Development of a Quality Index Method (QIM) for Maatjes Herring Stored in Air and Under Modified Atmosphere

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ABSTRACT. The aim of the study was to develop a Quality Index Method (QIM) scheme for maatjes herring stored in air and under a modified atmosphere at 4°C and 10°C. The attributes included in this new scheme are: appearance of skin side and bone side, color of the blood, odor (rancidity and other), taste (rancidity and other), aftertaste and texture. The QIM scheme developed proved to be potentially useful in evaluating and defining the quality of maatjes herring stored in air and under modified atmosphere. Since natural variations and processing of maatjes herring limit the use of the QIM scheme, the scheme must be specified taking the product-specific differences and storage conditions more in detail into account.

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INTRODUCTION

Maatjes herring is a lightly salted and fermented ready-to-eat fish product that is very popular in The Netherlands. The term "maatjes" refers to herring caught just before its first spawning between May and July and is characterized by a distinct level of sub-cutaneous fat of 16-20%. After being caught, the herring is partly gutted and cured. The remaining intestines produce enzymes, which stimulate a fermentation process resulting in the typical maatjes product characteristics. After brining, the fish undergoes a ripening period up to one day and it is then vacuum-packaged and stored frozen until further use. The product is thawed, filleted and sold unpacked or packaged under modified-atmosphere (MAP) and stored at chilled temperatures.

Sensory quality among other aspects determines consumer acceptance for maatjes herring as for fresh fish. The Quality Index Method (QIM) is a system for measuring the degree and rate of change in important characteristic product criteria and in the sum total of these changes, which can be interpreted into equivalent days of storage and remaining shelf life (Hyldig et al., 2004). During recent years, QIM has been developed for several fish species with regard to their intactness (whole, gutted, fillets) and technological treatment (raw, chilled, frozen, thawed, cooked). There are QIM schemes for: cod (*Gadus morhua*) including thawed, whole cod (Nielsen et al., 1994; Warm et al., 1998); raw, whole cod (Jónsdóttir et al., 1999); raw, gutted cod (Martinsdóttir et al., 2001); thawed, fillet cod (Nielsen et al., 1994; Warm et al., 1998); raw, whole Gilthead seabream (*Sparus aurata*) (Huidobro et al., 2000); raw, whole herring (*Clupea harengus*) (Martinsdóttir et al., 2001); raw, whole, farmed salmon (*Salmon salar*) (Sveinsdottir et al., 2002; Sveinsdottir et al., 2003); and raw octopus (*Octopus vulgaris*) (Barbosa and Vaz-Pires, 2003). QIM is based on a scheme originally developed by the Tasmanian Food Research Unit (Bremner, 1985). In the scheme, significant freshness-dependent sensory attributes, which define the characteristic quality of a particular fish product, are selected. They are precisely described during the storage of the fish from their initial stage through their change. Scores, assigned in whole numbers ranging from 0 for fresh to 3 for spoiled are allocated for each attribute. The more distinctive the changes are during the storage time, the higher score can be given for a single parameter (Hydlig and Nielsen, 1997). The sum of the evaluated points according to the QIM scheme is presented as the Quality Index (QI). The QI calculated for each time of sampling during the storage increases linearly with storage time.

The aim of this study was to develop a Quality Index Method (QIM) scheme specifically suited to the quality grading of maatjes herring. To the knowledge of the authors, a dedicated sensorial quality scheme has never been developed for this kind of fish product.

MATERIALS AND METHODS

Maatjes Herring: Herring (*Clupea harengus*) were caught in the North Sea at the Norwegian coast area in May-June 2002 and 2003, respectively. On board of the ship the fish were stored in chilled seawater. The ungutted but beheaded fish of 70-80 g were tube brined by a processor in Norway resulting in a NaCl concentration of 2.0% (w/w) in the final product. After a ripening process up to one day the fish were vacuum-packaged (each package consisting of 17 kg fish and 3 kg brine) and frozen in a tunnel with an air temperature of −40°C. After transport to The Netherlands, the packages were stored at −25°C. For further processing, the fish were thawed for 24 hours and machine filleted (Fieret, Barneveld, The Netherlands). For packaging the fish under modified atmosphere, one filleted fish at a time of approximately 75 g was placed in a polypropylene tray using Sealpac packaging machine (Ultrapak, Dronten, The Netherlands). The applied modified atmosphere contained 30% CO_2 and 70% N_2.

Immediately after processing, the unpacked and modified-atmosphere-packaged samples were transported to the laboratory and stored at 4°C and 10°C up to six days. Three series of storage experiments (I-III) were carried out in November 2002, February 2003 and June 2003, respectively. The fish in experiments I and II were caught in May-June 2002 and in experiment III in May-June 2003. The maatjes herring in experiment I was stored in air and in experiment II and III under modified atmosphere. A total of 144 herrings were used: 24 for the training and 120 for all experiments. At each sampling time, two fishes, respectively, of each temperature were taken twice a day for sensory analysis. Herring stored 1, 2, 3, and 4 days in air were analyzed during experiment I (total of 16 samples for each temperature). In experiment II samples (total of 20 samples for each temperature) were analyzed at 1, 2, 3, 4, and 5 days storage and in experiment III (total of 24 samples for each temperature) at 1, 2, 3, 4, 5, and 6 days storage under modified atmosphere.

Quality Index Method (QIM). Preliminary Observation: To develop the QIM scheme, panelists from the sensory panel at the Netherlands Institute for Fisheries Research who were familiar with the principles of sensory analysis (Luten et al., 1994a; Luten et al., 1994b) were selected. The maatjes herring was stored five days at 0°C and was tested in nine sessions twice a day during the storage. Changes observed in appearance, odor, taste, texture and aftertaste were listed in a preliminary scheme. The attributes were described and the scheme was set up with scores according to the principles of existing QIM schemes.

Development of the QIM Scheme and Training of the Sensory Panel: The preliminary scheme was used for further development of the scheme and training of the panelists in four sessions. In each session, six unpacked and modified-atmosphere-packaged maatjes herring from different retailers and of varying freshness were observed. Changes in the scheme were made in order to describe the attributes more precisely and to emphasize the differences between the unpacked and the modified-atmosphere-packaged product. Suggestions of improvements by the panel members were included in the final scheme. The panelists were trained further using the final scheme in evaluating both fish products included in this study.

In order to estimate the quality of the herring it is necessary to develop the Quality Index (QI) over storage time (hours). This is shown in the so-called calibration curve being a linear regression of the QI scores over the storage time. The linear model was used in previous QIM schemes (Luten and Martinsdóttir, 1997).

Application of the QIM in This Study: Five trained panelists participated in the sensory evaluation of this study. In the QIM scheme for maatjes herring stored in air and under modified atmosphere the following attributes and their changes during storage time were assessed: appearance of skin side and bone side, color of the blood, odor (rancidity and other), taste (rancidity and other), aftertaste and texture. Demerit points were given for each attribute according to the descriptions, ranging from 0 to 3 for appearance, color of the blood, odor and taste and 0 to 2 for texture and aftertaste (Table 1). After the assessment of appear-

TABLE 1. The QIM scheme developed for maatjes herring stored in air and under modified atmosphere.

Quality parameters		Attributes	Demerit points
Appearance	Skin side	White-silver, creamy-white, light-brown, shiny	0
		Light-grey, light-creamy, light-brown, matt	1
		Grey, creamy, some yellow, brownish, matt, light aubergine	2
		Dark grey, yellow, brownish, matt, aubergine, green	3
	Bone side	Creamy-white, clear, shiny, translucent	0
		(Creamy) white, clear, less shiny, grey	1
		Creamy, matt, grey, light-brown, margins get darker	2
		Green, aubergine, brown, pink, margins get darker	3
	Color of the blood	Fresh-red	0
		Red-brown	1
		Brown-red	2
		Brown	3
Odor	Rancidity	Not rancid	0
		Little rancid	1
		Rancid	2
		Very rancid	3
	Others	Marine, fresh seaweedy, fresh, fresh fish	0
		Less marine, fresh seaweedy, watery	1
		Light sour, prickly, like wet carton, musty, rotten egg	2
		Light sour, prickly, like wet carton, musty, rotten egg, rancidity is dominating	3
Taste	Rancidity	Not rancid	0
		Little rancid	1
		Rancid	2
		Very rancid	3

TABLE 1 (continued)

Quality parameters		Attributes	Demerit points
	Others	Salty, metal, creamy	0
		Light sour, salty, light butter, watery	
		Sour, bitter, like wet paper, light musty, rotten egg	2
		Sour, bitter, like wet paper, light musty, rotten egg, rancidity is dominating	3
Texture	Texture	Firm, good bite, tender	0
		Grainy, mealy, fibrous	1
		Soft, mushy	2
Aftertaste	Aftertaste	Marine, metal, creamy	0
		Fatty, light bitter, light sour	1
		Bitter, sour, salty, rotten flower water	2
		Quality Index Total	**0-25**

ance and odor, the samples were cut in pieces and assessed on texture, taste and aftertaste. The panel evaluated in each session two samples per storage temperature and one control sample served in a random order. The control sample was thawed before each session. For each sample, one fish with one fillet showing the skin side and the other the bone side was placed on a plate on ice 10 minutes before the evaluation and kept at constant temperature. All observations were conducted individually under standardized conditions with as few interruptions as possible. The samples were coded with a randomized three-digit code unrelated to storage temperature and observed under day light conditions using lamps of > 5000 K.

Statistical Data Analyses: Multivariate analysis of scores for the different parameters assessed with QIM was carried out with the statistical program Unscrambler® (version 6.11, CAMO ASA, Trondheim, Norway) with principal component analysis (PCA). The variables were scaled prior to the statistical analysis: each element in the matrix was multiplied with the inverse of the standard deviation of the corresponding variable when variables had different ranges. A fully crossed validation method was used, i.e., as many sub-models were calculated as there were samples, where the samples, one at a time, were kept out of the calculation. The squared difference between the predicted and real *Y*-values for each omitted sample was averaged, thus giving an estimate of the prediction variance (Esbensen et al., 1998).

The correlation coefficient (R^2) of linear regression was calculated for the QIM scores against the storage time using Microsoft® Excel 2000 (Microsoft Corporation, Redmond, WA, USA).

RESULTS AND DISCUSSION

During the development of the QIM scheme, scores were omitted or added and some changes in the selection of the words were made to describe the changes more precisely in color of skin and bone side, odor and taste of rancidity and aftertaste. After the development, the maximum sum of the demerit points was 25 (Table 1) describing nine attributes in the following categories: appearance, odor, taste, texture and aftertaste. Note that 25 demerit points is the maximum score of the QIM scheme, the limit for sensory rejection is typically much lower. In the present study, for the first time the taste has been included in a QIM scheme resulting in an extensive scheme. In the previous schemes mostly raw unprocessed fish has been studied in which the taste did not play a role (Nielsen et al., 1994; Warm et al., 1998; Jónsdóttir et al., 1999; Martinsdóttir et al., 2001; Sveinsdottir et al., 2002; Barbosa and Vaz-Pires, 2003). Maatjes herring is a processed fish product that is ready-to-eat and the taste and also the texture are very important sensory parameters available for quality determination.

During the development of the QIM scheme, the aim was to obtain a regression line beginning at the origin (0,0). This was not reached in experiments I-III (Figures 1-3). The product quality of maatjes herring is influenced by many factors, both natural and processing related. The fat content in the herring flesh depends on the time and place of catching, and this influences taste, odor, texture and shelf-life of the maatjes herring (Wurziger, 1977). The herring of this study were caught between May and July and the high levels of fat typical for this season can cause intercepts values higher than 0. In experiment II, the texture was assessed by the sensory panel as very soft. The texture of maatjes herring varies from product to product due to differences in the ripening process (Luten et al., 1994a; Luten et al., 1994b; Nielsen and Børresen, 1997; Olsen and Skåra, 1997). Sensory analyses at the Netherlands Institute for Fisheries Research showed that gibbed herring was more tender and

FIGURE 1. Average QIM scores of each sampling time analysed versus storage time (hours) for maatjes herring stored under air (experiment I) at 4°C and 10°C.

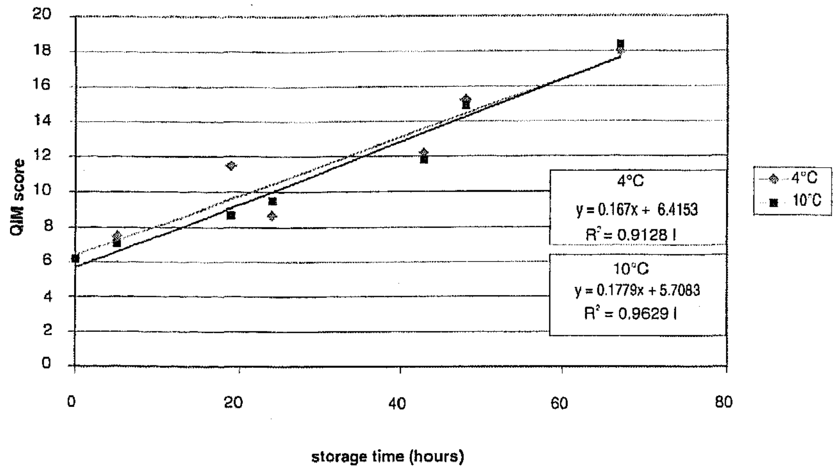


FIGURE 2. Average QIM scores of each sampling time analysed versus storage time (hours) for maatjes herring stored in modified-atmosphere (experiment II) at 4°C and 10°C.

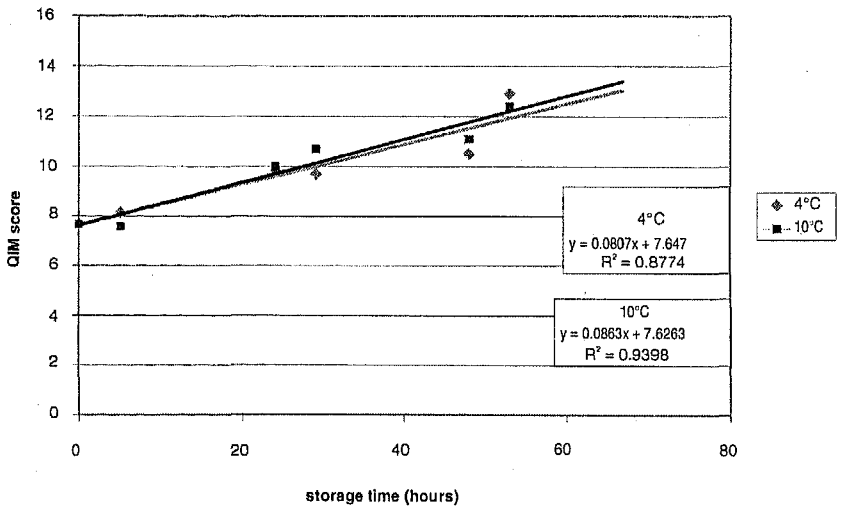
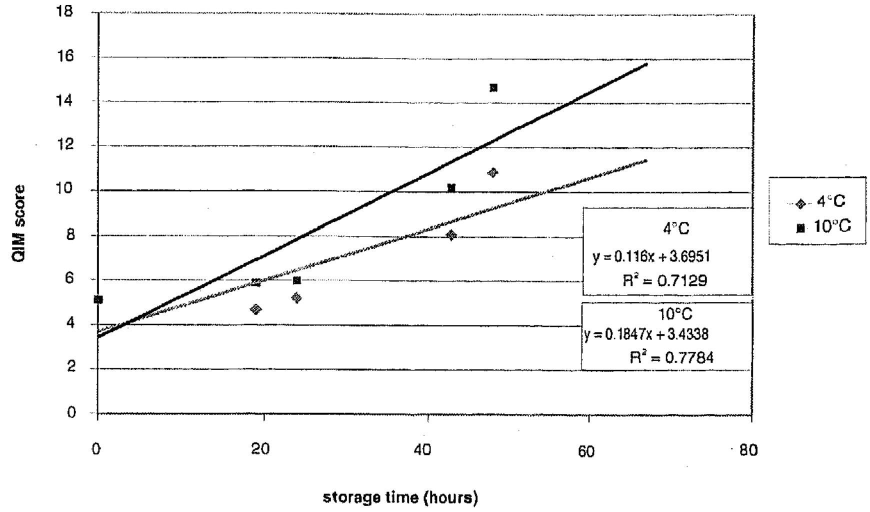


FIGURE 3. Average QIM scores of each sampling time analysed versus storage time (hours) for maatjes herring stored in modified-atmosphere (experiment III) at 4°C and 10°C.



weaker than gutted herring (Luten et al., 1994a; Luten et al., 1994b). It is believed that endogenous intestinal proteases, released from the parts of viscera left in the fish, cause the hydrolysis of muscle proteins, thus creating a softer texture (Nielsen and Børresen, 1997). Olsen and Skåra (1997), studying ripened products of deheaded or gutted North Sea herring, concluded that intestinal enzymes are the major cause of the development of the characteristic taste and texture. The herrings in this study were deheaded and ungutted and the intestinal enzymes might be the reason for the soft texture causing the high intercepts values.

Evaluation of the calibration curves showed no significant differences between the calibration curves of experiments I and II for both temperatures. It is known that in spoilage of fish, enzymatic and chemical processes alter the quality during the first storage period. Autolytic enzymes from the fish tissue have major impact on textural deterioration. Microorganisms are involved at a later storage stage in the spoilage and cause the characteristic off-odors and off-flavors (Truelstrup Hansen et al., 1996). Temperature controls the rate of both enzymatic and bacterial spoilage; the higher the temperature the faster the fish spoils. However, in chilled herring enzymatic changes may precede and predominate bacterial spoilage (Huss, 1995). Shelf-life at a storage temperature of below 4°C of the unpacked herring (experiment I) is limited to one day and for the modified-atmosphere-packaged products (experiment II) to five days when sold after the season (July-April) according to the producers. The bacteria level in the rejected samples was low (data not shown) and storage temperature seems to have little or no effect on the enzymatic reactions resulting in similar regression lines for 4°C and 10°C.

During the storage period, all parameters of the sensory analysis showed consistent changes that varied from each other. In order to understand these changes better, the results were analyzed with principal component analysis (PCA) (Figures 4-6). The first Principal Component axis (PC1) defined the variation between the samples observed with the storage time. PC1 explained 49%, 29% and 36% of the variation of the samples in experiments I, II and III, respectively. All variables in the QIM scheme were located on the right side of the PC1. According to the PCA analysis in experiment I, rancid taste is the most pronounced sensorial change. Oxygen is known to be responsible for the oxidation of fat and, therefore, rancidity is the major spoilage indicator for air-stored maatjes herring. In experiment II changes in taste

FIGURE 4. Loadings in PCA for maatjes herring stored under air (experiment I) at 4°C and 10°C including all attributes assessed in the QIM scheme and storage time.

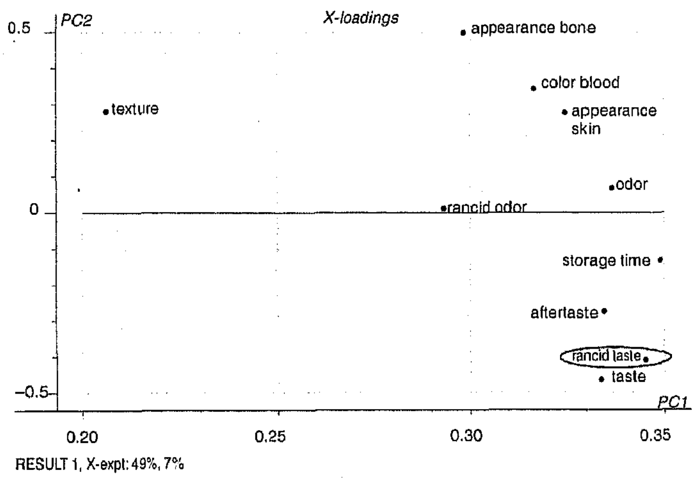


FIGURE 5. Loadings in PCA for maatjes herring stored in modified-atmosphere (experiment II) at 4°C and 10°C including all attributes assessed in the QIM scheme and storage time.

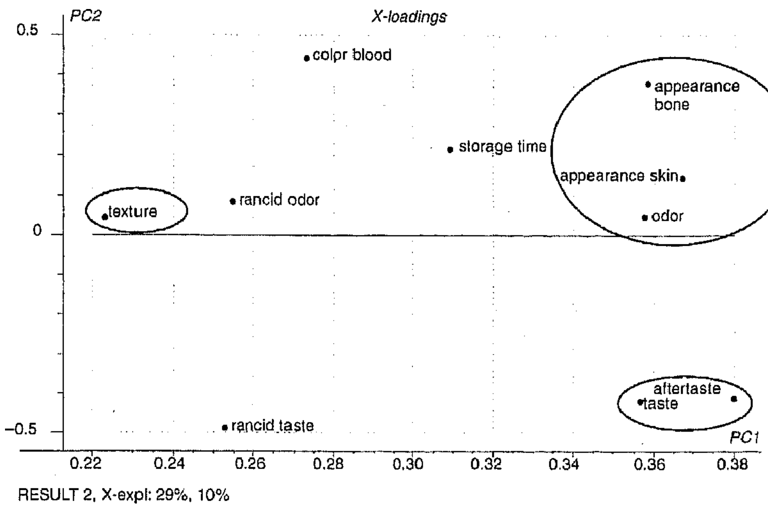
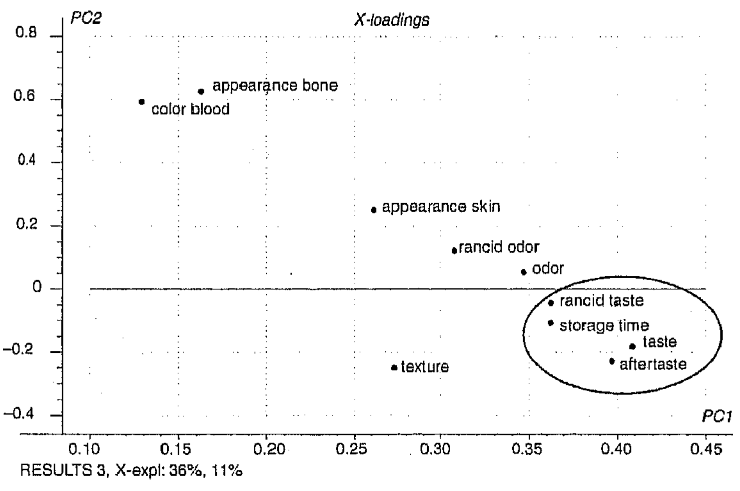


FIGURE 6. Loadings in PCA for maatjes herring stored in modified-atmosphere (experiment III) at 4°C and 10°C including all attributes assessed in the QIM scheme and storage time.



and aftertaste were found to be more important in evaluating sensory properties than rancid odor and rancid taste. The removal of oxygen in order to avoid fat oxidation is one of the major mechanisms in MAP and, therefore, changes in taste or odor due to other chemical or enzymatic reactions are easier to notice. The texture did not change in experiment II over the storage time. This might be due to the very soft texture of the freshly produced samples. In experiment III overall taste and aftertaste, but also rancidity, were important sensorial properties influencing the quality of the product. The strong rancid taste resulted from fat oxidation, and was probably due to oxygen leakage into the package through small gaps in the seals.

There was a linear relationship between the average QIM scores and the storage time with high correlation in experiments I and II for both storage temperatures and with low correlation in experiment III. The correlation coefficients (R^2) for experiment I are 0.9128 (4°C) and 0.9629 (10°C), for experiment II 0.8774 (4°C) and 0.9398 (10°C), and for experiment III 0.7129 (4°C) and 0.7784 (10°C). The high correlation coefficients for experiments I and II suggest that the QIM scheme is applicable. The low calculated correlation coefficients for experiment III are questionable. One reason may be the unexpected rancidity development. The herring of experiment III were caught one year later than the herring of experiments I and II and were studied immediately. These differences in the experiments show the need for improvement and validation of the QIM scheme.

CONCLUSIONS

The developed QIM scheme could be useful in evaluating and defining the quality of maatjes herring stored in air and under modified atmosphere. This is a first step in the QIM system implementation for fish products and is expected to be the main method in the future for use in laboratories, research, fish auctions, markets and retail. However, since natural variations and processing of maatjes herring limit use of the QIM scheme, more intensive studies will help to improve and validate the method. The future development of the scheme will concentrate more on the product-specific differences and storage conditions of the fish product.

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