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Abstract

Aquaculture supplies almost half of the world's seafood consumption. As the market for farmed seafood matures, an increased differentiation through the use of labels is expected. Labels can be categorized as mandatory or voluntary, depending on whether the label is required by law or not. In most developed countries, mandatory seafood labels include information about species, whether the seafood is farmed or wild, and area of origin. Voluntary labels frequently includes information regarding sustainability, organic production, and safety. We discuss labeling practices and conduct a review of consumer studies related to labels used for farmed seafood.

Key words: aquaculture, farmed seafood, mandatory label, voluntary label, product differentiation.

Highlights

- Consumer studies on the effects of labels on farmed seafood are reviewed.
- The importance and limitations of mandatory and voluntary labels are discussed.
- Potential uses of labels on farmed seafood are discussed.
- Research needs concerning farmed seafood labels are outlined.

1. Introduction

According to Grunert (2005), consumers' intentions to buy a food product depend on the perceived cost and expected quality. The expected quality depends on extrinsic and intrinsic quality signals. Extrinsic quality signals are factors such as labeling, price and retailer reputation, whilst intrinsic quality signals are the physical properties of the product itself that the consumers can use for creating their own quality expectations (Olson and Jacoby, 1972). For seafood, intrinsic signals include the color, odor, and texture of the seafood, while extrinsic signals include labeling of area of origin and production method.

Food labels typically provide signals of credence attributes, which are attributes that consumers cannot realize even after consumption (Darby and Karni, 1973; Caswell and Mojduszka, 1996; Wessells, 2002). Credence attributes are frequently related to nutrition, area of origin, production method, animal welfare, fair trade, and sustainability. Search attributes are attributes that consumers can determine by searching (Nelson, 1970; Nelson, 1974; Wessells, 2002). Search attributes of seafood include price, color, smell, texture, and fat content. Labels allow the consumers to evaluate credence attributes before purchase, and may transform a credence attribute into a search attribute (Wessells, 2002).

Depending on the ownership of a label, labels can be categorized as own labels, third party labels, or government labels (Caswell and Anders, 2011). Government labels are usually mandatory and provide essential information of the main characteristics (e.g., EU, 1999). Own labels and third party labels are usually voluntary labels (Caswell and Anders, 2011), which often provide information related to production practices or some enhanced features of the product.

In the increasingly competitive seafood market, seafood producers are attempting to differentiate their products from competitors' products to increase profits (Wessells, 2002;

Grunert, 2005). Recent efforts on developing new voluntary labeling schemes for seafood has created a number of labels such as the Marine Stewardship Council (MSC) and Friend of the Sea labels for sustainable fisheries, the Best Aquaculture Practices and Aquaculture Stewardship Council labels for farmed fish, and the Dolphin Safe label for wild fish (Ward and Phillips, 2009).

For high profile companies who sell seafood, certification for sustainability, organic production, or animal welfare labels will reduce risks related to negative publicity about production practices and fits well into their corporate social responsibility programs (Roheim, 2008). An example of such a company is IKEA, who writes in their sustainability report for 2014: "Fish and seafood: Our goal is for all the seafood served in our restaurants and sold in our Food Markets will be Aquaculture Stewardship Council (ASC) or Marine Stewardship Council (MSC) certified by the end of FY15. Achieving our target will be a challenge because there is a limited supply of certified seafood in certain markets. But we hope that our commitment can support the growth of this market" (IKEA, 2015, p. 35).

The most successful seafood label is the MSC label for sustainable seafood (see e.g., Constance and Bonanno, 1999; May et al., 2003; Jacquet and Pauly, 2007; Gulbrandsen, 2009; Uchida et al., 2014; Pérez-Ramírez et al., 2015). As of April 2015, MSC had certified 255 fisheries worldwide, and MSC labeled seafood is sold by leading retailers all over the world. In a study of the UK market, Roheim et al. (2011) found that consumers paid a premium of 14% for MSC labeled fish. Roheim (2008) argues that certifying seafood with the MSC label can be beneficial for processors and retailers because of the positive effect on demand and public image. Consumers turn away from purchasing the seafood product when environmental groups publically advocate against the production practices of a seafood product; having their seafood products ecolabeled will reduce this type of risk for the producers and retailers (Roheim, 2008). Stakeholders in aquaculture have created labels such

as Best Aquaculture Practices Certification (Best Aquaculture Practices, 2015) and Aquaculture Stewardship Council Certification (Aquaculture Stewardship Council, 2015b) that are similar to the MSC label. Although these labels do not have the same widespread distribution as the MSC label, they are gaining more and more recognition and receive participation from an increasing number of countries. For example, the Aquaculture Stewardship Council now certifies bivalve, pangasius, salmon, shrimp, tilapia, and trout, and their certification program have participating countries from every continent except for Africa (Aquaculture Stewardship Council, 2015a).

Farming seafood has many similarities to livestock production, which allow farmed seafood producers to develop labels that are similar to those used in agriculture (Teletchea and Fontaine, 2014). Organic is an example. Organic labeling was designed for agricultural products and is now used for some aquaculture products. Also country of origin labeling is similar for agriculture and aquaculture. The origin for farmed seafood is usually a country, while the origin for most wild seafood is a specific area of water, for example, cod from the Northern Atlantic. Utilizing well-established labels from agriculture such as organic or country of origin labels is likely to increase the recognition of the label used on aquaculture products, and will reduce the time and resources needed to make the label known among consumers.

If aquaculture continues to grow at the current pace of 6.2% per year (FAO, 2014, p. 6), it will provide more seafood globally than wild fisheries in the near future. The majority of the research on seafood labels has been related to wild seafood. Given the increasing importance of aquaculture in seafood supply, this paper surveys the literature on the effects of labels used in aquaculture and discuss some future labeling opportunities and research needs.

2. Mandatory labels

The World Trade Organization (WTO) regulates the labeling of seafood products in international trade. WTO's regulations focus on labeling for species designation, production method, date of catch or slaughter, and area of catch or country of origin (WTO, 2009). The EU (1999) published their "Council Regulation (EC) No 104/2000 of 17 December 1999 on the common organization of the markets in fishery and aquaculture products" (hereafter EC1999). According to these regulations, national laws mandate which information is required to be displayed on labels within each country. For example, in the US, food labeling is guided by the Food and Drug Administration; in Canada, the Canadian Food Inspection Agency is responsible for mandatory food labeling (Canadian Food Inspection Agency, 2014). We review the literature on eight mandatory labels in each of the following subsections.

2.1. Species of designation

WTO requires that the scientific name of the species has to be labeled prior to the sales to consumers (WTO, 2009). In the EU, EC1999 requires a label of the seafood species.[1] In the US, FDA has a seafood list with acceptable market names (FDA, 2015).

Species are strongly related to the sensory characteristics of the fish, and taste has been found to be one of the most important food values (Lusk and Briggeman, 2009). Johnston and Roheim (2006) found that US consumers were reluctant to switch from their most-favored seafood species by taste (cod, salmon, flounder, and swordfish) to a less

[1] According to EC1999, a European Union's member state is responsible for the scientific name for each species, the name in the official language(s) of the member state, and if applicable, any other name(s) accepted locally or regionally in the member state.

favored species bearing a "no overfishing" label. Furthermore, using a hedonic regression model, Roheim et al. (2007) found that species, brand, product form (e.g., fillet), package size, and process form (e.g., smoked) affect retail prices of fish significantly.

2.2. Country of origin label (COOL)

WTO (2009) requires that seafood products caught at sea and in fresh waters have to be labeled with the catch area and the country in which the product was caught, respectively. WTO also requires farmed seafood products to be labeled with the country in which the final development stage of the product took place. In the European Union, EC1999 requires seafood products to be labeled with the catch area. In the US, COOL legislation for seafood and shellfish was passed as part of the Farm Bill in 2002 (formally known as the Farm Security and Rural Investment Act of 2002) and the Farm Bill in 2008. All perishable agricultural commodities, including farm-raised and wild-caught seafood products, have to be labeled so that consumers are informed about their country of origin, starting September 30, 2008. COOL is also mandatory in Japan, and farmed seafood products must be labeled with the country in which the product underwent its final development stage (Uchida et al., 2014).

Country of origin is important for food choices in general (e.g., Alfnes, 2004), and producers with a preferable country of origin can use this origin to their benefit. Many explanations for country of origin preferences have been suggested including ethnocentrism, economic development, country image, and cultural distance (e.g., Balabanis and Diamantopoulos, 2004). The literature has found similar effects of COOL on seafood. Jaffry et al. (2004) and Salladarré et al. (2010) found that COOL is important for seafood preferences in the UK and France, respectively. This is also the case in the Chinese salmon market. Chen and Garcia (2015) report that Chinese consumers prefer Norwegian farmed Atlantic salmon compared to farmed Atlantic salmon with other countries of origin. Uchida et

al. (2014) found that their focus group participants regarded wild salmon from Alaska and the US and farmed salmon from Norway to be of higher quality and provide better food safety than farmed salmon from Chile. Finally, domestically produced seafood is often preferred to imported seafood (e.g., Uchida et al., 2014).

2.3. Production method: farmed or wild-caught

WTO requires that seafood products are labeled with a description of production method: caught at sea, caught in freshwater, or farmed (WTO, 2009). The US regulations for COOL, also requires that the seafood should be labeled with production method, wild or farmed (USDA, 2015). EC1999 requires labeling of the production method, i.e., whether the seafood was caught at sea, in inland waters, or farmed (EU, 1999).

Consumer research have found that consumers in general prefer wild seafood to farmed seafood. The results in Uchida et al. (2014) show that Japanese consumers prefer wild salmon to farmed salmon and perceive farmed salmon less environmentally friendly. Roheim et al. (2012) found that a segment of US consumers prefer non-ecolabeled wild seafood relative to ecolabeled farmed seafood, suggesting that for these consumers the preference for wild seafood is stronger than the preference for ecolabeled seafood. Salladarré et al. (2010) and Roheim et al. (2012) found that whether seafood is farmed or wild is an important factor that affects consumers' purchase decisions in France and the US, respectively. Furthermore, the results in Roheim et al. (2012) show that when a consumer perceives seafood farming to be more damaging to the environment than wild-capture fishery, then an ecolabel is valued higher for farmed seafood and vice versa for wild-capture fisheries.

2.4. Fresh and frozen

Fish may be frozen one or several times in the distribution channel but sold as unfrozen. In the EU, seafood that has been frozen, but are sold unfrozen, must be labeled as such. To our knowledge, there is no consumer research on the effect of this labeling.

2.5. Genetically modified (GM)

There are two main areas of application of GM technologies in aquaculture. They are used to produce genetically modified organisms (GMOs) that are used in fish feed, which are used in the breeding of fish for aquaculture.

GM products are used as ingredients in fish feed. Among the more restrictive countries on the use of GM feed are the EU and Norway. In March 2013, there were 48 GMOs that were allowed for use in feed in the EU (Food Standards Agency, 2015). In 2014, The Norwegian Food Safety Authority Board stopped the approval of the use of 8 out of 19 GMOs, which the fish feed industry had previously been given permission to use (Sustainable Pulse, 2014). No countries have mandatory labeling requirements of meat or seafood coming from animals that have eaten GM feed (International Service for the Acquisition of Agri-Biotech Applications, 2015). However, organic labeling schemes do not typically permit the use of GM feed.

No GM animals have been approved for human consumption anywhere. The transgenic salmon developed by the US company AquaBounty Technologies is likely to be the first commercialized genetically engineered animal approved for human consumption (Ledford, 2013; Bremer et al., 2015). AquaBounty applied the Food and Drug Administration (FDA) for approval in 1995, the FDA decided that the GM salmon was safe to eat in 2010 (Ledford, 2013), but in April 2015 there is still no published decision. Even with US regulatory approval, the success of GM salmon is questionable. According to Bloomberg

Business (2014), 65 US supermarkets have signed a pledge not to sell it. A number of countries including the EU, Japan, and China require mandatory labeling of all food containing GMOs. In the US, there is no federal law that mandates such labeling (Senauer, 2013).

Several studies have found that a large majority of consumers support mandatory labeling of GM food in many countries (e.g., Chern et al., 2003). Several studies also investigate specific attitudes towards transgenic salmon. Qin and Brown (2006) used focus groups in the US and found strong support for labeling, Nep and O'Doherty (2013) used a deliberative public forum of 25 British Columbians who called for mandatory labeling, Amin et al. (2014) found a strong support for labeling in a survey of Malaysian stakeholders, and Bremer et al. (2015) present results from workshops with aquaculture stakeholders in Northern Europe, who emphasized labeling as very important to facilitate informed choices of salmon. Chern et al. (2003) report substantial willingness to pay values for conventional farmed salmon relative to GM-fed and GM salmon in the US and Norway. American consumers were willing to pay a premium of 41% for conventional salmon as compared with GM-fed salmon and 53% as compared with GM salmon. Norwegian consumers were willing to pay even higher premiums for conventional salmon as compared with GM-fed (54%) and GM salmon (67%).

2.6. Nutrition

The Nutritional Labeling and Education Act (NLEA) in the US, which was passed by the US Congress in 1990 and have been effective since 1994, authorizes the FDA to require most pre-packaged foods to be labeled with nutritional information, only excluding foods sold in restaurants (Drichoutis et al., 2011). Since farmed fish are fed, it is possible to alter the nutritional composition of the fish. For example, the amount of omega-3 in salmon

depends on what the salmon eats. To our knowledge, there has been no consumer research related to labels of the nutritional content of seafood.

2.7. Date of catch and slaughter/best-before/use-by date

WTO (2009) requires wild-caught seafood to be labeled with the date of catch and farmed seafood to be labeled with the date of slaughter. Both in the US and the EU all pre-packed seafood has to be labeled with a best before date. Regulation (EU) No 1169/2011, which is the 2011 EU food information provision regulation, requires perishable foods including seafood to be labeled with a use-by date (EU, 2011).

Lusk and Briggeman (2009) found that freshness is one of the most important food values. Verbeke and Roosen (2009) found that the best-before date is the most important quality cue for fish consumers.

2.8. Feed additives

It is common to use color additives such as canthaxanthin or astaxanthin in feed of farmed salmon and trout to impart color to the fish flesh. If not for these color additives, the flesh of the farmed varieties of these fish would be a possibly less appealing, paler color. In the US, it is mandatory to label farmed salmon that has received these colorants with color added (Upton, 2015).

Steine et al. (2005) and Alfnes et al. (2006) investigated the effects of informing Norwegian consumers about the origin of the color in farmed salmon. They found strong preferences for salmon redness both before and after informing the consumers that the redness was due to synthetic colorants in the feed. However, the non-informed participants preferred the extreme redness to normal redness, while those informed about the origin of the color did not. As far as we know, there is no positive labels related to feed or feed additives used on seafood.

3. Voluntary labels

The variety and number of voluntary labels used on seafood are growing. Examples include Friends of the Sea (international), KRAV (Sweden), Label Rouge (France), Marine Eco-Label (Japan), Naturland (Germany), Bio-Siegel (Germany), Økologisk (Norway), and the MSC label (international). None of the internationally used voluntary labels for farmed seafood have the same recognition or distribution as the MSC label. Feucht and Zander (2014) found that among German consumers the MSC label was the only voluntary seafood label that was frequently mentioned and recognized without aid by the participants in their study.

3.1. Ecolabels

Blend and van Ravenswaay (1999, p. 1072) define "an ecolabel is a voluntary claim that a product reduces environmental damage associated with either production or consumption of that product". The development of aquaculture has raised people's concerns over the environment and the fish welfare. Recently, stakeholders in aquaculture have created several entities that are similar to the MSC for aquaculture. The Global Aquaculture Alliance (GAA) is currently "the leading international organization dedicated to advancing environmentally and socially responsible aquaculture and a safe supply of seafood" (Global Aquaculture Alliance, 2015). To obtain GAA's Best Aquaculture Practices certification, producers have to follow a series of guidelines mainly focusing on the sustainability of the production sites. Another similar organization is the Aquaculture Stewardship Council (ASC), with the stated mission "to transform aquaculture towards environmental and social sustainability using efficient market mechanisms which creates value across the chain" (Aquaculture Stewardship Council, 2015b). Both organizations are relatively new, and farmed seafood is not as widely ecolabeled as wild seafood. For example, the ASC label was

introduced in Germany in 2012, mainly because the food industry expects that this label will become an important sustainability label (Feucht and Zander, 2014).[2]

Overall, studies on ecolabels have found positive effects on consumer preference (Roheim et al., 2012; Uchida et al., 2014). Studies conducted between the late 1990s and early 2000s found that US consumers prefer ecolabeled seafood products and are willing to pay a small price premium (Wessells et al., 1999; Johnston et al., 2001). Aarset et al. (2004) found that whilst participants agreed on the importance of labels as indicators on seafood quality, most of them were unfamiliar with and/or skeptical about existing ecolabels. Moreover, Johnston et al. (2001) found significant differences in consumer preferences for ecolabels with respect to the country in which the label is used, trust in the labeling agency, the species that is ecolabeled, and the characteristics of the consumers. More recent European studies found that certain segments of consumers have a significant preference for ecolabels (Brécard et al., 2009; Salladarré et al., 2010; Chen et al., 2014). Furthermore, Feucht and Zander (2014) found that their participants could not distinguish between the ecolabels that are used for wild and farmed seafood.

3.2. Organic labels

The European Union introduced its regulation for organic aquaculture production on July 1, 2010. Before the production was based on regulations in a few member states and some private initiatives. The EU regulations for organic aquaculture require among other things that the feed should be based on organically produced feeds supplemented by feed derived from sustainably managed fisheries. The regulations also have lower limits for stock

[2] Feucht and Zander (2014) found 18 different sustainability labels that are used for seafood in Germany. They consider organic labels to be a type of sustainability label. When excluding organic labels, the number of sustainability labels were reduced to 10.

densities, which give the fish more space than in conventional fish farming. Moreover, the regulations specify that biodiversity should be respected, and do not allow the use of induced spawning by artificial hormones (EU, 2010). Finally, there are many species specific regulations. For example astaxanthin, which is an important antioxidant for salmon and also gives the red color of the salmon, should be derived from natural sources such as organic shrimp production, the yeast Phaffia, or certain bacteria. These sources of astaxanthin are more costly and less efficient than the synthetic sources used in conventional salmon production (IFOAM, 2014).

In the US, USDA is likely to propose standards for organic seafood in 2015 (Jalonick, 2015). There are federal legislations regarding organic food in general, which is regulated by the National Organic Program and codified in the Code of Federal Regulations (National Organic Program, 2000). In 2012, the EU and the US agreed that any organic product, which is produced in one of the areas could be sold as organic the other area (United States Mission to the European Union, 2015).

Consumer attitudes towards organic labeling of salmon were studied by Olesen et al. (2010). They found that most consumers are willing to pay significantly less for organic salmon than conventional salmon, and explained the reduced willingness to pay by the paler color of the organic salmon. Comparing organic and labeled salmon with non-organic salmon, hence comparing two similarly looking pale salmons, the consumers are willing to pay approximately 15% more for the labeled organic salmon.

Among all the 143 retail fish products in 30 retail stores in Germany, Feucht and Zander (2014) found that 61% of them originated from organic aquaculture. Among the 61% organic fish products, eight different organic labels were used. Furthermore, they found that their participants “expected sustainable aquaculture to restrain from drug usage as far as possible and to work without artificial additives and hormones. Sustainable aquaculture

should be a natural way of production respecting seafood welfare and the environment. Seafood feed should be sustainable itself and species-appropriate. Moreover, full transparency along the supply chain and outstanding quality were demanded by the participants" (Feucht and Zander, 2014, p. 376). Finally, they found that a large part of participants used sustainable and organic aquaculture interchangeably, i.e., the two terms were either used in a mixed or synonymous way.

Aarset et al. (2004) found that one motivation for consumers to buy organic seafood is to avoid the negative aspects of conventional seafood. However, they found that individual consumers have different understanding of what organic is. Although consumers in one country often share one common concept on organic, the common concepts differ among consumers in European countries. For example, Aarset et al. (2004) found that French consumers regard organic as natural and with limited human intervention, while British consumers think organic means freedom from artificial inputs and limited environmental damage. Recent research by Schlag and Ystgaard (2013) suggests that little research has been carried out towards understanding consumers' knowledge and perception of organic aquaculture. More research is needed.

3.3. Animal welfare

The English animal welfare organization, The Royal Society for the Prevention of Cruelty to Animals (RSPCA), has a farm assurance and labeling scheme called Freedom Food, which certifies British producers of meat and farmed seafood (Royal Society for the Prevention of Cruelty to Animals, 2015). The organization has guidelines for farmed salmon (Freedom Food, 2015). Olesen et al. (2010) examined Norwegian consumers' willingness to pay for Freedom Food labeled salmon in an experimental market. They found that the consumers on average were willing to pay approximately 15% more for the Freedom Food

salmon compared with conventional salmon of similar appearance, and more than twice as much as for the pale looking organic salmon.

Schwedler and Johnson (1999/2000) found that consumers pay attention to the health and well-being of farmed seafood and especially on proper farm planning and management. Grimsrud et al. (2013) found that Norwegian households are willing to accept tax increases for animal welfare improvements in farmed seafood. Through a mail survey with a representative sample of 2,147 Norwegian households, Ellingsen et al. (2015) found that Norwegians care about seafood welfare and willing to pay a price premium of about 50% for products made from welfare-assured seafood. Kole et al. (2008) found that although Dutch consumers are willing to pay up to 15% price premium for welfare-assured salmon, the purchased quantities are reduced. In a US study, Swanson and Mench (2000) found that 44% and 22% of the respondents are prepared to pay 5% and 10% more for animal-friendly products, respectively. In a Danish study, Solgaard and Yang (2011) found that 48% of the participants were willing to pay a premium for farmed seafood with animal welfare traits.

However, generalizations about consumer behavior across markets should be cautious as demonstrated by the results obtained by Honkanen and Olsen (2009). They concluded that among Spanish consumers, seafood welfare issues do not yet seem to be important. This result is supported by the special EUROBAROMETER survey on animal welfare in 2005. Among 12 farmed animals, respondents in EU-25 only ranked farmed seafood as the third least important animal to receive improved welfare or protection (EUROBAROMETER, 2005). One possible explanation for the differences in results are the differences in the welfare (Ellingsen et al., 2015). Furthermore, most consumers do not perceive animal welfare as their own responsibility (Te Velde et al., 2002). Instead consumers point at the retailers' responsibility to secure animal friendly production of their foods and at government duties

with regards to adopt appropriate animal welfare laws (Te Velde et al., 2002; Ellingsen et al., 2015).

3.4. Safety

Food safety is one of the most crucial factors in explaining consumers' choice of seafood. Pieniak and Verbeke (2008) found that consumers in five European countries consider labeling as an essential guarantee for safe seafood. They also found that consumers correlate information of product safety with information of product quality. Perception of food safety is sometimes also correlated with COOL. For example, Uchida et al. (2014) found that consumers in Japan perceive wild salmon from Alaska, US and farmed salmon from Norway of high food safety.

3.5. Traceability

Pieniak and Verbeke (2008) found that consumers in five European countries were least interested in batch number for product identification, which is used for traceability. However, they identified two segments of consumers who were more interested in traceability: the consumers that had a high level of trust in fish information and the consumers that found ethical issues more important (Pieniak and Verbeke, 2008). There is a clear discrepancy between consumers' interest in other fish information and the lack of interest in traceability in Pieniak and Verbeke's (2008) study. Logically consumers should only trust a label, when the label is supported by plausible controls and guaranteed by a good traceability system (Pieniak and Verbeke, 2008). The discrepancy may be due to that consumers failed to realize that batch number for product identification can be used for tracing the product, or that consumers do not know how to use such information.

3.6. Branding

The quality of wild seafood is largely not controlled by humans, but determined by the water where the seafood is from, for example temperature, nutrition, and pollution in the water. This is different for farmed seafood. As in agriculture, aquaculture producers are able to control the quality in all the stages of the production. As a result, it is possible for a producer to consistently provide high quality seafood. Therefore, aquaculture firms can develop their own brands as a signal of quality assurance. For example, Marine Harvest has its own in-store brand in the Chinese market (Chen and Garcia, 2015). Roheim et al. (2007) found, through hedonic regressions on a scanner dataset from UK, that national and private retail (own-label) brands are valued differently by consumers. Among five national brands, only Bird's Eye and Young's/Bluecrest brands yield price premiums over private retail brands (Roheim et al., 2007).

4. Labeling possibilities and research needs

4.1. Interaction effects of labels

Most of the research have been on the effects of a single label on consumer demand and willingness to pay (Wessells et al., 1999; Ward and Phillips, 2009; Roheim et al., 2011; Roheim et al., 2012; Chen et al., 2014; Chen et al., 2015). In the marketplace, often multiple labels are presented simultaneously, which creates complex trade-offs for consumers. Uchida et al. (2014, p. 68) suggest that "it is important to recognize, however, that ecolabels signal just one of many attributes that a product possesses. As such, the effect of ecolabels on consumers' overall valuation of a product and ultimately purchase decision must be investigated in a broader context". Currently the research on interaction effects are limited. Although not specifically studied, the mandatory labels are often presented simultaneously

with voluntary labels, and the reported effects of one particular voluntary label may be the net effect of all mandatory labels and the investigated voluntary label.

Brécard et al. (2012) studied the interactions of ecolabels, fair trade, and health labels on seafood and found that French consumers' preference on ecolabels is positively correlated with fair trade labels. Uchida et al. (2014) explored direct and interactive effects of seafood ecolabels with other common seafood labels, and found moderate interaction effects between ecolabels and COOL. They also found significant interaction effect of ecolabel and COOL. In particular, they found that ecolabeled Chilean farmed salmon has most positive effect of labeling, suggesting that an ecolabel may be most effective when it is used on seafood from commonly perceived poor-practice countries. Chen et al. (2015) found significant interaction effects between negative environmental information and labeling of farmed and wild fish. For example, would negative environmental information about cod farming increase the willingness to pay for ecolabeled as well as unlabeled farmed salmon. Such interaction effects is an important topic for future research.

4.2. Labeling possibilities

The world's population continues to increase, and expanding aquaculture production is essential in providing more food (Godfray et al., 2010). Whilst in developing countries the main concern may be to increase the supply of seafood, in developed countries consumers are increasingly demanding higher qualities of seafood and higher standards in the production of seafood. As farmed seafood becomes a more mature product, we will see more product differentiation through labels. However, some of the production methods with associated marketing and labeling activities are quite costly, for example, the production of organic salmon. It is important to know whether these additional costs results in price premiums and

profitability for the firms. More research on the profitability of labeling for specific attributes would be welcome.

4.2.1. Nutritional labeling

Seafood is an important source for nutrients. For example, omega-3 long-chain (≥C20) polyunsaturated fatty acids (hereafter LC omega-3), which are semi-essential nutrients in humans' diets (Nichols et al., 2014), have been attributed to Greenland Eskimos' lower incidence of heart disease (Bang and Dyerberg, 1980). Recent research suggests that some farmed seafood is rich in LC omega-3 (Nichols et al., 2002; Tacon and Metian, 2008; Nichols et al., 2010; Nichols et al., 2014). Nichols et al. (2014) found that two Australian farmed finfish species, Atlantic salmon (Salmo salar) and barramundi (Lates calcifer), have higher LC omega-3 content than the same species from the wild. This provides an opportunity for the seafood industry to label some seafood with a nutrition label, for example an omega-3 label.[3]

The richness in LC omega-3 of some farmed seafood has been consistently high during the past 15 years, despite increased usage of plant oil (e.g., canola and palm oil) and non-marine animal oil (e.g., poultry oil) in seafood feeds (Glencross and Turchini, 2010; Nichols et al., 2014). In this process, the aquaculture industry has significantly reduced feed costs. Furthermore, as production of seafood oil requires wild seafood (Tacon and Metian, 2008), increased usage of plant and non-marine animal oil in seafood feed has helped the industry to improve the sustainability of the production. However, Nichols et al. (2014) reported that the omega-3 oil content has been decreasing in farmed Atlantic salmon and

[3] However, some seafood meat may contain environmental toxic substances, such as heavy metal contaminants, in which case seafood meat may be harmful to human health.

barramundi in Australia between 2002 and 2013. Furthermore, when plant and non-marine animal oil are used as feed, research suggests that the seafood has a higher level of omega-6 fatty acids, which increases the risk of coronary artery disease and death according to a recent meta-analysis (Ramsden et al., 2010).

The nutritional attributes of farmed seafood provide an opportunity for the industry to certify the seafood and to increase per unit profit, particularly on the content of LC omega-3. Certification of LC omega-3 content is likely to promote the market opportunity for seafood with a healthy profile. Furthermore, recent developments in the biosynthesis of Docosahexaenoic acid (DHA), by inserting microalgae-derived genes into a range of omega-3 C18 polyunsaturated fatty acid (PUFA) accumulating land plants, offer a promise of sustainable development of aquaculture and high LC omega-3 content. (for discussion and brief literature review, see Nichols et al., 2014). To conclude, nutrition labeling is an overlooked opportunity, and future research is required.

4.2.2. The role of governments

Governments make important information available through mandatory labels. Given that voluntary labels tend to certify only positive attributes, there is a demand for more mandatory labels to provide information regarding negative attributes such as the content of components that are harmful, for example, heavy metals. Governments can also play a more active role in labeling. Uchida et al. (2014, p. 75) suggest that "the challenge for certification bodies, governments, and NGOs promoting seafood ecolabels is building credibility and assurance among the consumers." As Wessells et al. (1999, p. 1084) note, factors that affect consumer acceptance of ecolabels include: "(a) the credibility of the agency providing a label or certification, (b) consumers' understanding and perception of the link(s) between product choices and environmental impact, and (c) an accurate and clearly understood meaning of the certification." For some attributes, governments should consider to establish credible

voluntary certification schemes and labels across several countries. An example of such schemes is the European organic label, and the EU-US agreement to accept each other's organic products (United States Mission to the European Union, 2015). Finally, government voluntary certification schemes, if credible and trusted by consumers, can potentially reduce the number of schemes and labels available. Consumers will benefit from a smaller number but more trustworthy labels.

4.2.3. The role of international organization

Both GAA and ASC certify producers that comply with their standards for responsible aquaculture. It is worth noting that while the MSC considers the entire stock of one specific species in one area, e.g. Barents cod, the GAA and ASC certify specific producers. The certification of specific producers gives a potential for including producer specific attributes into future criteria for these labels, for example a particular producer's organic aquaculture practice across its farms in different countries. No research has so far investigated the effect of these labels on consumer preferences.

4.2.4. Private labels

The UK retailer Tesco has introduced a new series of Tesco Finest salmon including Wild, Organic, and Specially Selected (Tesco, 2015). In France, Carrefour established its Responsible Seafood ecolabel and certified a number of species caught around Iceland and Greenland between 2004 and 2007 (Salladarré et al., 2010). The effects of these private labels have not been studied and is an area for future research.

4.2.5. Carbon footprint

Production of different seafood is associated with different greenhouse gas emissions. For example, Ziegler et al. (2013) found that production of herring shipped frozen in bulk from Norway to Moscow emits 0.5 kilograms CO_2 equivalents per kilogram, while production of fresh gutted salmon airfreighted from Norway to Tokyo emits 14 kg CO_2

equivalents per kilogram. Many consumers are concerned with the environment, and differences in greenhouse gas emissions from seafood production are likely to affect consumers' preferences and attitudes towards different seafood. Future research on these issues are of considerable interest.

5. Concluding remarks

Labeling helps producers to differentiate their product in an increasingly international and competitive market. Aquaculture producers can look both at successful labels in agriculture such as country-of-origin and organic labeling, and successful labels in wild fisheries such as the MSC label. Labels that are well perceived by the consumers are also likely to increase the profitability of the labeled seafood. Furthermore, organic, animal welfare, and sustainability labeling improves the public image of the aquaculture sector and is important in the corporate social responsibility strategies of aquaculture companies and food retailers.

Most of the recent research is related to the effects of voluntary rather than mandatory labels. This concentration of research does not indicate that mandatory labels are less important or less useful. On the contrary, a number of studies have found that consumers use information provided by mandatory labels related to species, country of origin, and production method (farmed or wild-caught) to infer the unobserved levels of product quality (Jaffry et al., 2004; Johnston and Roheim, 2006; Salladarré et al., 2010).

The role of mandatory labels is to assure that essential information is provided to the consumers. However, it is infeasible for governments to require the industry to provide all types of information that consumers request. Voluntary labels supplement mandatory labels and provide information on attributes that a consumer desires but cannot otherwise observe. Important examples include organic and animal welfare. By providing information of

desirable attributes, voluntary labels benefits consumers, and producers and retailers are able to obtain price premiums. However, because voluntary labels are largely driven by self-interest of the industry, voluntary labels only certify attributes that have positive impacts on consumer preference. Attributes that have negative impacts on consumer utility, for example the content of heavy metal in seafood, are typically not voluntarily labeled.

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