high compared to imported products and linked to many factors such as fluctuation of local fish price, quality control, electricity fees and investment capital (Fig. 8c).

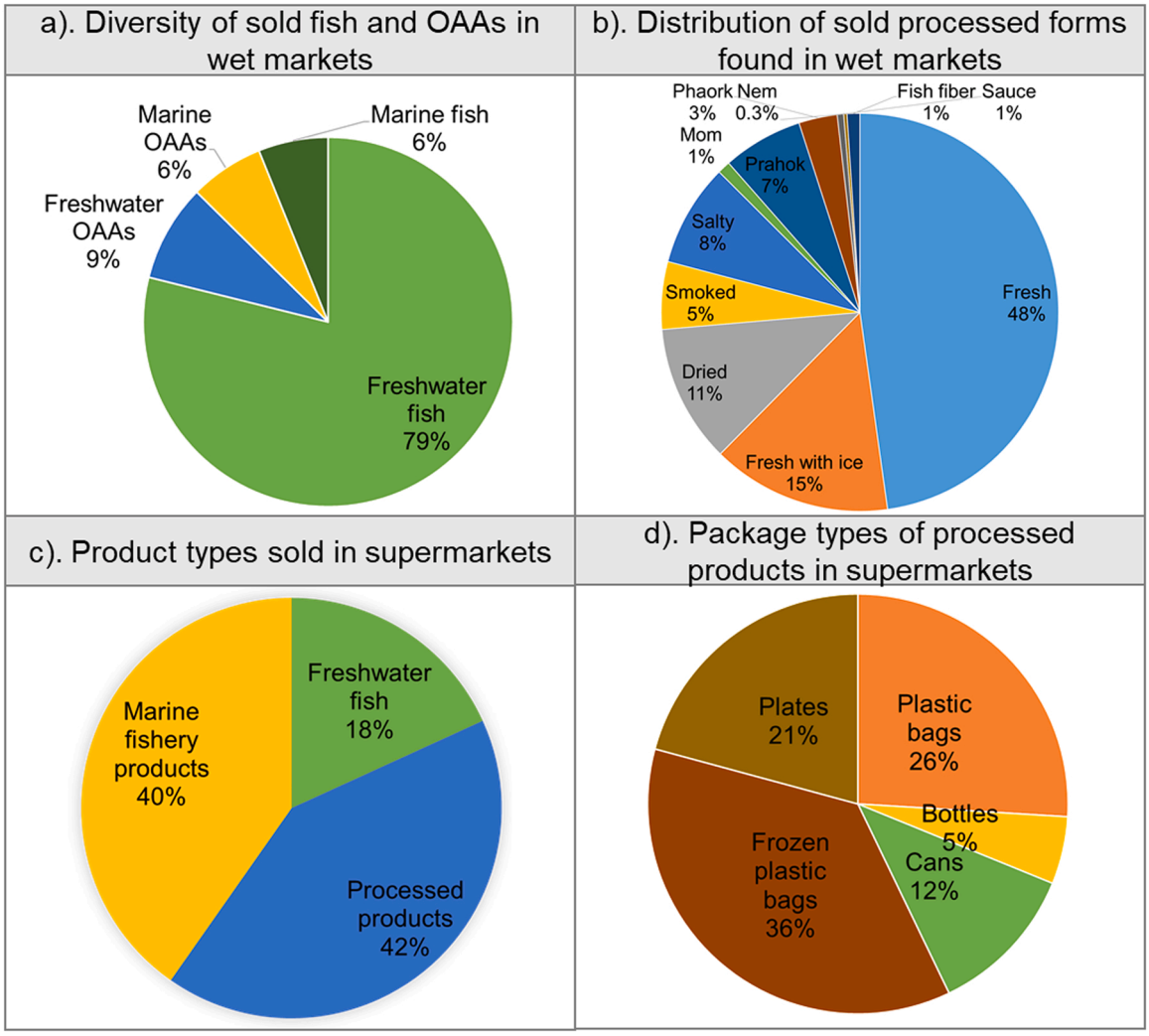

Fig. 3. Diversity and distribution of fish and fishery products and consumption preferences in northwestern Cambodia. (a) diversity of freshwater fish and other aquatic animals (OAAs) diversity sold in wet markets, the percentage was expressed in proportion of the number of recorded fish species and OAAs from the wet market; (b) percentage of different forms of fish and fishery products sold in wet markets (i.e. sold as fresh fish form, fresh with ice or processed forms such as dried form, smoked or salty.etc); (c) distribution of fishery related products as percentage found in supermarkets (freshwater fish, marine fishery products and processed products from freshwater and marine fisheries); (d) type of product's packages (plates, plastic bags, bottles, cans, frozen plastic bag).

Half of the processors' responses related to production costs, showing that investment capital was a main production challenge, while 22% of responses reported high electricity fees as major factors driving the high costs (Fig. 8c). Most processors faced financial constraints to develop their businesses because they tend to be home based (family scale) processors who are exposed to high production costs. Due to their limited financial capital, home based processors buy all packaging materials in small quantities, resulting in higher production costs per unit. Additionally, the cost of quality control is relatively high since all samples must be sent to laboratories located in Phnom Penh for testing. This makes local products, particularly those targeting medium- and low-income consumers, increasingly uncompetitive. Product packaging, which refers mainly to labelling design and information, packaging material selection and technology, also adversely affected the competitiveness of local products. However, according to the survey, local products or local materials seemed to garner more consumer support, and both processors and consumers rated it healthy and sustainable compared to the imported products.

4. Discussion

4.1. Diversity of aquatic resources and consumers' preferences in northwestern Cambodia

This study revealed that Cambodian markets have mainly local freshwater fish products, with limited imported products and marine products. While there was no significant difference between the prices of imported and local products, processed fish and fishery products fetched a higher price than fresh products. Despite this higher value, most fish and fishery products were sold mainly in fresh form, or fresh with ice. Traditional processing plays an important role in the value chain as smoked, dried, salted, and fermented fish were the most popular commodities.

This analysis shows three main findings. First, local and non-processed fresh fish is the main commodity of the fishery sector in northwestern Cambodia. Improvements in the supply chain of local and fresh products, such as improving transportation and hygiene conditions, would have the most immediate and short-term effects on the price of fishery products. Second, prices depend more on whether a product is processed rather than whether it is local or imported. Certificates of origin can be an opportunity for the sector, especially if

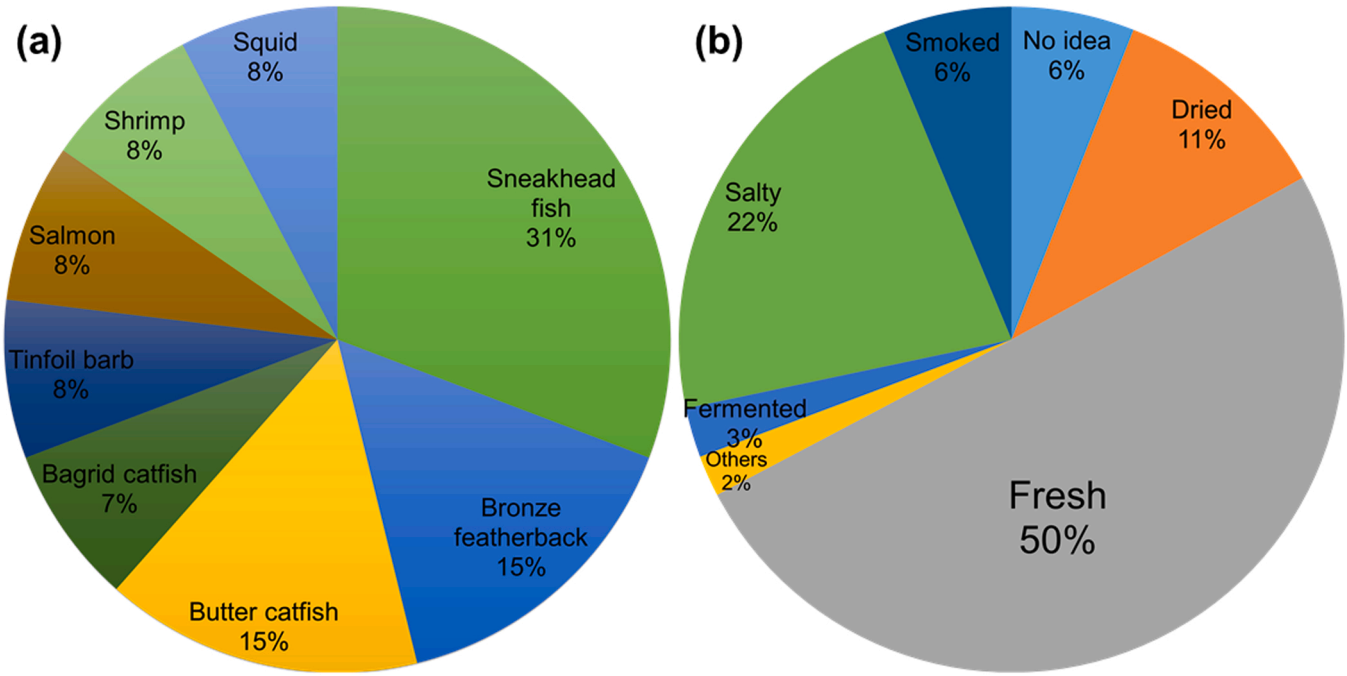

Fig. 4. Consumption preferences of fish and fishery products from consumer survey (households and restaurants) in northwestern Cambodia. (a) The most consumed type of fish species and marine fishery products for daily food consumption; (b) The most consumed forms (fresh form, salty, dried, smoked or fermented) of fish and fishery products for daily food consumption. Percentages in the charts represent the percentage of responses from household consumers and restaurant owners in both locations (Battambang and Siem Reap).

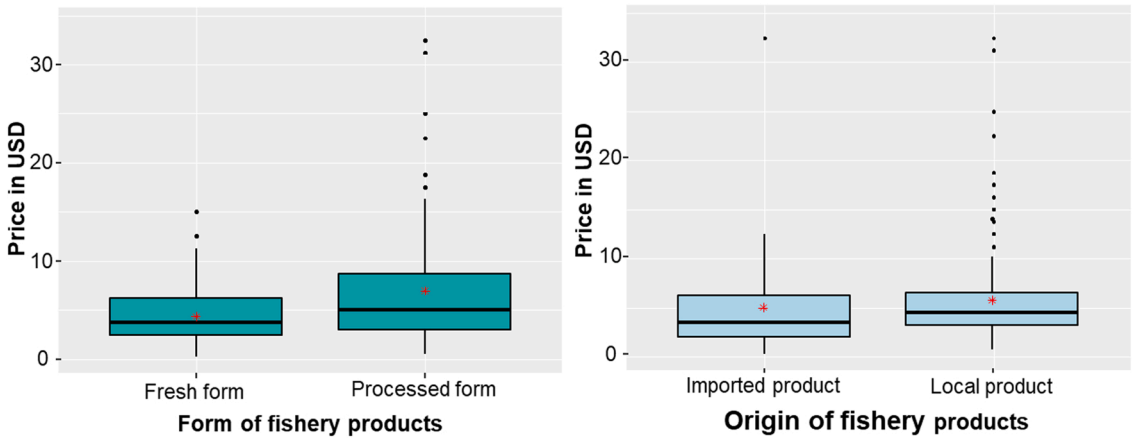

Fig. 5. Market price analysis comparing the price per kilogram of fish and fishery products (a) form of products (fresh vs. processed form) and (b) origin of products (imported vs. local products).

sustainability aspects such as eco-labelling or traceability are included, although these actions are not exempt from challenges (Duggan and Kochen, 2016). Third, the lower presence of processed products in the markets, their higher price and the acceptance of consumers (who appreciate fresh and processed fish equally and are used to consuming smoked, dried, salted, and fermented fish), could be an important market opportunity for processing.

4.2. Actors' roles in the fish supply value chain in northwestern Cambodia

The Cambodian fish supply value chain consists of multiple stakeholders -fishers, fish farmers, intermediaries (wholesalers, distributors), retailers (fish mongers, supermarkets, restaurant), processors, exporters, and importers- who can play different roles. Several governmental agencies and NGOs are also playing a pivotal role.

In this study we see that the input suppliers (including small-scale fishers and local fish farmers) participate in the value chain mainly by selling their product to the collectors, depending to a great extent on them (in some cases even obtaining credit from them). These primary producers do not seem to take advantage of the added value in the other stages of the supply chain. Two actions to focus on would be to improve the bargaining power of small-scale fishers, and improve their access to markets, as highlighted in Target 14.b. of the Agenda 2030 (UN, 2015) and in several case studies (Jacinto and Pomeroy, 2011; Pascual--Fernández et al., 2020; Penca et al., 2021; Said et al., 2020). In this sense, it has been seen that relative to other players in the value chain, small-scale fishers and fish farmers are receiving the smallest economic benefits for their products, while processors and retail markets receive more of the distributional benefits of the value chain owing to their stronger bargaining power (Bailey et al., 2016; Bjorndal et al., 2014; Di Cintio et al., 2022).

Wholesalers and big processors mostly depend on intermediaries for

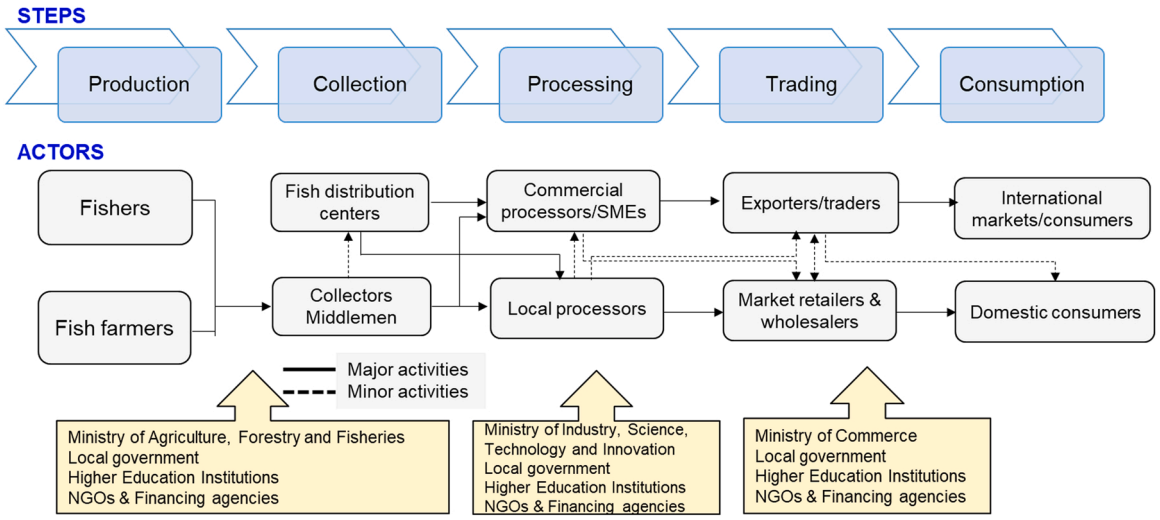

Fig. 6. Fish and fishery product supply chain in northwestern Cambodia.

Table 2
Overall postharvest challenges raised by respondents regarding fish and fishery products in northwestern Cambodia (in percentage). The percentage in the table indicates the average frequency of responses raised by each category of respondent (each respondent identified several challenges and 138 respondents gave 233 responses).

Challenge	Types of respondents							Average Frequency of responses
	Fish distributors	Supermarkets	Wet market sellers	Processors	Household consumers	Restaurant owners	Government officials	
Processing technology issues	16.7	37.5	18.8	33.0	22.6	31.3	25.0	**26.4**
Marketing issue	8.3	25.0	15.9	29.0	17.0	12.5	25.0	**19.0**
Shortage of fishery resources	25.0	0.0	13.0	12.0	39.6	12.5	25.0	**18.2**
Declining wild fish stocks	33.4	0.0	28.9	5.0	1.9	0.0	12.5	**11.7**
Quality control and food safety	8.3	12.5	0.0	3.0	5.7	18.8	0.0	**6.9**
Production cost	0.0	25.0	0.0	14.0	5.7	0.0	0.0	**6.4**
Quality of fish's meat	8.3	0.0	1.4	2.0	0.0	12.5	0.0	**3.5**
Experts in fishery and food	0.0	0.0	0.0	0.0	0.0	0.0	12.5	**1.8**
Local supports	0.0	0.0	0.0	0.0	3.8	0.0	0.0	**0.5**
No idea	0.0	0.0	22.0	2.0	3.7	12.4	0.0	**5.7**
Total number of respondents	5	3	49	29	38	10	4	
Total number of responses by type of respondent	12	8	69	64	56	16	8	

the raw materials, not directly on small-scale fishers. This situation of the Cambodian fishing sector is similar to other neighboring countries and developing countries. At the same time, our survey shows that fish distributors and fish sellers (composed of retailers, middlemen and some wholesalers) consider the declining wild fish stocks as the main barrier to the development of postharvest activities (they also give great importance to raw fish supply chain deficiencies).

Home based processors are also important actors of the Cambodian fish value chain. Even so, wet fish and home processed fish products are associated with high risk and uncertainty because these are highly perishable products. The perishable nature of products necessitates effective marketing channels (FAO, 2014) and economic success of small-scale producers largely depend on market availability, accessibility, and affordability (Antwi and Seahlodi, 2011).

Improving the organization in the fishing sector could improve the positions of some actors and have benefits for the value chain. Collective action initiatives (i.e. fisheries cooperatives and associations) have the potential to help in different aspects such as: i) managing supply; ii) reducing transaction costs; iii) enhancing the negotiating position of small-scale fishers; iv) providing regular training on good hygienic and fish handling practices; v) increasing market competitiveness and improving value added; vi) achieving easy access to formal credit systems (Bailey et al., 2016; Jacinto and Pomeroy, 2011). In the case of Cambodia, Community Fisheries are already one existing community-based organization that could be encouraged (García-Lorenzo et al., 2021).

The integration of information technology (IT) to processing techniques and marketing strategies would also help to improve the competitiveness of fishery products in the markets. In Nigeria's fisheries sector, IT plays the following roles in fish farming: information exchange, knowledge sharing, promotion of education, monitoring illegal fishing and price information provisioning (Ejiogu-Okereke et al., 2016). Similarly, in Cambodia, integration of IT systems could help to manage fish stocks, which are used in all stages of the value chain. For example, establishing a fishery database system to balance supply and demand can help to improve prices in all stages of the value chain (Bradley et al., 2019). The introduction of alternative marketing systems -such as e-marketing, e-commerce and social media channels- has also been seen as one opportunity after COVID-19 (Kaewnuratchadasorn et al., 2020). Retailers could make direct contracts with fish farmers and transport live fishes from farm to store.

The role of the government is another important aspect for fisheries development. So far, no specific policy to support fishery postharvest development in Cambodia is available. The existing policies seems to be unclear and scattered under the direction of different institutions which act as barriers for sustainable postharvest development. Cambodia's Fishery Law, established in 2006, aimed to ensure sustainable management of fisheries resources (RGC, 2006). While the law recognizes

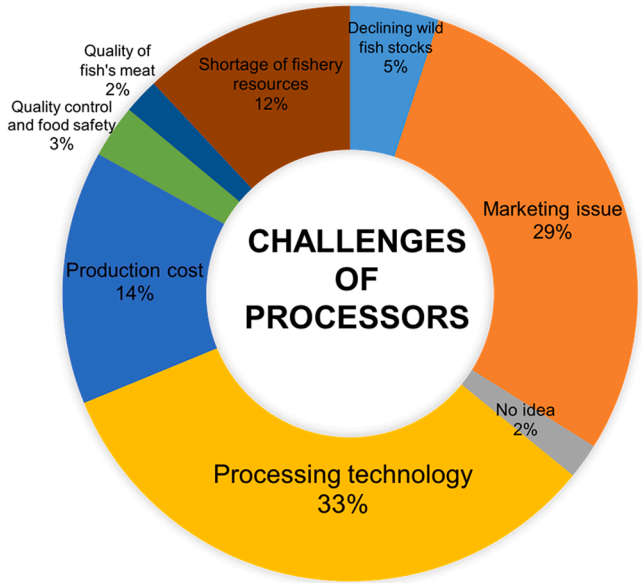

Fig. 7. Overall challenges encountered by local fish and fishery products processors in northwestern Cambodia. Percentages in the charts represent the percentage of responses from processor's survey in both locations, Battambang and Siem Reap (each processor identified different challenges, so that 29 processors gave 64 responses, which were grouped into 7 different categories of challenges).

many activities in the production phase, processing, handling and trading activities have not been given proper emphasis.

Consequently, there are no clear national policies to support the development of a comprehensive fishery database that would include all phases in the supply chain in order to match supply and demand from the sector. Policies such as cheap electricity to support local processors, development of fish landing sites, and transportation infrastructure are important for improving the quality and competitiveness of Cambodian fishery products. Therefore, a holistic policy involving different stakeholders (fish sellers, government, researchers, private sector partners and consumers) should be adopted.

4.3. *Fishery postharvest development and improvement*

Technological issues were the main postharvest challenge identified in this study, many of them related with preservation techniques and product quality control. The following initiatives can contribute to maintaining proper quality of raw fish and reduce postharvest losses along the whole fish value chain.

Infrastructural development is one of the pre-conditions for improved fish quality. Some governments in South and South-East Asia have been focusing on developing cost-effective and user-friendly fish handling and processing technologies, as well as on modernizing fish landing centers and cold chain development. Cambodia should establish similar facilities, as it lacks fish market infrastructure, ice conservation techniques, and transportation capacities.

Cambodian processors have limited knowledge on modern processing techniques, relying more on traditional ones. Drying, smoking, salting and fermentation were the most common processing techniques found in wet markets; their appropriate improvement would upgrade the postharvest value chain and ensure health safety for consumers. Value addition techniques can also lead to increased value and diversification in the range of products available (Zelasney et al., 2020), a great opportunity given the abundance of aquatic resources and species in Cambodia. However, these forms of traditional processing still present multiple problems that must be improved (Appendix B).

To improve the skill of local household fish processors, fish handling, processing and preservation training is essential, and government agencies can provide financial support to organize such training with the technical support of NGOs. Priority could be given to environmentally friendly packaging technology for fish and fishery products and developing local brands to attract domestic and foreign customers. The participation of women in postharvest processing activities, as in many other fishing-related activities, should also not be overlooked (Bradford and Katikiro, 2019; Cole et al., 2020; Kaewnuratchadasorn et al., 2020).

The financial aspect of technological development is still one huge challenge for fisheries actors, as demonstrated by production costs being one of the main problems faced by processors. This situation could be improved with providing processors with better access to financial services, including low-interest credit and microfinance, savings services, and payment and remittance services (Asiedu et al., 2022; Zelasney et al., 2020).

5. Conclusion

Fish are a perishable commodity which requires proper handling to maintain good quality after harvesting. Good postharvest handling and practice along the supply chain from producers to consumers could definitely create more value for fishery products. Though a great variety

Fig. 8. Specific composition of the three main challenges highlighted by local fish and fishery products processors in northwestern Cambodia; (a) specific challenges in processing technology issues; (b) marketing issues; and (c) production cost challenges. Percentages in the charts represent the percentage of responses from processors' survey in both locations, Battambang and Siem Reap (each processor identified different challenges, so that 29 processors gave 49 responses regarding these three main challenges −21 responses for challenge (a), 19 for (b) and 9 for (c)-, which were grouped into different subcategories).

of fishery products are available at fish markets in northwestern Cambodia, value addition to these fishery products seems to be low and some products are not up to proper quality standard. Even though fishery trade has improved over the last few decades, postharvest issues, market access, production costs and raw fish supply are still the major challenges for processors and traders. Specifically, the home-based processors rely on traditional processing techniques and have limited knowledge on food safety and hygiene. Furthermore, production cost is relatively high due to the high price of electricity and auxiliary materials, resulting in local products being less competitive compared to imported ones. Therefore, investment in fisheries infrastructure development, replacement of traditional processing techniques by innovative solutions, integration of information-communication-technology (ICT), and promulgation of postharvest supporting policies should be considered to improve fish and fishery products in Cambodia.

In addition, a strong linkage of key actors in the fish supply chain is equally important to ensure the sustainability and competitiveness of Cambodian fish and fishery products. Our current findings provide evidence to tackle the challenges of postharvest handling and processing of artisanal fisheries that could be essential for sub-national fisheries policy to enhance fishery governance for a sustainable and competitive fishery value chain. More importantly, while this is a case study of Cambodia, it can be applied to other highly fish dependent countries in Southeast Asia (SEA) and Africa, where fish and fisheries are a primary source of nutrition and income, to improve regional food security and livelihood sustainability for millions of people facing rapid global environmental change.

CRediT authorship contribution statement

Ratha Chea: Conceptualization, Writing – review & editing, Formal analysis, Writing – original draft, Visualization. **Dewan Ahsan:** Conceptualization, Writing – original draft, Writing – original draft. **Iria García-Lorenzo:** Conceptualization, Writing – original draft, Writing – review & editing. **Louise Teh:** Writing – review & editing. **Louise Teh:** English proof reading.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2023.106677.

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