Food Quality and Preference 27 (2013) 26–34

Contents lists available at SciVerse ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

How fresh is fresh? Perceptions and experience when buying and consuming fresh cod fillets

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ARTICLE INFO

Article history:
Received 10 October 2011
Received in revised form 20 April 2012
Accepted 26 May 2012
Available online 12 June 2012

Keywords:
Fish
Cod
Freshness
Shelf life
Survival analysis

ABSTRACT

From January 1st 2010 it was mandatory for all retail stores selling fresh fish in Norway to provide their customers with capture date information for wild fish and slaughter date for farmed fish. The objectives of this study were to: (a) evaluate how many days after capture are consumers willing to buy fresh fish stored on ice, (b) once they have bought the fish how many days are they willing to keep it at home before eating it, and (c) estimate the shelf life of fresh cod using consumer acceptance/rejection data, with and without capture-date information. To cover (a) and (b) a survey was conducted in Norway among 419 respondents visiting retail stores asking them to evaluate how many days after capture they were willing to buy fresh Atlantic cod (*Gadus morhua*) stored on ice. The respondents were also asked how many days after purchase they were willing to keep the fresh cod at home before cooking and eating it. To cover objective (c), fillets of wild Atlantic cod were evaluated by a total of 389 consumers from three Norwegian cities in three different stages: raw and cooked without information on capture data, raw with capture date information. Survival analysis statistics were used to analyze the data with the inclusion of respondents' age, self-reported degree of fresh fish expertise and frequency of fresh fish consumption. When respondents were asked for the last day they would buy fresh cod after capture, there was a 75% probability that this would be approximately 3 days and 5 days for elder and young respondents, respectively. There was a 75% probability that these respondents would have the fish approximately 1 day at home before cooking and eating it. The shelf life (as measured in an acceptability test) corresponding to a 25% rejection probability was approximately 7 days and 11 days, with and without capture-date information, respectively. Thus, in general, when respondents were asked which was the last day they would be willing to buy cod after capture, this time (3–5 days) was shorter than the shelf life (7–11 days).

1. Introduction

Fresh is a frequently used term to describe the quality of a given food item. Fruit is fresh, milk is fresh and coffee-shops prepare freshly brewed coffee and/or freshly made sandwiches. At the same time fresh indicates a comparable state: fresh versus non-fresh, fresh versus old or fresh versus frozen. Fresh could also have different meanings depending on the person or the cultural context (Cardello & Shultz, 2003).

Freshness in seafood has received attention in the literature. Bremner (2005) state that it is a difficult concept, about which there is no set agreement. How shelf life of food products in general and seafood in special could be understood and implemented is discussed by Barbosa and Bremner (2005). Howgate (2011) reviewed different approaches to the sensory measurement of fish freshness by trained assessors. His recommendation was to have a single scale for freshness, with the scale points anchored by descriptions of various diagnostic attributes. The assessors are trained to scale a sample by its freshness, not by its individual attributes. In his discussion on different approaches there was no reference to consumers' evaluation of freshness in fish. Chouliara, Savvaidis, Riganakos, and Kontominas (2005) defined the shelf life of sea bream with a 5-member trained panel who measured acceptability on a 0–10 scale, and they arbitrarily considered a score of 7 as the lower limit of acceptability. Martinsdottir and Magnusson (2001) used an 8–10 member trained panel to evaluate freshness with a 3–10 freshness scale, and they considered 5.5 as the borderline for estimating the end of storage life. This limit was chosen because it "*has been used as borderline for estimating the end of storage life at Icelandic Fisheries Laboratories for years*". Other authors have also used trained panels to measure fish freshness, defining the cut-off point based on their experience or on a trained panel finding significant differences in relation to the fresh product, and with no mention of consumer input (Díaz, Nieto, Bañón, & Garrido, 2009; Goulas & Kontominas,

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http://dx.doi.org/10.1016/j.foodqual.2012.05.008

2007; Gómez-Guillén, López-Caballero, Martínez-Alvarez, & Montero, 2007). In Norway there is no standard on how to estimate sensory shelf life of fresh fish.

In 2009 the Royal Norwegian Ministry of Fisheries and Coastal Affairs issued a regulation making it compulsory from January 1st 2010 for domestic retailers to label fresh seafood products with the date of capture for wild species and the day of slaughter for farmed species (Norwegian Regulation., 2009). The main reason for doing this was to enable consumers to calculate the age of the fresh seafood and use this information to select what to buy at point of sale. One interesting question not considered before issuing the regulation, was how many days after catch/slaughter could pass before consumers would stop buying the fresh fish.

When dealing with fresh fish fillets, due to several reasons (time from catch to processing, distribution and purchase) it is rarely possible to purchase these products in retail with less than 3–4 days after capture. If the "non-fishing" Saturday and Sunday are included, 5–8 days is more probable. Bonilla, Sveinsdottir, and Martinsdottir (2007) reported a shelf life for cod fillets kept on ice of 8 days; and Magnusson and Martinsdóttir (1995) shelf lives of cod fillets between 10 and 12 days depending on previous frozen storage. In both these studies the shelf lives were established with trained panels. There are no reports on shelf life established by using consumers, nor on how consumers' perception is influenced by information on capture or slaughter date. Another aspect which has not been researched is the following: once the fresh fish is purchased, for how long is a consumer willing to keep the fish in the home refrigerator before cooking and eating it.

There has been limited research on the effect shelf-life labeling can have on consumer's perception of the product. Wansink and Wright (2006) conducted an interesting experiment to analyze the influence of freshness dating on acceptability of yogurt samples. The same yogurt 30 days prior to its "best if used by..." date, was labeled as 30 days before (+30), 1 day before (+1), 1 day after (−1) and 30 days after (−30) its "best if used by..." date. A non-labeled sample was also evaluated. There was a significant decrease in acceptability between +30 days and +1 day. The acceptability decreased to a lesser degree for −1 and −30 days. Perceived freshness also decreased similarly. With no labeling, acceptability and freshness was intermediate between +30 and +1 labeled samples. As demonstrated by Wansink and Wright (2006) for yogurt, it is hypothesized that capture date labeling could influence perceived freshness of fish.

Hough, Langohr, Gómez, and Curia (2003) applied survival analysis statistics to determine sensory shelf life based on consumer acceptance or rejection of products with different storage times. Their key concept was to focus the shelf life hazard on the consumer rejecting the product, rather than on the product deteriorating. Hough (2010) presented the methodology in detail together with extended applications. López et al. (2008) estimated optimum internal cooking temperature of beef based on consumers observing photographs of beef cooked to different degrees of doneness. Consumers from different countries answered the survey and survival analysis statistics was used to analyze the data considering country of origin and consumer age group as covariates. Ares, Martínez, Lareo, and Lema (2008) presented lettuce with different storage times to consumers and asked them if they would buy the lettuce and if they would consume the lettuce. They applied survival analysis statistics to their data considering evaluation stage (buy or consume) as an explanatory factor in their model. Curia, Aguerrido, Langohr, and Hough (2005) applied survival analysis statistics to estimate sensory shelf life of yogurt considering flavor and fat content as explanatory factors in their model. Sensory shelf life of cod fillet can be estimated using survival analysis as it has proved to be a useful and reliable method in a variety of food products. Covariates related to consumer demographics or explanatory factors such as evaluation stage (with and without capture date information) or product presentation (raw or cooked) can be included in the model to analyze their effects on the shelf life estimations.

Fresh fish is a sensitive product regarding its shelf life. It depends largely on culture how fish is bought, and how long consumers estimate it can keep. In many countries it is most often bought from a fresh fish counter, without packaging and with limited labeling; in this case the fish monger becomes the "label" as he is trusted to inform the consumer on the freshness of the fish. However, this changed in Norway when under the Norwegian Regulation (2009) consumers should be informed on capture or slaughter date. When a consumer sees this date on the fish, he/she can estimate how many days have elapsed between capture/slaughter date and the day he/she is buying fresh fish. Thus, the consumer can use his/her own criteria in deciding if this information contributes to product selection or not. In a survey, one can place the consumer in a similar situation by asking the following question: "If cod is caught on a Sunday, till what day are you willing to buy cod: Monday, Tuesday, etc.?"; and the consumer answers Thursday, then we can assume that this consumer is willing to buy the cod with up to 4 days after capture. In this decision the only cue consumers are receiving is a labeling cue; there is no product evaluation involved.

When estimating shelf life with the use of consumers, the consumers are presented with samples with different storage times and they decide if they accept or reject each sample. For example, if a consumer accepts a sample with 8 days storage time, and rejects a sample with 10 days storage time, this consumer's data is considered interval censored between 8 and 10 days (Hough, 2010). As different consumers will have different buying times, there will be a time-to-buy distribution which can be modeled using survival analysis statistics (Meeker & Escobar, 1998).

There are no overall reports available where the seafood consumption or purchase pattern in Norway is segmented according to age or consumption frequency. Trondsen, Braaten, Lund, and Eggen (2004) report a mean level of seafood consumption of 2.7 times per week for women aged 46–69 years. This number includes fresh, frozen and processed seafood products. Neither are there any reports on how consumers themselves evaluate their own abilities to assess the quality of fresh seafood. Health authorities and other Norwegian governmental bodies want to encourage a higher domestic consumption of seafood. On this background we found it relevant to examine if the consumers' age, consumption frequency of seafood and own ability to assess seafood quality could help getting a broader understanding of possible effects of the new regulation on capture date information. We also included the cities where the consumers lived to uncover possible differences due to geography.

The objectives of the present work were: (a) evaluate how many days after capture are consumers willing to buy fresh fish stored on ice (time-to-buy), (b) once they've bought the fish how many days are they willing to keep it at home before cooking and eating it (time-to-eat), (c) estimate the shelf life of fresh cod from consumer acceptance/rejection data, with and without capture-date information.

2. Methodology

To estimate time-to-buy and time-to-eat (objectives (a) and (b)) a survey was conducted among respondents who consumed fresh cod (Section 2.1). To estimate the shelf life of cod an acceptability test was performed among consumers from three Norwegian cities (Section 2.2).

2.1. Survey to estimate time-to-buy and time-to-eat

A survey was placed in 30 retail stores in different parts of Norway, both in specialty shops (fishmongers) and supermarkets

Table 1
Gender and age distribution of respondents in the time-to-eat and time-to-buy survey and the consumers in the shelf-life study.

	Survey			Shelf life		
	Distribution	Average age ± std.dev	Degree of expertise (%high–%low)	Distribution	Average age ± std.dev	Degree of expertise (%high–%low)
Total number of respondents	419	–	–	389		
Women	55%	–	–	55%		
41 years or younger	33%	30.1 ± 7.2	48–52	32%	31.4 ± 8.1	46–54
Between 42–58 years	32%	49.9 ± 6.5	51–49	50%	48.6 ± 4.7	53–47
59 years or older	35%	66.7 ± 6.2	65–35	18%	67.2 ± 6.7	62–38

having fresh fish counters. A stand carrying a board was placed close to the counter. The text on the board encouraged consumers to give their opinions on seafood and that five winners would receive a check having a value NOK 2000 (approximately US$ 350) if completing the questionnaire within a specific date (1 week after the stands were taken away). Below the board, the consumers found the questionnaires with prepaid envelopes. Staff working in the fresh fish counter was requested to encourage their clients to pick a questionnaire, complete it at home and post it. A fishmonger in Norway deals mostly with fresh fish and it was therefore logical to place the stand on a comparable site in the supermarket.

The Norwegian authors were responsible for placing the boards and questionnaires and all shops were contacted at least once during collection time (3 weeks in March 2009) to ensure they still had questionnaires and pre-paid envelopes to hand out. A total of 3000 questionnaires were placed in the shops; and a total of 419 questionnaires were completed and returned, representing a 14% response rate. Gender and age distribution of respondents is presented in Table 1.

The survey covered many aspects related to fish consumption, mainly cod and salmon. The relevant questions for the present study are given in Table 2. To simplify data analysis the levels of the last three questions were classified as follows:

- Frequency of fresh fish consumption: once or more times a week was classified as "often", and less than once a week as "rarely". As stated above, the seafood consumption for Norwegian females aged 45–69 years is reported to be 2. 7 times per week, all seafood products included. On this background we found it plausible to characterize those consumers reporting a consumption of fresh seafood equal or higher than once a week as "often" and those with a lower consumption as "rarely"
- Degree of self-expressed fresh fish expertise: answers 1, 2, 3 or 4 were classified as "low" and 5, 6 and 7 as "high". The reason for this classification was the breaking point in the middle of the scale and also to have approximately equal number of respondents in each category.
- Age: 59 years or over were "elder", between 42 and 58 years were "middle" and 41 or lower were "young". Average ages for these groups were (Table 1): 67, 50 and 30 years, respectively. As explained above the survey was placed in stores and picked up by willing participants. There was no fixed age quota, thus the classification responded to having approximately equal number of respondents in each category. The average ages respond to what would be expected regarding aged, middle and young fish buyers.

Table 2
Questions asked in the time-to-eat and time-to-buy survey relevant to the present study.

Question	Answer options
From the moment the cod is captured, it must be washed, packed and transported. In most cases this will take at least 24 h. If you are told or notice that the cod is caught on a Sunday, and it is treated to conserve freshness, which is the last day you would be willing to buy the fish?	☐ Monday (1 day) ☐ Tuesday (2 days) ☐ Wednesday (3 days) ☐ ... ☐ Sunday (14 days) ☐ Longer
Imagine yourself buying the cod mentioned in the previous question. You then bring it home to keep it in the refrigerator (not freezer). Which would be the last day you would be willing to prepare and consume the cod?	☐ The same day I bought it ☐ 1 day after I bought it ☐ 2 days after I bought it ☐ ... ☐ 14 days after I bought it ☐ Longer
How often do you eat fresh fish?	☐ Never ☐ Once a month or less frequent ☐ Once every two weeks ☐ Once a week ☐ Twice a week ☐ More frequent than twice a week
I am an expert in assessing fresh fish quality	1- Totally disagree 2- 3- 4- Neither agree nor disagree 5- 6- 7- Totally agree
What is your age?	Filled in by participants

2.2. Shelf-life study

2.2.1. Raw material

Fillets of wild Atlantic cod (*Gadus morhua*) were used. Cod is both a well known and often consumed species in Norway and at the time of the year the test was done (April–May) there is an abundant supply of fresh cod products. To ensure availability and equal quality on day 0, the number of cods needed for making the fillet samples was calculated and the cods were caught alive and kept in pens.

A commercial fish processing plant was responsible for preparing the samples. The fish was slaughtered, bled, gutted, beheaded and stored on ice in a cold store at the processing plant. The average weight was 3 kg. Two days after being slaughtered (to avoid filleting problems due to *rigor mortis*) the fish was filleted, skinned, trimmed and packed with plenty of crushed ice both under and above the layer of fillets. The procedure ensured that the fish, both previous to filleting as well as the fillets, were kept at 0 °C until being prepared for the CLT (Central Location Test). All processing took place at the same time of the day and two of the plant

Table 3
Slaughtering date (day = 0) and the number of storage days of the cod fillet samples presented to consumers on the four testing dates in Tromsø.

Slaughtering date (day = 0)	Test May 11 [*N = 30*][a]	Test May 12 [*N = 40*]	Test May13 [*N = 40*]	Test May 14 [*N = 30*]
April 28	13	14	15	
April 30	11	12	13	14
May 2	9	10	11	12
May 4	7	8	9	10
May 6	5	6	7	8
May 9	2	3		5
May 11			2	3

[a] This column means that $N = 30$ consumers evaluated cod samples with 2, 5, 7, 9, 11 and 13 days storage at 0 °C. For example: the sample stored for 13 days evaluated on May 11 had been slaughtered on April 28.

employees were instructed and thereby dedicated to follow up the samples. This ensured that all the fish, filleting, trimming and boxing were handled the same way for all batches. It also ensured that the samples were made according to the regulations all Norwegian producers of food meant for human consumption must comply with.

2.2.2. Storage and sampling

In the sensory study each consumer assessed in one session samples from six batches of cod fillets stored for different number of days. This is referred to as the reversed design method (Hough, 2010). Table 3 illustrates the sample logistics used in one of the cities. The left column shows the dates for slaughtering the fish (storage day = 0). The column headings show the dates when the sensory study took place, including the number of consumers attending. As an example, 40 consumers assessed cod fillets being stored for 2, 7, 9, 11, 13 and 15 days on May 13.

2.2.3. Consumers

Three Norwegian cities were chosen as test locations both due to geography and availability of test facilities (kitchen and cold stores): Tromsø, 68,000 inhabitants, 6th biggest city in Norway is located on the coast in the north of Norway; Hamar, 29,000 inhabitants, 23rd biggest city, in the inland in the south of Norway; and Stavanger, 126,000 inhabitants, 4th biggest city, is located on the coast of western Norway.

The consumers were recruited through various organizations like clubs, dancing groups, choirs and soccer teams. The minimum requirements for participating were regularly buying and consuming fresh fish in general and cod in particular. Since the payment for participation went to the recruiting club/organization and not to each consumer, we experienced a substantial peer pressure for attending. Each attendant received an SMS in the morning on the day they were booked to remind them about the event.

Hough et al. (2006) recommended approximately 100 consumers for sensory acceptability tests and Hough, Calle, Serrat, and Curia (2007) estimated that approximately 120 consumers were necessary for shelf-life estimations based on survival analysis statistics. In each city we recruited 140 consumers, a total of 420 consumers. Due to missing values in one or more questionnaires only the data from 389 of the 420 consumers were included in the analysis. The gender and age of the consumers who participated in the shelf-life study is given in Table 1.

2.2.4. Acceptability test

The acceptability test for shelf-life estimation was organized as a CLT conducted in each city. The test was first run in Tromsø in the first week of May 2009. Since everything in Tromsø worked as planned the test was repeated in the other two cities 3 weeks later. All the tests were administered and run by the Norwegian authors and co-workers.

The consumers were organized in groups of ten to arrive every hour. It took 3–4 days to complete the test in each city. When the group arrived, they were given a brief instruction about what to do and also given an individual number to be written on all questionnaires. No information was given regarding the final objective of the test, only that they were there to test samples of fresh fillets of cod. Once they had received the instructions they were directed to individual tables.

After being placed one at each table, they completed a two page questionnaire. In this study we will use the last three questions of Table 2: frequency of fresh fish consumption, degree of fresh fish expertise and age. The results from these questions were categorized as indicated above for the survey study.

The acceptability test consisted of two parts. First a tasting session of cooked cod fillets done in a temperate room, thereafter an assessment in a cold room of raw cod fillets displayed on an ice-bed without and with information about capture date. No instructions were given about how to assess the products.

2.2.4.1. Tasting cooked fillets of cod. Once the consumers had completed the questionnaire mentioned above they were served the six samples one at a time, all from different storage times as discussed in the reverse storage design (Section 2.2.2). Serving order was random. The six samples were all cut from the thickest part of the fillet and each sample weighed approximately 50 g. After being steam cooked for 12 min (core temperature 70 °C, see NMKL, 2008) in containers of aluminum with closed lids, the samples were immediately transferred to small plastic trays labeled with a three digit number before being served consecutively to each consumer, one sample at a time. Consumers were adjacent to the cooking facilities. After assessing a sample the consumers expressed their acceptance/rejection by ticking whether they would buy a fillet with an equal quality or not. A plastic fork, water, crackers, napkins and spittoons were available at each table and the consumers were encouraged to cleanse their palates between each sample.

2.2.4.2. Raw fillet evaluation without capture date information. After the tasting session consumers were asked to evaluate raw cod fillets displayed in a cold room (temperature set at 10–12 °C, extra clothes were provided if necessary). On each of two tables in the cold room we placed six trays packed with ice, each tray labeled with a 3-digit code, enabling two consumers to do the assessment simultaneously. On each tray, on top of the ice bed, we placed two fillets of cod picked from the same batches used for the tasting session. One fillet was placed skin-side up (the fillets were skinned), the other skin-side down. The displaying of the fillets resembled what is seen in fresh fish counters, with the difference that in this test the consumers were allowed to smell by putting their nose close to the fillet. This is usually not possible when buying fresh fish in retail. We observed that very few consumers actually smelled the fish; the assessment was for the majority only visual. They were not allowed to touch the fillets and they assessed the samples in the order they chose. For each tray the consumers expressed their acceptance/rejection by ticking whether they would buy the fillet or not. We were unable to detect which visual clues consumers used in expressing this decision. The setting was in accordance to general CLT tests.

2.2.4.3. Raw fillet evaluation with capture date information. After finishing the raw fillet evaluation without capture date information, consumers were led out and asked to wait for the next assessment. We exchanged the 3-digit number and put a label showing the capture date on each tray. The trays were shuffled and the consumers were invited back for the second assessment. The reason for this exercise was to disguise the fact that the consumers assessed the same fillets twice. For each tray the consumers again expressed their acceptance/rejection by ticking whether they would buy the fillet or not. The ice bed and low temperature in the cold store secured fillets had consistent quality during the 4 h they were exposed to consumers. All fillets were discarded at the end of each session day. Once finished with the second assessment the participants were followed to the gate to avoid them speaking to the consumers waiting to enter the cold room.

2.3. Data analysis

2.3.1. Time-to-eat and time-to-buy data

For the survey data we were interested in estimating the time-to-buy after a fish had been captured and, once bought, how long would they be willing to keep it at home before cooking and eating it. The models to estimate these times are basically the same as those presented by Hough (2010) for shelf-life estimations based on survival analysis statistics.

The buying probability $B(t_{buy})$ can be defined as the probability of a consumer willing to buy fresh fish beyond time t, that is $B(t_{buy}) = P(T_{buy} > t_{buy})$. Analogously, the eating probability $E(t_{eat})$ is the probability of a consumer willing to eat the fresh fish after having it at home beyond time t_{eat}, that is $E(t_{eat}) = P(T_{eat} > t_{eat})$. For the evaluation of these times a log-linear model is often chosen:

$$Y = \ln(T_{buy}) = \mu_{buy} + \sigma_{buy} W, \tag{1}$$

where W is the error term distribution.

In Klein and Moeschberger (1997) or Meeker and Escobar (1998) different possible distributions for T are presented, for example the log-normal, normal or the Weibull distribution. In case of the former, W is the standard normal distribution, in case of the Weibull distribution, W is the smallest extreme value distribution.

If the log-normal distribution is chosen for T_{buy}, the buying probability $B(t_{buy})$ is given by:

$$B(t_{buy}) = 1 - \Phi\left(\frac{\ln(t_{buy}) - \mu_{buy}}{\sigma_{buy}}\right), \tag{2}$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function, and μ and σ are the model's parameters.

In the time-to-buy and time-to-eat survey, respondents were also asked how often they consumed fresh fish, to what degree did they consider themselves as fresh fish experts and their age (Table 2). To analyze whether these variables influenced time-to-buy the following log-linear regression model with inclusion of covariates was applied (Klein & Moescherger, 1997; Meeker & Escobar, 1998). Its form is analogous to Eq. (1):

$$Y = \ln(T_{buy}) = \mu_{buy} + \sigma_{buy} W = \beta_0 + \beta_1 Z_{frequency} + \beta_2 Z_{expertise} + \beta_3 Z_{middle} + \beta_4 Z_{young} + \text{Interactions} + \sigma_{buy} W, \tag{3}$$

where:

- T_{buy} is time-to-buy after a fish has been captured,
- β_{0-4} are the regression coefficients to be estimated by the regression model,
- $Z_{frequency}$: 0 if consumer's buying frequency was often, 1 if rarely,
- $Z_{expertise}$: 0 if consumer's degree of expertise was high, 1 if low,
- Z_{middle}: 1 if consumer's age was middle, 0 if aged or young,
- Z_{young}: 1 if consumer's age was young, 0 if aged or middle,
- Interactions: due to having four covariates only two-way interactions among the previous covariates were considered,
- σ_{buy} is the shape parameter, which does not depend on the covariates,
- W is the error distribution.

The time-to-eat equation was similar to Eq. (3) but with the addition of an extra covariate: time-to-buy. We considered that the time a consumer kept the fresh fish at home before cooking and eating it could be influenced by the time-to-buy after capture. A covariate is generally additional background information about the experimental units. When a consumer has fresh fish in the refrigerator, his/her decision as to when to cook and eat it can depend on his/her knowledge of the fish's capture date; this last can thus be considered background information. Regarding the way time-to-buy can influence time-to-eat there are basically two possibilities:

(a) If a consumer was fussy and was only willing to buy very fresh fish, then this consumer would get home and cook/eat the fish the same day; alternatively,
(b) if a consumer bought fish that was not that fresh, then this consumer would get home and cook/eat the fish the same day as he/she knew when he/she bought the fish that it was not that fresh.

When analyzing shelf-life data, the exact storage time at which a consumer rejects a sample is rarely observed. This leads to censored data (Hough, 2010). When asking a consumer about time-to-buy after capture, the response is considered as exact time. In this case there is no censoring.

For time-to-eat some consumers answered that the last day they would prepare and consume the fish was the same day they had bought it. Considering that dinner in Norway is generally before 6 pm, this preparing and eating would occur between time = 0 (buying the fish) and time = 8 h = 0.33 days. Thus data from these consumers was considered as left censored with time-to-eat $\leqslant$ 0.33 days. The times-to-eat of the rest of the consumers were considered as exact.

2.3.2. Shelf-life data

The survival analysis model presented by Hough (2010) was used to estimate shelf life. In food shelf life studies, samples with different storage times are presented to consumers. Assume that we define a random variable T_{reject} as the storage time at which the consumer rejects the sample. The rejection function $F(t_{reject})$ can be defined as the probability of a consumer rejecting a product before time t, that is $F(t_{reject}) = P(T_{reject} \leqslant t)$. As shown in Section 2.3.1, for the evaluation of these times a log-linear model is often chosen:

$$Y = \ln(T_{reject}) = \mu_{reject} + \sigma_{reject} W,$$

where W is the error term distribution.

If the log-normal distribution is chosen for T_{reject}, the rejection probability $F(t_{buy})$ is given by:

$$F(t_{reject}) = \Phi\left(\frac{\ln(t_{reject}) - \mu_{reject}}{\sigma_{reject}}\right), \tag{4}$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function, and μ and σ are the model's parameters.

Previous to the acceptability tests consumers were asked how often they consumed fish, to what degree did they consider themselves as fresh fish experts and their age (Table 2). These variables and the city where the test was being held were included as covariates in the model. The evaluation stage was considered as an explanatory factor:

– tasting cooked cod fillets without capture date information,
– assessing raw cod fillets without capture date information, and
– assessing raw cod fillets with capture date information.

To analyze whether these variables influenced rejection time the following log-linear regression model with inclusion of covariates and explanatory factor was applied (Klein & Moescherger, 1997; Meeker & Escobar, 1998):

$$Y = \ln(T_{\text{reject}}) = \mu_{\text{reject}} + \sigma_{\text{reject}}W = \beta_0 + \beta_1 Z_{\text{frequency}} + \beta_2 Z_{\text{expertise}} + \beta_3 Z_{\text{middle}} + \beta_4 Z_{\text{young}} + \beta_5 Z_{\text{stav}} + \beta_6 Z_{\text{trom}} + \beta_7 Z_{\text{cooked}} + \beta_8 Z_{\text{raw-yes}} + \text{Interactions} + \sigma_{\text{reject}}W, \tag{5}$$

where:

- T_{reject} is the time after capture that the fish is rejected,
- $\beta_{0\text{–}8}$ are the regression coefficients,
- $Z_{\text{frequency}}$: 0 if consumer's buying frequency was often, 1 if rarely,
- $Z_{\text{expertise}}$: 0 if consumer's degree of expertise was high, 1 if low,
- Z_{middle}: 1 if consumer's age was middle, 0 if aged or young,
- Z_{young}: 1 if consumer's age was young, 0 if aged or middle,
- Z_{stav}: 1 if the consumer was from the city of Stavanger, 0 if from Hamar or Tromsø,
- Z_{trom}: 1 if the consumer was from the city of Tromsø, 0 if from Hamar or Stavanger,
- Z_{cooked}: 1 if the evaluation stage was on the cooked fillets without capture date information, 0 if the evaluation stage was on the raw fillet,
- $Z_{\text{raw-yes}}$: 1 if the evaluation stage was on the raw fillet with capture date information, 0 if the evaluation stage was on cooked fish or on the raw fillet without information,
- interactions: due to having five variables only two-way interactions among the previous variables were considered,
- σ_{reject} is the shape parameter, which does not depend on the variables,
- W is the error distribution.

In the case of the evaluation stage explanatory variable there were three stages: cooked without information, raw without information and raw with information. In the regression model these three stages are expressed as two variables: Z_{cooked} and $Z_{\text{raw-yes}}$.

2.3.3. Software and model checking

The buying, eating and rejection probabilities were estimated using the CensorReg procedure from the TIBCO Spotfire S + statistical software (TIBCO Inc., Seattle, WA). A log-likelihood test (Meeker & Escobar, 1998) was used to test the significance of the different covariates and explanatory variable and interactions corresponding to each model (Eqs. (3) and (5)). A 5% significance level was considered. The lowest absolute log-likelihood value was taken as criteria in choosing between the Weibull, log-normal or normal distributions (Hough, 2010).

3. Results

3.1. Time-to-buy and time-to-eat survey

As mentioned in Section 2.1 a total of 3000 questionnaires were placed in the shops; and a total of 419 questionnaires were completed and sent back, representing a 14% response rate.

For the time-to-buy (Eqs. (2) and (3)) the age × frequency-of-consumption and age × degree-of-expertise interactions were significant; thus the three main effects and these two interactions were considered in the final model. The log-normal distribution had the lowest log-likelihood in comparison to the normal and Weibull distributions (Hough, 2010). The β coefficients corresponding to Eq. (3) were: $\beta_0 = 0.66$, β_1: −0.09 (frequency-rarely), β_2: 0.28 (expertise-low), $\beta_3 = 0.29$ (age-middle), β_4: 0.65 (age-young), β_5: 0.18 (age-middle, frequency-rarely), β_6: 0.06 (age-young, frequency-rarely), β_7: −0.33 (age-middle, expertise-low), and β_8: −0.38 (age-young, expertise-low). The σ_{buy} value was = 0.47. These coefficients, together with the Z values (Eq. (3)) were used to calculate the 12 μ values of Eq. (2) corresponding to each combination of age (elder, middle, young), frequency (often, rarely) and expertise (low, high). The resulting 12 buying probability curves are shown in Fig. 1. Fig. 1 shows that in general the age differences were more pronounced when degree of expertise was high; the elder wanted the fish to be fresher (less time elapsed since capture) than the middle aged and young. Frequency of consumption had lesser influence.

Fig. 1 can serve two purposes. For example, if an elder consumer, who buys fresh fish often and considers that his/her degree of expertise is high, wants to buy fish and is presented with a specimen labeled as having been captured 2 days ago, there is a 57 ± 7% probability that he/she will buy it. Furthermore if we demand a 75% buying probability, the time-to-buy estimate for middle aged consumers, who buy fish rarely and consider themselves to have low expertise is 2.04 ± 0.35 days.

In shelf-life studies the storage time has been estimated considering 50% of the consumers rejecting the product (Cardelli & Labuza, 2001; Hough, 2010). It should be noted that this means that in general retail practice only few consumers actually buy and taste food products close to the end of their shelf life, and of these few consumers 50% of them will reject the product. In estimating time-to-buy the situation is different as a 50% buying probability would be too low. Considerations of the probability of a consumer buying the fish on a certain date after capture are not the same as considerations on the probability of the consumer rejecting a product at the end of its shelf life. Thus a 75% buying probability was considered and these time-to-buy values are plotted in Fig. 2.

For the time-to-eat data there were four covariates: time-to-buy, frequency of consumption, degree of expertise and age; and their two-way interactions. The significant effects were time-to-buy, age and the time-to-buy × age interaction. The normal distribution had the lowest log-likelihood in comparison to the log-normal and Weibull distributions (Hough, 2010). The β coefficients corresponding to the Eq. (3)-type model were: $\beta_0 = -0.55$, β_1: 0.59 (time-to-buy), β_2: 0.36 (age-middle), β_3: 1.24 (age-young), β_4: −0.08 (age-middle, time-to-buy), and β_5: −0.29 (age-young, time-to-buy). The σ_{eat} value was = 1.09. The age covariable was categorical with three levels: elder, middle and young. The time-to-buy covariable was continuous, thus it could take any value >0. Fig. 3 shows eating probability versus time after having bought the fish for consumers who had a time-to-buy = 2 days and 4 days after capture. An example to aid interpretation of Fig. 3 would be: for an elder consumer who had bought a fish 2 days after capture, there is a 37 ± 7% probability that he/she would keep the fresh fish 1 day at home before eating it.

3.2. Shelf-life estimation

For the shelf-life data estimation there were five variables (Eq. (5)): frequency of consumption, degree of expertise, age, city and evaluation stage. The only significant effects were city and evaluation stage. The log-normal distribution had the lowest log-likelihood in comparison to the normal and Weibull distributions (Hough, 2010). The β coefficients corresponding to Eq. (5) model were: $\beta_0 = 2.74$, β_1: 0.04 (evaluation stage-raw without information), β_2: −0.46 (evaluation stage-raw with information), $\beta_3 = -0.06$ (city-Stavanger), β_4: 0.05 (city-Tromsø). The σ_{reject} value was = 0.44.

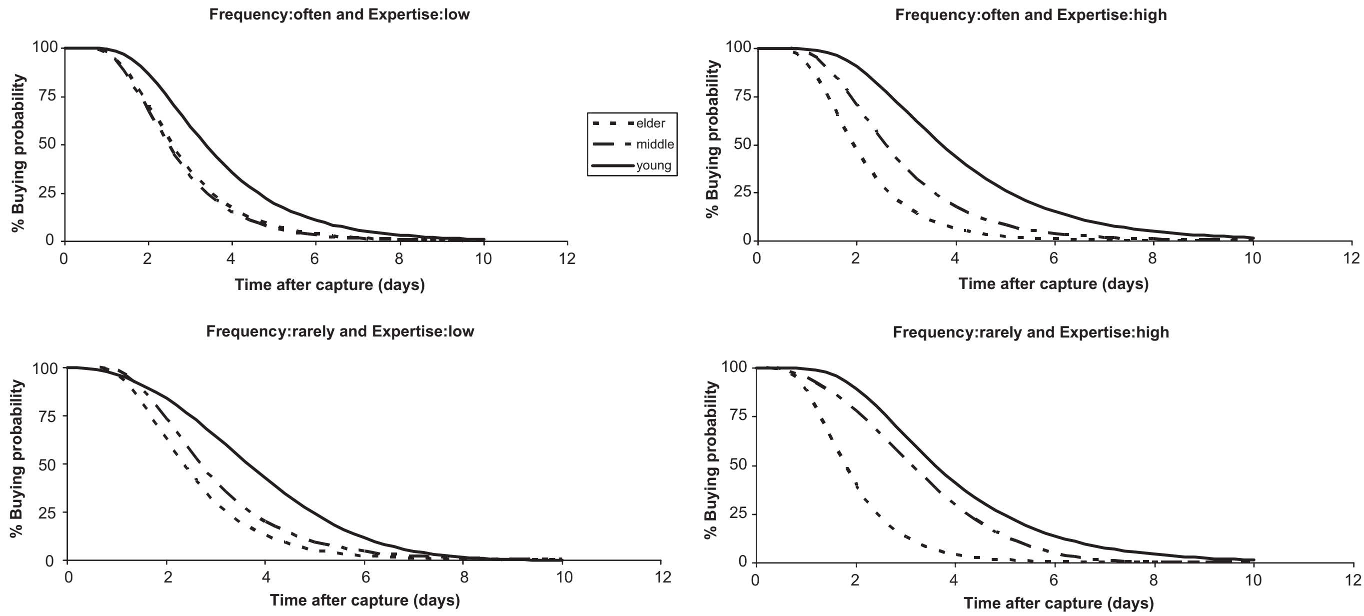

Fig. 1. Buying probability versus time after capture for different age groups, frequency of consumption and degree of expertise.

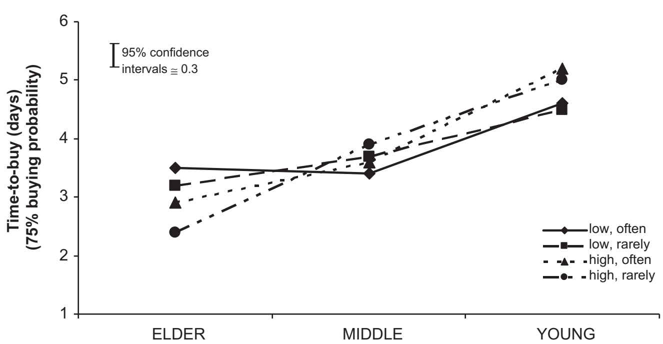

Fig. 2. Time-to-buy corresponding to a 75% buying probability for consumers from different age groups, frequency of buying fish and degree of expertise.

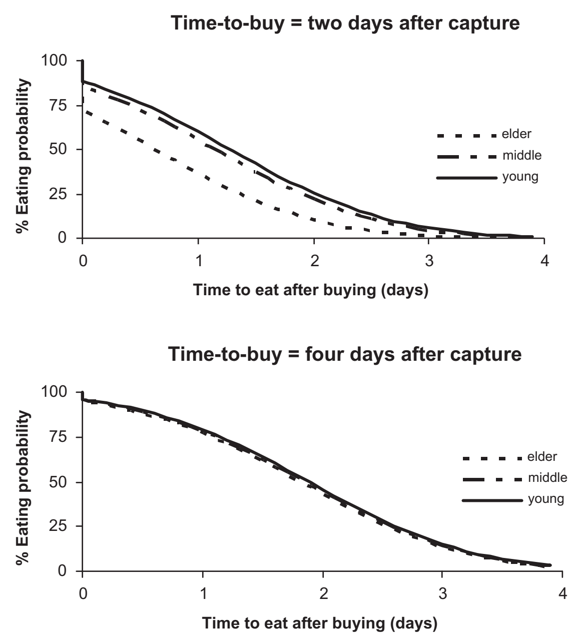

Fig. 3. Eating probability versus time after buying for consumers who bought the fish 2 days and 4 days after capture; and for different age groups.

[Fig. 4](#) shows rejection probability versus storage time for one of the three evaluation stages: raw fillets without capture date information. The overall city effect was statistically significant ($P < 5\%$), however the magnitude of the differences between cities was small. This small difference between cities was also noted for the other evaluation stages: cooked without capture date information and raw with capture date information.

The percentiles corresponding to each city can be compared by calculating the confidence interval of the differences. The confidence interval (CI) for the difference between storage times corresponding to two cities is (Curia et al., 2005)):

$$\mathrm{CI} = \text{storage-time}_{\ \mathrm{City1}} - \text{storage-time}_{\ \mathrm{City2}} \pm Z_{(1-\alpha/2)}\mathrm{se}_{\mathrm{difference}} \tag{6}$$

where $Z_{(1-\alpha/2)}$ is the $(1-\alpha/2)$ quantile of the standard normal distribution and, $\mathrm{se}_{\mathrm{difference}}$ is the standard error of the storage time difference, calculated by the following equation:

$$\mathrm{se}_{\mathrm{difference}} = \sqrt{\frac{1}{2}\frac{n_1+n_2}{n_1 n_2}}\sqrt{\mathrm{se}^2_{\mathrm{City1}}n_1 + \mathrm{se}^2_{\mathrm{City2}}n_2} \tag{7}$$

n_1 and n_2 are the number of consumers corresponding to each city, and $\mathrm{se}_{\mathrm{City1}}$ and $\mathrm{se}_{\mathrm{City2}}$ are the standard errors of the storage-time estimations of each city. As an example calculation we consider Hamar to be City 1 and Stavanger City 2. For a 50% rejection

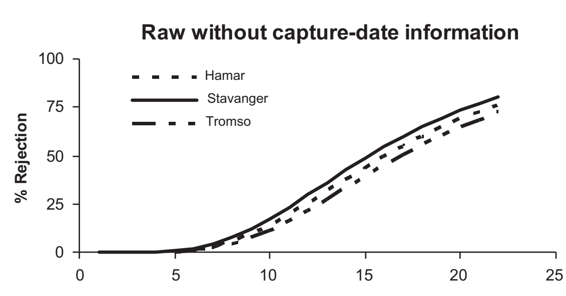

Fig. 4. Rejection probability versus storage time for the evaluation of raw cod fillets without capture date information in three Norwegian cities.

probability (Hough, 2010), for the two cities and for the raw-without-information evaluation stage, we obtained the following values of storage times ± se:

– Hamar: 16.2 days ± 0.75.
– Stavanger: 15.2 days ± 0.70.

Introducing these values in Eqs. (6) and (7) gave:

$$CI = 16.2 - 15.2 \pm 1.96 \times 1.02 = 1 \pm 1.99$$

As this confidence interval includes zero, we concluded that there were no significant differences between the 50% percentiles corresponding to these two cities and at this evaluation stage. All other percentile comparisons between cities were non-significant, thus this effect was eliminated from the model. The resulting β values corresponding to the log-normal distribution were: $\beta_0 = 2.73$, β_1: 0.05 (evaluation stage-raw without information), β_2: -0.45 (evaluation stage-raw with information). The σ_{reject} value was = 0.45.

Fig. 5 shows rejection probability versus storage time for each one of the evaluation stages. When consumers evaluated the fish without capture-date information, whether they evaluated the fish eating it cooked or looking at it raw, their probability of rejection was similar and significantly lower than when they evaluated the fish with capture-date information. In shelf-life studies storage time has been estimated considering 50% consumers rejecting the product (Hough, 2010). It should be noted that this means that in general retail practice only few consumers actually buy and taste food products close to the end of their shelf life, and of these few consumers 50% of them will reject the product. Considering this, Table 4 shows the storage-time estimates corresponding to 25% and 50% rejection probabilities for each one of the evaluation stages. When looking at the 25% rejection probability we see that the tasting session (cooked without capture-date information) resulted in an estimated storage time of 11 ± 0.7 days. When given capture date information (raw with capture date information) the estimated storage time dropped to 7 ± 0.4 days. The results when using a 50% rejection probability was 15 ± 1 days and 10 ± 0.5 days, respectively.

4. Discussion

The type of survey used in this study was similar in methodology to a classical mail survey. Reported response rates for food-related mail surveys vary: Lusk and Sullivan (2002) a 14% for a survey on genetically modified foods; Jaeger, Danaher, and Brodie (2009) a 16% for a study on wine purchase decisions and consumption behaviors; Trondsen et al. (2004) a 53% for a research on health and seafood consumption patterns; and Wansink, Sonka, and Park (2004) a 48% in their study on food consumption patterns. Thus the response rate obtained in the present study was within these ranges, yet low. The low value could be due to subjects not receiving the questionnaire compulsively, rather they chose to pick it up or not from a stand, and also there was no means of insisting on a response with a follow-up letter.

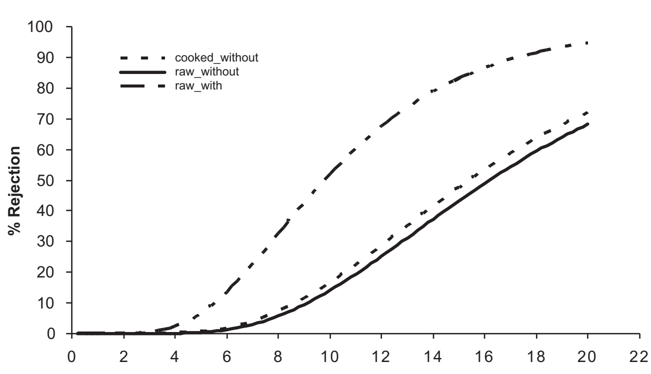

Fig. 5. Rejection probability versus storage time for the evaluation of raw and cooked fish, with and without capture-date information.

Table 4
Estimated storage-time values corresponding to 25% and 50% rejection probabilities for evaluation of raw and cooked fish, with and without capture-date information.

Evaluation stage	Estimated storage-time (days) ± 95% confidence intervals	
	25% of rejection	50% of rejection
Cooked without capture-date information	11 ± 0.7	15 ± 1
Raw without capture-date information	12 ± 0.8	16 ± 1.2
Raw with capture-date information	7 ± 0.4	10 ± 0.5

Elder consumers who considered themselves as having high degree of expertise had lower time-to-buy values (more fresh) than those elder consumers who considered themselves as having low degree of expertise. Middle-aged consumers who bought fresh fish often had lower time-to-buy values (more fresh) than those middle-aged consumers who bought fish rarely. Young consumers were not affected by degree of expertise or by buying frequency; overall their times-to-buy were higher (less fresh) than the elder.

A general comparison shows that consumers being fussy about buying their fish 2 days after capture were also fussy about not wanting to keep the fish long at home before cooking and eating it. Consumers who were willing to buy the fish 4 days after capture were also willing to keep the fish longer in their homes before cooking and eating it. This difference was more pronounced for the elder compared to middle and young aged consumers.

Summarizing, when elder respondents were asked which was the last day they would be willing to buy cod after capture, there was a 75% probability that this would be approximately 3 days (Fig. 2); for young respondents this time was approximately 5 days. There was a 75% probability that these consumers would have the fish approximately 1 day at home before cooking and eating it (Fig. 3).

Regarding shelf-life, it is well known that the quality of fresh seafood is dependent upon a number of factors (i.e., Rotabakk, Skipnes, Akse, & Birkeland, 2011). Chilling and maintenance of low storage temperature is probably the single most important contributor to an extended shelf life (i.e., Kaale, Eikevik, Rustad, & Kolsaker, 2011). In the acceptability (shelf life) experiment in this study, all samples were equally treated, stored at 0 °C, and storage time was the only factor to be varied.

The results from the consumer panel are in accordance with the results using sensory panels, although depending on the rejection probability to be used (Table 4). Using a rejection probability of 25% results in a shelf life of approximately 11 days when no capture date information was given. Bonilla et al. (2007) reported a shelf life for cod fillets kept on ice of 8 days, and Magnusson and Martinsdóttir (1995) shelf lives of cod fillets between 10 and 12 days depending on previous frozen storage. However, when capture-date information was available, the shelf-life, as determined by the consumers, decreased to approximately 7 days. The hypothesis stated in the introduction that capture date information could influence perceived freshness of fish was confirmed. Wansink and Wright (2006) showed a similar effect for yogurt.

In general, when respondents were asked which was the last day they would be willing to buy cod after capture or slaughter, this time was shorter than the shelf life measured in the acceptability test. It was also a pronounced drop in acceptability (shelf-life) when the products to be assessed carried capture date information compared to products with no such information.

The overall conclusion was that if legislation is introduced, as it was in Norway, whereby consumers are informed of a fresh fish's capture date, there will be a conflict between the last day a consumer is willing to buy the fresh fish and the time the fresh fish is acceptable from a sensory perspective. One way to reduce this conflict is to inform consumers on sensory and microbiological shelf life of fish before introducing capture date legislation. This way the consumers may be more willing to accept buying fish that has been caught in a time more in accordance with true sensory changes.

Acknowledgments

We would like to thank colleagues Mats Carlshög, Guro Eilertsen and Ingelinn Eskildsen Pleym in Tromsø for superb support in accomplishing the sensorial study. We are also most thankful to the Fishery and Aquaculture Industry Research Fund in Norway for funding the project.

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