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Consumer's perception and acceptance of lumpfish used in salmon cages

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Abstract
Lumpfish (*Cyclopterus lumpus*) are used as cleaner fish in salmon aquaculture to treat sea lice. However, after 18–24 months and reaching 0.4–0.6 kg, the fish is removed from the salmon cage and usually discarded, which raises social, economic, and environmental challenges, as well as ethical concerns. This paper assesses the viability of marketing lumpfish as food by exploring possible products that can be made from the fish in Vietnamese cuisine, and understanding the stakeholder's perception and acceptance of the fish. We used a customer co-creation method to investigate market potential, sending a sample of 45 kg of frozen and whole lumpfish from Norway to Vietnam. Researchers, industrial stakeholders, restaurant chefs, and household consumers collaborated to discuss, process, cook, and taste the fish, and the evaluations were assessed before and after consumption. More than 10 Vietnamese dishes were identified as possible use for lumpfish, including grilled, fried, sour soup, hotpot, and several value-added products. Household consumers and restaurant buyers evaluated the fish positively in terms of sensory quality (taste, color, flavor, size, and texture), but the rough skin and sharp thorn are negative aspects. Individual consumers accept the fish and were willing to buy it if the price is reasonable. In contrast, industrial stakeholders evaluated the lumpfish less favorably, citing its soft and mushy texture, sticky smell, and very low fillet-recovery-ratio (only 15.9% of skinless fillet and 16.7% of kama can be obtained from whole-defrosted lumpfish). They also found that the taste of the fish was not delicious and bitter in some value-added products. In addition, this study found that the information relating to lumpfish as a cleaner fish is not an issue in the Vietnamese context.

Keywords Lumpfish · Consumer perception · Consumer acceptance · Market assessment · Vietnam cuisine

Introduction

Sea lice pose a significant challenge to salmon farming, causing a high mortality rate and limiting growth worldwide. This parasite results in substantial physical and biochemical damage and leads to significant economic losses in terms of production and treatment costs

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(Wootten et al. 1982; Grimnes & Jakobsen 1996). The economic impact of sea lice was estimated to be £700 million globally in 2015 (Brooker et al 2018). Sea lice infection typically causes up to a 16% reduction in production biomass, leading to an approximately 9% loss in farm revenues for the Norwegian salmon industry (Abolofia et al. 2017). Various innovative solutions have been developed to tackle this problem, including physical and chemical technologies (Brooker et al 2018). The use of lumpfish (*Cyclopterus lumpus*) as a cleaner fish was considered the most effective, safe, and environmentally friendly solution.

Lumpfish (*Cyclopterus lumpus*) have become the most widely adopted biological delousing method for Atlantic salmon in large scale production since 2010 (Brooker et al 2018). Providing lumpfish for salmon aquaculture is now one of the most valuable aquaculture businesses in Norway. In 2018, the country farmed 32 million individuals with a value of 640 million NOK (Waatevik 2019; Ulvan 2018). Lumpfish are placed in net cages with the salmon when they weigh about 25 g, and they stay there until the salmon is ready for slaughter (after 18–24 months). An average salmon net cage in Norway requires between 8000 and 16,000 lumpfish, which are removed with the salmon and slaughtered when lumpfish weigh between 400 and 600 g (Nøstvold et al. 2016). Unfortunately, the lumpfish stop eating lice when they reach maturity, and therefore, they cannot be reused in salmon cages. Currently, a few salmon producers are able to use the lumpfish as raw material for silage, while others need to pay to dispose of it as waste. In 2018, approximately 12,800 tons of lumpfish were produced in Norway's salmon industry, most ending up as waste (Waatevik 2019; Ulvan 2018). This raises social, economic, and environmental challenges, as well as ethical concerns.

Recent research confirms that lumpfish may be a good source of B12 and D3 vitamins, while environmental pollutants and heavy metals are below the EU maximum levels, making it safe for human consumption (Ageeva et al. 2021). However, there is still a lack of studies that have investigated the market potential for lumpfish as human food. This paper is the first attempt to explore this potential by investigating two research questions: (1) what products can be made from lumpfish for human consumption, and (2) how do the stakeholders evaluate and accept this unfamiliar fish? This study used a customer co-creation approach in which researchers, industrial stakeholders, restaurant buyers, and household consumers collaborate in a "real meal context" to explore possible products and meals that can be made from lumpfish, and also their preference, perception, and willingness to buy the fish. To successfully introduce new species or products to the market, it is important to take into consideration the local consumption culture in the product's innovation process (Olsen 2008). Lumpfish are marine fish and found only in the North Atlantic, so the fish is unfamiliar to consumers in Pacific countries such as Vietnam. Therefore, our research approach is appropriate to explore Vietnamese consumer's perception and acceptance of this novel fish species.

This study was conducted in Vietnam because the country is known for its rich culinary culture, diverse and innovative food production, and its people open to unfamiliar food. This paper is organized into five sections, beginning with a brief literature review of the factors influencing consumer choice and consumption of seafood, with a focus on consumer acceptance of unfamiliar food products. The "Methodology" section presents our research method and prototype of the research process, using the real meal context approach in collaboration with stakeholders to test the market potential for unfamiliar and new seafood products from different perspectives. The "Results" section presents the research results, including possible products made from lumpfish, and the stakeholders' perception and acceptance of lumpfish as a new food. Finally, this paper concludes with a discussion and remarks section.

Literature review

Toward developing a methodological framework for the study, this section reviews issues related to the consumer's perception and acceptance of an unfamiliar food. Then determinants of the decision-making of industrial buyers, who are gate keepers for market penetration, are reviewed.

Determinants of consumer choice of food

Seminal works such as Randall and Sanjur (1981) and Shepherd and Sparks (1994) propose that three groups of factors determine the consumer's preference and consumption of food, which are the characteristics of the food, the characteristics of the environment, and the characteristics of the individuals. Food characteristics consist of intrinsic and extrinsic attributes or cues (Steenkamp 1990; Zeithaml 1988). Intrinsic cues include the inherent characteristics of the products, such as protein content, color, and taste, which are usually determined by nature and are difficult to change with production processes. Extrinsic cues such as price, packaging, and product label are external factors that can be modified during the production process and are often used as marketing tools in the marketing strategy. The characteristics of the individuals include biological, physiological, psychological, and socio-economics factors, such as age, gender, income, education, knowledge, and lifestyle. Finally, the characteristics of the environment include regional culture, religions, and traditions.

Food choice is a complex behavior influenced by multiple interrelating factors from the characteristics (Köster 2009; Shepherd and Sparks 1994). Consumer purchase behavior is often analyzed in economic and marketing research as a cost–benefit trade-off decision-making process. Consumers choose a certain product over other alternatives because its perceived benefit or value exceeds that of the others, which is subjective and varies among individuals based on different characteristics (Ajzen 1991).

In the seafood consumption context, quality (Olsen 2002; Thong and Olsen 2012), nutrition (Brunsø 2003), and health (Trondsen et al. 2004) are key attributes that influence the consumer's positive attitudes toward eating fish. Intrinsic cues such as freshness, taste, ease of digestion, and omega 3 content play important roles in shaping the consumer's perception of quality, nutrition, and health when purchasing fish (Olsen 2002). However, certain intrinsic cues, such as the smell of the fish and its bones, have negative impacts on consumer attitudes toward consuming fish (Olsen 2002; Verbeke and Vackier 2005; Thong and Olsen 2012). Extrinsic cues such as product origin (local vs. imported), production method (farmed vs. wild caught), product format (filleting, whole-fish, round-cut, ready to eat), preservation method (fresh, chilled, frozen, or marinated), packaging, price, and product certificates (e.g., eco-label) are recognized as factors that consumers may consider during the buying process (Thong et al. 2015; Menozzi et al. 2020; Tran et al. 2022).

Fish is a healthy and nutritious food source, and approximately 6% of global dietary protein is derived from fish and seafood (Nesheim et al. 2015). Fish also provide essential micronutrients, such as vitamins and minerals (Nesheim and Yaktine 2007), which make fish an ideal dietary option for the elderly and children. Previous studies have found that individuals with higher income and elderly consumers tend to consume fish more frequently (Thong and Solgaard 2017; Trondsen et al 2004). Other consumer characteristics, such as gender (with females consuming fish more frequently than

males), education, habits, family size, and careers, can also play a role in fish choice (Oken et al. 2012; Thong and Olsen 2012; Thong and Solgaard 2017; Carlucci 2015). However, factors such as lack of knowledge on how to prepare and cook fish, inconvenience, and unavailability of fish can negatively impact the frequency of fish consumption (Olsen 2004; Thong and Olsen 2012; Thong and Solgaard 2017).

Recently, extrinsic attributes such as the eco-label have been proposed as a viable solution to promote more environmentally conscious purchasing decisions among consumers (Gorton et al. 2023, 2021; Meis-Harris et al. 2021; Marrucci et al. 2019, Vitale et al. 2017). Studies have shown that the consumer may be more influenced by quantifiable perceptions of the environmental information on the label than by intrinsic environmental concerns (Brécard et al. 2012; Hiroki 2019). A recent study conducted by Coderoni and Perito (2020) revealed that 56% of Italian consumers expressed their willingness to purchase "waste-to-value food" that contains ingredients otherwise discarded in the supply chain food. Consumers who consider the importance of reading food labels and who believe that food products have environmental or health benefits are more likely to purchase waste-to-value food. Brécard et al. (2009) analyzed data of 5000 consumers from an original European survey of seafood products to examine the impacts of intrinsic motivation, information, localization, and socioeconomic factors on the demand for an eco-label for fish. Their results show that there is a significant association between the desire for eco-labeling and seafood features, particularly the freshness, the geographical origin, and the wild vs. farmed origin of the fish.

Introducing exotic foods to local markets faces a number of challenges, including barriers such as food neophobia and food technology neophobia (Muhammad et al. 2016). Food neophobia and food technology neophobia refer to a psychological attitude that influences the consumer's acceptance and consumption of exotic food. It can cause a tendency to avoid trying new foods, increasing the likelihood of rejecting new foods over other factors (Muhammad et al. 2016). Additionally, food neophobia is negatively correlated with familiarity with novel foods, which can limit dietary options and results in a high failure rate for newly introduced food products (Damsbo-Svendsen et al. 2017; Pliner and Hobden 1992). In a study of Coderoni and Perito (2020), as mentioned above, it was found that food neophobia and food technology neophobia negatively impacted the likelihood of Italian consumers expressing a positive purchase intention to buy "waste-to-value food." Moons et al. (2018) found that neophobia only has a negative effect on the intention of buying functional food for a small segment in the Belgium market.

Food neophobia can manifest in a number of ways, including aversion to food from different cultures, unfamiliar food, unusual food, food of unknow origin, functional and convenience food, new brand food on the market, novel food, and healthy food as alternative versions of already known food (Siddiqui et al. 2022). Several factors determine the level of neophobia toward new foods, including taste information (Hoyer 2001; Tuorila et al. 1994; Pelchat and Pliner 1995); familiarity of the new food and its nature (Archer et al. 1979); travel habits (e.g., people who travel more and are more accepting of other cultures and tend to exhibit less neophobic behavior) (Olabi et al. 2020; Antuono et al. 2012); disgust sensitivity and personality traits (Torri et al.

2020); and socio-demographic characteristics, such as age (Loewen and Pliner 2000; Tuorila et al. 2001), gender (women were less food neophobic than men) (Nordin et al. 2004), and income (Meiselman et al. 2010); and spatial context, such as the place of residence (e.g., urban residents are more likely to have a lower level of food neophobia than rural residents due to their exposure to a wider variety of foods) (Flight et al. 2003; Tuorila et al. 2001).

Factors determining industrial buyer's decision

While there has been a lot of research on the consumer's buying behaviors, the buying behaviors of distribution channel members have not received as much attention (Skytte and Blunch 2006), especially for foreign products. Understanding their perspectives and purchasing behavior, as well as identifying the purchasing decisions made by individuals (buyers) or a group (buying centers), is critical because, as gatekeepers, they determine the range of products that are available to the end consumers. Members of a distribution channel may include industrial buyers, wholesalers, and retailers. The key factors influencing their import/buying decision are product quality and customer services (Young 1997). In addition, elements such as risk, the level of trust that they can build with a supplier company, and the strength of the buyer–supplier relationship are also taken into consideration (Landeros and Monczka 1989; Chicksand 2015). Therefore, decisions about importing or buying can be influenced by both economic and sociological concerns (Mukherji and Francis 2008).

In the food industry, industrial buyers, who often focus on raw materials for further manufacturing, pay close attention to a number of factors, including the characteristics of the supplying company, the product's characteristics, the variety of products offered, pricing considerations, marketing support for the product or brand, the capacity to precisely adhere to delivery conditions, and individual and interpersonal considerations (McGoldrick and Douglas 1983). In addition, when importing or buying, they often consider where and under what conditions the food was produced, as well as consumer concerns (Johnston et al. 2001).

Wholesalers and retailers often purchase branded food products. According to Farrell's (2006) study of the factors influencing Caribbean importers' decisions to buy branded food products made in Canada, price and the local customers' demands are the most crucial factors in purchasing decisions, followed by the brand image and package design. The need for product variety, premium or standard positioning, and quality considerations were also highlighted by the food retailer (Shaw et al. 1992). For countries that depend heavily on food imports, the importance of the importers' decisions, who ultimately decide what factors go into the purchase of foreign products, is of even greater interest. In this context, three factors—internal business factors, external factors (such as those in domestic markets), or supplier factors (those associated with foreign suppliers)—may influence the retailers' and wholesalers' purchases of foreign good (Soto et al. 2019). Therefore, the key to creating value and enhancing the supply chain's competitiveness is to strengthen the relationships between suppliers, retailers, and wholesalers with the aim of promoting mutual benefit at all stages of the buying process (Powers and Reagan 2007).

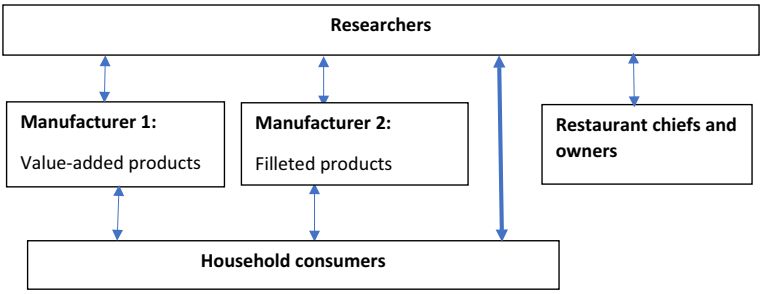

Fig. 1 Prototype of the research process

Methodology

To assess the comprehensive market potential of lumpfish, an unfamiliar fish to Vietnamese consumers, we applied a customer co-creation method in a real meal context. Our assessment covered aspects such as sensory quality, economics, product variety, processing issues, and customers' perception. We sent a sample of 45 kg frozen whole lumpfish from Norway to Vietnam and collaborated with two industrial stakeholders[1] to carry out various stages of the market assessment. Together, we identified possible products that lumpfish could be processed into and supplied to the Vietnamese market. The stakeholders also helped us to process, package, cook, and test the sensory quality of the fish. In addition, we worked with a restaurant owner and chief[2] (referred to as the restaurant buyer) to investigate the potential for using whole lumpfish as raw materials in their restaurant. Finally, we conducted tests with household consumers by using both whole frozen lumpfish and processed products made by the industrial stakeholders. The assessment process involves close collaboration between industrial stakeholders and researchers from universities in the first three stages. A prototype of the assessment process is shown in Fig. 1.

The assessment of the market potential was carried out in five stages. Step 1, "introduction," aims to introduce lumpfish and the research goals to the industrial stakeholders. University researchers and representatives of industrial stakeholders participated in the introduction and discussion, which were facilitated by using online meetings and email communication. In step 2, "processing," industrial stakeholders were tasked with processing the sample of whole frozen lumpfish that was shipped from Norway to Vietnam via air freight. The average size of the fish was about 400 g, and the fish was preserved at − 18 °C. After receiving the sample, the researchers and industrial stakeholders discussed the possible processed products. Two types of products were ultimately produced, fillet products and value-added products. In step 3, "stakeholder evaluation," the evaluation was conducted by group discussions after the presentation of the processing results by experts from the industrial stakeholders.

[1] Haivuong group (http://www.haivuong.com) specializes in processing marine fish such as tuna and sword fish; and VILFOOD company of Hainam group (https://www.hainam.com.vn/products/value-added-food.html) specializing in value-added products from fish and seafood.

[2] Zalo restaurant in Nha Trang (http://nhahangzallo.com.vn/) specializes in seafood buffet, which is similar to a street food restaurant.

Steps 4 and 5 aimed to assess the perception and acceptance of both the household consumers and the restaurant buyers. In step 4, the research team introduced lumpfish and outlined the research objectives before seeking inputs from household consumers and restaurant buyers. This was followed by group discussions to gain insight into the consumers and buyers' evaluation of the fish, including their first impression, the product's features, comparison to similar fish, and possible meal options. Lumpfish samples (whole fish and filleted/marinated products) were then given to households and restaurant buyers,[3] who were asked to prepare and cook their preferred dishes. In step 5, separate group discussions were held with household consumers and restaurant buyers the day after they processed, cooked, and ate the fish.

The group discussions were verbally chaired by academic researchers, and the participants included industrial stakeholders (steps one, two, and three), household consumers (steps four and five), and restaurant buyers (steps four and five). To obtain more detailed information and avoid bias caused by interferences from one to another group (e.g., influences of industrial buyers on household consumers), the group discussions were arranged separately. The predetermined questionnaire consists of open-ended questions (Table 3) that require more than a yes/no answer, were neutral, sensitive, and easy to understand (Gill et al. 2008). Similar questionnaires were used for stakeholders, restaurant buyers, and consumers in steps 2 to 5. The questions were developed in accordance with the research objectives, which aimed to explore the potential products and meals that could be made from lumpfish, as well as the customers' evaluation and acceptance of the product. The discussions were immediately noted and, if the participants agreed, were recorded. Additionally, the stakeholders and customers were asked to take photos of the products and to document their processing and cooking procedures if possible. The photos and documents were provided to the researcher's team after each discussion.

Results

Products possibly made from lumpfish

Vietnamese cuisine is known for its diversity, offering a wide range of fish dishes (Table 1), which contain a surprising variety of recipes using lumpfish. Popular dishes in Vietnamese households include sour soup, fried fish with or without tomato sauce, while in restaurants grilled fish and hotpot are commonly served. The value-added products made from lumpfish are suitable for consumption both at home and in restaurants. The recipes (Table 1) were described by the stakeholders, consumers, and Vietnamese researchers who participated in the study.

The processing of lumpfish in a factory of one of the industrial stakeholders[4] was carried out in multiple stages, including defrosting, filleting, washing, brining, draining, and seasoning (for marinated products). The fish was cut into three parts: the fillet, the kama (the section right behind the fish's head and gills), and the waste (head, gills, thorn, etc.). The fillet and kama were used to make two unmarinated and two marinated final products.

[3] One household consumer (female, 35-year-old public service officer) was given a whole fish; two others (females, 37-year-old service officer and 51-year-old teacher) were given two different filleted products. The restaurant chief was given a whole fish.

[4] Nha Trang Tuna factory, Haivuong group.

Table 1 Summary of the results

Feature	Processing stakeholders	Restaurant stakeholders	Household stakeholders
First impression	Fish looks ugly, first time seeing it	Fish look ugly but is not scared, first time see it, similar to some local and marine fish	Fish looks ugly but is similar to some local and marine fish; "ugly means tasty"
Size	Too small size for processing	Size is not too big not too small; it is fine for restaurant recipes	Size is fine, good enough for preparing and cooking at home
Color	Normal color, like marine fish, some light blue color part indicates low quality	Normal color, like marine fish	Normal color, like marine fish
Shape	Ugly, rough skins, sharp thorns and head	Fine shape, rough skin and sharp thorn	Ugly, rough skins, sharp thorns and head
Familiar to known fish	Some kind of marine fish	Box beef fish	Puffer fish, stone trigger fish, box beef fish
Suitable products/meal	Fillet, marinated, braided products; but it is hard to process at industrial scale	Fillets, sashimi, grill, hotpot, sour soup	Fillet, fried dishes, sour soup, braided fish, and hotpot
Processing stages	a. Defrosting > skinning > washing > filleting > brining > draining > seasoning (marinated) > packaging b. Defrosting > skinning > washing > filleting > seasoning > steaming > value-added products	Defrosting > skinning > washing > filleting > cooking	Defrosting > skinning > washing > filleting > cooking
Processing products/cooking meals	a. Fillet and kama (frozen fillet and marinated products b. Value-added products	Fried, grilled, sashimi, sour soup	Fried and sour soup
Taste	- Pale and unfavorite taste - Salty and bitter taste	Tasty and delicious	White color, soft/firm and tasty meat
Smell	- Unpleasant smell, fishy and sticky smell - Good smell and flavor after steaming	Not fishy	Not fishy
Texture	Mushy meat	Firm meat and fine color	White color and soft/firm meat; edible fat below the skin
General perception	Manufacturer 1: neutral, may be not feasible for industrial production Manufacturer 2: negative, unfeasible for industrial production	Positive	Positive

Table 1 (continued)

Feature	Processing stakeholders	Restaurant stakeholders	Household stakeholders
Positive aspects	Foreign origin	Marine and exported fish; good taste; good size; can be cooked in different dishes	Marine and imported fish, good taste, and reasonable size for family cooking; can be made different dishes
Negative aspects	Low meat ratio, bad smell, small size, rough skin, and sharp thorn	Rough skin and thorny, low meat content	Rough skin and thorny
Acceptance	Need further assessment	Yes, it can be typical dishes in our restaurant	Yes, my family members like the fish. We could buy if the price is reasonable
Willingness to pay	Could not say	100,000–120,000 VND for a whole frozen fish (400–500 g)	- A whole fish (400–500 g): 100,000–120,000 VND - Fillet package (200 g): 120,000–200,000 VND - Kama package (200 g): 100,000–140,000 VND
Impact of information of lumpfish as cleaner fish in salmon production	May not a problem, but some individual consumers may concern	Not a problem, farmed with salmon and imported from Norway are attractive factors	Not a problem, some cleaner fish in aquariums are also consumed; farmed with salmon and Norwegian origin are good thing

Fig. 2 Processing and cooking stages of filleted and marinated products from lumpfish

Fig. 3 Value-added products processed from lumpfish

Additive substances such as salt, satay, galangal, and chili were used to make marinated products. The final products were packaged in 200-g plastic bags and can be stored in frozen form for up to 6 months. These processed products can be used for frying, grilling, and cooking various fish soups in households or restaurants (Fig. 2). Two households' consumers were provided with a small sample of the frozen filet and kama, as well as marinated fillet and kama. They were asked to cook any meal that they thought was suitable for their family's preference. The consumer who received two marinated products cooked grilled and fried dishes, while the consumer who received both frozen fillet and kama prepared grilled and fried dishes and sour soup.

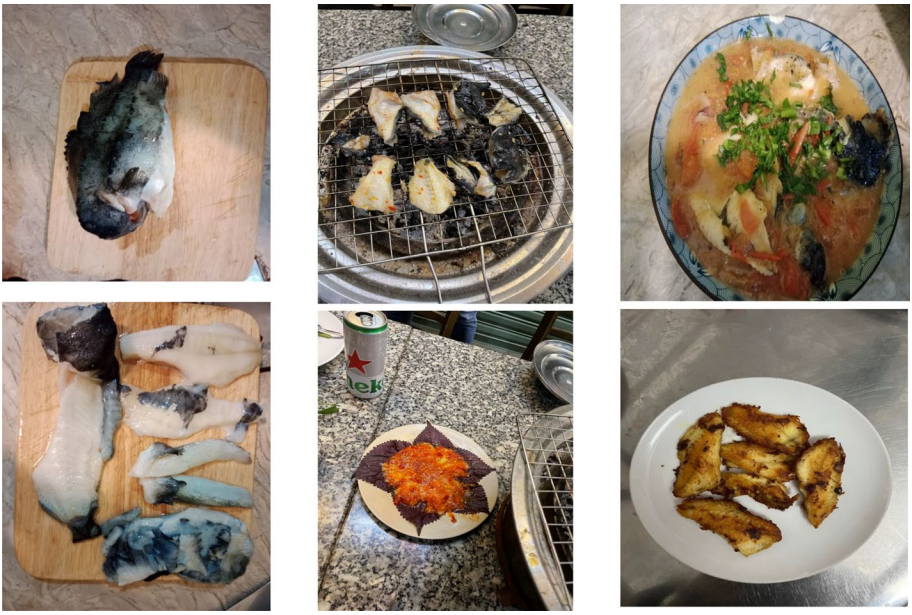

Fig. 4 Household and restaurant chef processing and cooking lumpfish

Value-added products made from lumpfish were produced at another factory that was owned by our industrial stakeholder.[5] The processing stages include defrosting, filleting, adding spices, and steaming the cooked fish meat, which is then used as material for value added products. Four different products were made as follows: gyoza, dumpling cake, flitter, and breaded fish (Fig. 3). These products were frozen and stored in plastic bags and can be stored for up to 6 months. Due to the limited sample, these value-added products were not provided to individual consumers but were instead tested among stakeholders and researchers. Three staff members from the industrial stakeholder who helped us produce the value-added products, as well as four academic researchers, tasted the products during the group discussion.

Two whole lumpfish were given to a household consumer and a street food restaurant chief to cook meals suitable for the fish. The consumer (female) cooked sour soup and fried dishes, while the male restaurant chefs cooked sashimi, hotpot, and grilled dishes. Figure 4 illustrates the processing and cooking stages and the meals made from lumpfish by the household consumer and the restaurant chef.

Consumer's evaluation and acceptance

Group discussions were conducted both pre- and post-consumption to obtain a comprehensive understanding of aspects ranging from the first impression of the characteristics of the fish to sensory quality. The researchers facilitated the discussions and predetermined open-ended questionnaires were used. Three groups were formed as follows:

[5] VILFOOD value-added product factory, Hainam seafood processing, and exporting group.

two group discussions with industrial stakeholders, a group with restaurant owners and a chef, and a group with three individual consumers. The group discussions were conducted for each group at different times and locations. The group discussions with the industrial stakeholders were held in their company offices, with the restaurant chef and owner in their restaurant, while the discussion with household consumers was conducted in a café. The results from the group discussions are summarized in Table 1.

Pre-consumption

After viewing the frozen whole lumpfish, stakeholders were asked about their impression of the fish. Two questions were posed to each stakeholder, namely "Have you ever seen this type of fish before?" and "What was your first impression when you saw the fish?" All of the respondents indicated that they had not seen the fish before. The general impression was that the fish looked ugly but not scary.[6] The respondents also associated the lumpfish with local and marine fishes, such as puffer fish, stone trigger fish, and box beef fish. Interestingly, one respondent pointed out that an "ugly fish usually has a good taste."

We further investigated the stakeholder's evaluation of the characteristics of the lumpfish, starting with its shape, size, color, and smell. Regarding the size of the fish, household consumers and the restaurant buyer considered it to be neither too big nor too small; they evaluated the size of the fish as suitable for various occasions for family meals and restaurant servings. However, the processing stakeholders evaluated it as being too small for their process. Household consumers and the restaurant buyers evaluated the fish's color positively, which was lightly black and resembled some marine fish. However, the fish's rough skin, spines, and sharp thorns were negative features.

Post-consumption

Industrial buyers' evaluation The most pressing comments raised by processing stakeholders regarding lumpfish were its high water content and proportion of waste. Specifically, when frozen whole lumpfish was defrosted, it released 18% of its weight in water, and in the processing stage, it released an additional 4.7% of water. Furthermore, 60.2% of the weight of defrosted lumpfish consists of waste, which includes skins, head, thorn, and bones. The high proportion of waste contributes to the low percentage of edible parts in lumpfish, in comparison to other fish used for filleting. In fact, defrosted whole lumpfish only yields 15.9% of skinless fillet and 16.7% of kama, with only the skinless fillet being suitable for use as raw materials for value-added products.

The two industrial stakeholders had differing evaluations of the taste of the grilled dishes made from fillet and kama, as well as various value-added products. Participants from the fillet processing company did not give a positive evaluation of the fish taste. They commented that:

> "The grilled dishes tasted bland and mushy, were not firm as we thought. It has a sickly smell, some parts of fish fillets had a green color, and we need to check its quality."

[6] Only one female participant from the industrial stakeholders said that the fish looked scary.

The stakeholders from the value-added product factory evaluated the overall quality of the four value-added products, gyoza, dumpling, fritter, and breaded lumpfish, served warm during the discussion, positively. They noted that the products had good flavor, did not taste fishy, and had a firm texture. However, they also mentioned that "taste was a bit bitter and acrid." In addition, the fish's rough skin and big head made it difficult to process, and the low fillet recovery ratio was also a concern.

Restaurant buyers' evaluation Overall, the restaurant owner and chef gave a highly positive evaluation of the lumpfish. They assessed the size, shape, and color of fish as acceptable and noted that its origin is a positive factor in "making our restaurant become more attractive." The fish was found to have delicious taste and a firm texture, which are highly desirable attributes in a seafood dish. Interestingly, the fish was prepared into two distinct meals: sashimi and hotpot. Both are popular options for dining and gathering, suggesting that the lumpfish has the potential to be a versatile ingredient that can be used in a variety of culinary contexts. For example, the owner of the street food restaurant commented that:

> "The fish imported from Norway is a good thing, as people know salmon also come from Norway and it is a luxurious fish and too expensive for our guests. We can serve this lumpfish as a typical meal for grilled buffet or special order, that it makes our restaurant more attractive."

Household consumer's evaluations In steps 4 and 5 of the research process, one female household consumer was provided with a whole frozen lumpfish, while the other two were provided with processed products as mentioned above. They were asked to cook whatever meal they preferred and take notes of their cooking process. The consumer who received the whole fish was asked to record a video of the cooking process and return it to the researchers.

On the following day, at the second group discussion, which focused on their cooking meals and perception of the fish quality, all three consumers agreed that the fish has a thin fillet, inedible rough skin, and high edible fat. The fish fillet is white in color and soft in texture, with no fishy or unpleasant odor. Overall, the fish is delicious and can be cooked on various occasions. The marinated products (marinated fillets and kama) can only be used for grilled or fried dishes, while frozen fillets and kama can be cooked as sour soup, fried, or grilled. Interestingly, The female consumer who received the whole fish was very interested in cooking it. She said that the fish can be prepared and cooked for several dishes, such as grilled, fried, sour soup, and sour hotpot.

> "The fish is not the same as salmon. But I can cook different delicious dishes. Head, skin, and bone can be cooked for sour soup. The fillet can be used for grilled and fried dishes after seasoning or can be cooked with ketchup. The fat content is quite high. The texture is like ray fish but a bit soft and mushy. I used the fillet to cook the dish with ketchup (cá sốt cà chua) and my 7-year-old daughter like it very much."

We asked the participants about their willingness to purchase the fish for manufacturing, for household consumption, or for restaurants. While the two industrial stakeholders

expressed concerns about the fish quality, low fillet conversion ratio, and the need for further information, the restaurant and household consumers showed interest in purchasing the fish and its processed products if the price is reasonable. Restaurant and household consumers stated that they could pay 100,000 to 120,000 VND[7] for a whole lumpfish weighing 400–500 g. Willingness to pay for processed products (200 g/package) varied among household consumers. Household consumers expressed that they could pay for a frozen fillet package (marinated or unmarinated) price ranged from 120,000 to 200,000 VND and kama package ranged from 100,000 to 140,000 VND. All of the individual consumers indicated a preference for unmarinated products because they can be used for a wider variety of dishes compared to marinated products, which are suitable only for grilled or fried dishes.

In the final section of the group discussion, we provided some information about lumpfish in salmon aquaculture to eat sea lice and asked questions to gage the impact of this environmental information on the buyer's perception and acceptance of lumpfish,[8] as follows:

> "This fish is used in the aquaculture value chain for eating lice from salmon. The fish is given feed but eat lice[9] as a kind of snack or treat. Do you think this will be problematic for marketing and selling Lumpfish to Vietnam consumers?"

All of the industrial stakeholders, restaurant buyers, and individual consumers responded that the information regarding lumpfish farming for eating lice from salmon would not be problematic for marketing and selling the fish in Vietnam if it is confirmed to be safe and not harmful for health. One staff member of industrial stakeholders expressed that some consumers may be scared by this information. However, one individual consumer mentioned that fish farmed with salmon is a good thing because salmon are known to be beneficial for the health. Another individual consumer even drew a comparison to another fish species that is also used as a cleaner fish in aquaria and has recently been used for human consumption.

Discussion and conclusion

It is possible to continue lumpfish culture to increase the meat ratio after they finish consuming sea lice. However, the lack of market demand information prevents the investment on the extended period of growing lumpfish. This study is the first attempt to explore possible products that can be made from lumpfish in a particular cooking tradition and to understand the stakeholder's acceptance of the fish by employing a customer co-creation method in a real meal context. A sample of frozen whole lumpfish was sent from Norway to Vietnam, where researchers, industrial stakeholders, restaurant buyers, and household consumers collaborated to process, prepare, cook, and evaluate the fish.

[7] US $1 is equivalent to about 23,000 VND in July 2022.

[8] We did not provide this information in earlier steps (e.g., pre-consumption) to avoid the possibly negative impacts of the information on stakeholders' perception and valuation of sensory quality of the fish.

[9] We explained further "Sea lice (*Lepeophtheirus salmonis*) is a natural parasite on salmonids in salt water in the northern hemisphere. It is a small crustacean that feeds from the blood, skin, and mucus from the salmon, and is not harmful to people.".

Almost all respondents were not afraid to eat the unattractive fish and did not consider the fact that the fish used as cleaner fish in salmon aquaculture as problematic, in contrast to the average human inclination to reject unfamiliar food (Guidetti et al. 2018) and to choose familiar and safe food over novel and unfamiliar ones (Rozin & Vollmecke 1986; Borgogno et al. (2015). In fact, in some places of Vietnam, people can eat cleaner fish (suckermouth catfish) that are typically kept in aquariums (Dulichvietnam 2020). Additionally, the lumpfish is imported from Norway and farmed alongside salmon is seen as positive aspects by consumers.

Both home-cooking consumers and restaurant buyers prefer whole lumpfish and frozen fillets that are unseasoned and unmarinated to the marinated products, because they can prepare and serve a variety of dishes for different occasions. From the diverse Vietnamese culinary culture, more than 10 distinct dishes can be created with lumpfish, such as, sour soup and hotpot. This rich local cooking culture increases the likelihood of successful market penetration (Olsen 2008).

The industrial stakeholders have expressed concerns regarding the low fillet recovery ratio, transportation cost from Norway to Vietnam, and expensive labor cost associated with processing lumpfish, which requires many hours of work. Additionally, these stakeholders evaluated negatively the sensory quality and the taste, while the industrial buyers also viewed the appearance, small size, tough skin, and sharp thorns as disadvantages. However, the industrial buyers represent seafood processing companies, primarily using marine and large fish such as tuna and sword fish as raw materials, and therefore, their evaluation may reflect only the experiences of high-end consumers, while the lumpfish would target the consumers with less buying power. For the later, the nutritive value of their diet is a policy concern, while lumpfish is a good source of B12 and D3 vitamins, despite its low mineral content (Ageeva et al. 2021).

Our findings suggest that there is a market potential for whole lumpfish in Vietnam, among restaurant buyers, particularly street food restaurants, canteens, and medium to low-income households. Marketers have a high chance of success if the whole fish is packed in different sizes that fit family or restaurant demand, while highlighting its Norwegian origin and farmed-with-salmon status. Further studies are needed to verify whether the price the consumer is willing to pay allows to compensate also for the environmental cost of the deep-frozen transport.

The main limitations of this study are the small number of participants, the absence of retailers, and the solely qualitative method. The prices that the consumers expressed their willingness to pay for the fish in this study should not be used as the input data for any study of economic feasibility or developing business plan. To confirm this study's findings, more research is needed using larger samples, including small- and medium-sized companies, retailers and a more diverse range of individual consumers, and incorporating methods based on a quantitative approach—such as customer survey, conjoint analysis, and a choice experiment. Then, other aspects of sustainability, such as the environmental cost of transporting deep-frozen fish across the globe, need to be analyzed also.

Appendix

Table 2 Possible meals made from lumpfish

No	Name of dishes	Description
1	Fried fish (Cá chiên)	Ingredients: fish, cooking oil, lettuce, herbs, and cucumber Spices: fish sauce, garlic, chili, lemon, and salt Processing: heat the cooking oil in a pan then evenly coat the fish to golden fry Dipping sauce: make a dipping sauce with fish sauce, crushed chili and garlic and lemon, or make a salt sauce with crushed chili and lemon How to use: serve with white rice or in rice rolls with lettuce, herbs, and cucumbers
2	Grilled fish (Cá nướng)	Ingredients: fish, cooking oil, lettuce, herbs, and cucumber Spices: fish sauce, garlic, chili, lemon, salt, and lemongrass Processing: fish grilled by charcoal or oven, can be grilled without spices or seasoned and then grilled (marinated lemongrass, chili or salt peppers) Dipping sauce: make a dipping sauce with fish sauce, crushed chili and garlic and lemon, or make a salt sauce with crushed chili and lemon How to use: Serve with white rice or in rice rolls with lettuce, herbs, and cucumbers
3	Sour soup (Canh chua)	Ingredients: fish, pineapple, tomato, bean sprouts, and *Colocasia gigantea* Spices: sorrel, seasoning powder, fish sauce, sugar, peppers, vegetables, and green onions Processing: prepare the broth by cooking the pineapple, tomato, and seasoning powder with the sorrel, fish sauce, and sugar. Then, add the fish to cook, add along the *Colocasia gigantea* and bean sprouts to a boil and season with peppers, vegetables, and onions How to use: serve with white rice or rice noodle
4	Braided fish (Cá kho tộ)	Ingredients: fish, pork belly (only 1/5 the amount of pork belly as fish), and one coconut Spices: fish sauce, sugar, ground pepper, seasoning seeds, dried onions, peppers, and green onions Processing: mix the fish well with fish sauce, seasoning seeds and marinate the fish for about 30 min. Thinly sliced pork belly sautéed with cooking oil and dried onions, then added marinated fish, coconut water, and fish sauce, and simmered until the fish juice was still thick, then sprinkled with ground pepper and finely chopped scallions How to use: use braided fish with white rice

Table 2 (continued)

No	Name of dishes	Description
5	Hotpot (Lẩu)	Ingredients: fish, pineapple, tomato, pork bone or chicken bone Spices: sorrel, seasoning powder, fish sauce, sugar, peppers, Vietnamese coriander, and green onions Vegetables: Chinese cabbage, *Colocasia gigantea*, crown daisy, and okra Processing: chicken or pork bones can be used to make the broth. Put pineapple and tomatoes in the broth, season with seasoning powder, sorrel, fish sauce, sugar, peppers How to use: cook the fish with vegetables in the broth, then serve with white rice or rice noodle
6	Stew fish (Cá kho)	Ingredients: fish Spices: fish sauce, sugar, ground pepper, seasoning seeds, dried onions, chili, fresh turmeric, and green onions Processing: marinate the fish for 30 min in a mixture of fish sauce, seasoning seeds, fresh turmeric juice, chopped dried onions, and sliced chili. Dry the onions with cooking oil and place the fish in a saucepan, add hot water, and continue to heat until the fish water is still invaded and thickly sprinkled with ground pepper and finely chopped green onions How to use: serve with white rice
7	Sashimi	Ingredients: fish, perilla, and green mustard Spices: wasabi, soy sauce, and pink ginger Processing: fish fillet then sliced into pieces measuring 2.5 cm×4 cm×0.5 cm. Mix the sauce in a ratio of 2 tablespoons soy sauce, 1 tablespoon wasabi How to use: eat fish with sauce with perilla, green mustard, and pink ginger
8	Fritter fish (Cá tẩm bột)	Ingredients: fish, deep-fried flour, and eggs Spices: salt, ground pepper, and olive oil Processing: marinate the fish for 15 min in salt, pepper, and olive oil. Beat the eggs, then dip the fish in the eggs before rolling it in the deep-fried dough and placing it in a pan of deep-fried boiling oil How to use: serve with mayonnaise or chutney and ketchup

Table 2 (continued)

No	Name of dishes	Description
9	Breaded fish (cá chiên xù)	Ingredients: fish, deep-fried flour, ruffled flour, and eggs Spices: salt, ground pepper, and olive oil Processing: marinate the fish for 15 min in salt, pepper, and olive oil. Beat the eggs, then roll the fish in the deep-fried dough, dip it in the egg, and roll it over the deep-fried dough before placing it in a pan of deep-fried boiling oil How to use: serve with mayonnaise or chutney and ketchup with cucumber salad and lettuce
10	Fish gyoza	Ingredients: fish, wheat flour, onions, cabbage, shiitake mushrooms, and chives Spices: Salt, sugar, seasoning powder, ground pepper, minced garlic, dried onions, sesame oil, rice vinegar, soy sauce, and paprika Processing: making the filling: to prepare the filling, grind the fish meat and finely chop the onions, cabbage, shiitake mushrooms, and chives. Then, combine the ingredients with salt, sugar, seasoning powder, ground pepper, minced garlic, dried onion, and sesame oil, and chill for about 30 min Making the crust: mix the flour with filtered water and a little salt, stuff the dough, and then leave the dough to prove for 30 min. Roll the dough thin with a thickness of about 0.5 mm, cut the dough into small round pieces, and then put the filling in the middle of the dough and fold it around the edge of the dough with your fingers to wrap the gyoza. It is possible to fry cakes with cooking oil or they can be steamed How to use: eat cake with brewed sauce
11	Value-added products (fish dumpling cake, gyoza, plitter, etc.)	Ingredients: fish, wheat flour, pork or chicken bones, pork skin, carrots Spices: sugar, seasoning powder, ground pepper, green onions, ginger, soy sauce, sugar, sesame oil, and green onions Processing: making the filling: finely grind the fish meat and mix the fish well with soy sauce, sugar, seasoning powder, ground pepper, sesame oil, green onions, and finely chopped carrots. Cook the broth from chicken or pork bones and pork skin puree to create adhesion, put it in the refrigerator to freeze and chop then mix with the individual and put it in the refrigerator Make the crust: mix the flour with filtered water and some salt, stuff the dough then brews the dough for 30 min. Cut the dough into pieces of about 10gr. Put the filling in the center of the dough, fold it into a circle. Steam or bake a cake depending on preference How to use: eat cake with brewed sauce

Table 3 Open questions for group discussion and interview

Pre-consumption	1. Have you ever seen this type of fish before? If yes, what is your experience with it? 2. What was your first impression when you received the fish? - Size, color, appearance 3. What kind of dishes do you think this type of fish is suitable for? 4. What will you do with the fish before preparation? (cutting, filleting, etc.) 5. Could any of these fish be used in Vietnam cuisine? 6. How much can you pay for this package?
Post-consumption	7. How did you cook the fish? 8. What is your evaluation of the fish after preparation? - Taste, appearance, color, size? - Any comparison to existing fish? 9. This fish is used in the aquaculture value chain for eating lice from salmon. The fish is given feed but eat lice* as a kind of snack or treat. Do you think this will be problematic for marketing and selling Lumpfish to Vietnam consumers? *Sea lice (*Lepeophtheirus salmonis*) is a natural parasite on salmonids in salt water in the northern hemisphere. It is a small crustacean that feeds from the blood, skin, and mucus from the salmon, and is not harmful to people 10. Would you buy any of these fish? 11. If yes Q10: What would be your most important buying criteria for this fish? (If willing to buy both this question must be asked for each specie) 12. If yes Q10: Could you give some kind of indication of what price you would be willing to buy this fish for? 13. What is important to think about when selling new seafood products into the Vietnam market? 14. What do you think about how this product test was conducted? What could be improved? 15. How much can you pay for the package of fish we provided yesterday?

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Declarations

Ethics approval and consent to participate No approval of research ethics committees was required to accomplish the goals of this study because no animals were involved in the study. This study involved a questionnaire-based survey of stakeholders for discussion. Participants provided their verbal informed consent for the related survey questions and discussion.

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