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Sensory quality of Atlantic salmon as affected of fish size and fillet part

Xi Lu
Aquaculture

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List of Abbreviations

AEDA	Aroma extract dilution analysis
GCO-H	Gas chromatography olfactometry headspace
MAP	Modified atmosphere packaging
NQC	Norwegian Quality Cut
PUFA	Polyunsaturated fatty acids
QDA®	Quantitative Descriptive Analysis
QI	Quality Index
QIM	Quality Index Method
RGB	Red, green and blue
SEM	Standard error of means
VLDL	Very low-density lipoprotein

Abstract

The aim of the present study was to investigate the effect of body weight and fillet parts on sensory quality of raw and cooled salmon fillets and consumer preference of cooked salmon fillets. Three groups of salmon with the average body weight of 3991 ± 61g, 5005 ± 54g and 6013 ± 68g respectively were filleted. Fillet colour, gaping, pigment, fat content and texture were analyzed in the raw fillets after 6 days of ice storage. A consumer sensory test was carried out to evaluate the acceptability of colour, odour, flavour, firmness and juiciness of cooked fillets after 5 months of storage at -40°C. No significant differences in the fillet colour, pigment content or gaping were observed between the 4kg, 5kg and 6kg salmon. The result also showed that the loin fillet (anterior dorsal section) contained significantly thicker and firmer muscle compared to the NQC parts (dorsal section between dorsal fin and gut). Sensory analyses of cooked fillets revealed significant higher preference for flavour and juiciness of the 5kg and 6kg salmon compared to the 4kg salmon. Also a tendency to preferred colour, firmness and juiciness were observed for salmon loin fillet part compared with the NQC part. The sensory parameters of all three groups of salmon were well acceptable. The odour, flavour, firmness and juiciness correlated significantly to the overall preference while the colour of the cooked fillets had no effect on the overall preference. To conclude, sensory quality differences were observed for both raw and cooked fillets among the three size classes of salmon and among two parts of the same fillets.

Key words: Sensory quality, Atlantic salmon, body weight, loin, NQC and consumer preference

1 Introduction

Kontali Analyse estimated the worldwide supply of Atlantic salmon (*Salmo salar L.*) has increased at an annual rate of 6% during the period 2000 – 2016 (cited in Marine harvest 2017 p.31). Norway is the leading producer of farmed Atlantic salmon, with approximately 33% of the total production. The growth of Norwegian Atlantic salmon production is expected to diminish with total harvest volumes of 1.17 million tonnes (whole fish equivalent) in 2017, 1% higher than that in 2016 (FAO, 2017).

The market size of farmed Atlantic salmon varies among countries and the types of processed products. In Norway, 4 – 5 kg gutted weight (head on) is the most common market size, while 3 – 6 kg gutted weight is the main market size for the processing industry in Europe (Marine harvest, 2017). The body weight significantly influences the price of harvested salmon. Compared with small fish sizes, large sized fish are generally sold at premium price. According to Marine harvest (2017), the largest producer of farmed salmon, stated that a normal distribution on average size of 4 – 5 kg gutted weight could balance between market risk and biological risk of Atlantic salmon farming; early harvested salmon at a smaller size may be a result of disease, cash flow or maintain ongoing capacity while larger fish (6 – 7kg+) may be connected to satisfy other market requirements. However, production of larger fish may lead to higher risk of exposure to pathogens and increasing production costs. Therefore, understanding the effects of body weight of raw salmon on the sensory properties and the overall acceptance of salmon fillet is of great importance.

Colour, texture, flavour and fat content are regarded as important quality parameters when consumers make choices to purchase salmon products (Gormley 1992; Sigurgisladottir et al., 1997; Anderson 2000; Steine et al., 2005). Increasing growth rate and fillet quality traits (especially flesh colour and fat content) have been the focus of Atlantic salmon genetic selection for decades. Body weights of Atlantic salmon at harvest-age (2 – 3.5 years) have been reported to show moderate heritability by previous investigations (Gunnes and Gjedrem, 1978; Gjerde and Gjedrem, 1984; Standal and Gjerde, 1987; Gjerde et al., 1994; Rye and Refstie, 1995). Thus body weight has been regarded as a reliable traits for improvement through genetic selection. These practices have resulted in researching the effects of body weight on sensory quality of salmon fillet. Quinton et al. (2005) reported positive genetic correlations between harvest body weight of Atlantic salmon and colour scores, carotenoid pigment deposition and fillet fat contents. Therefore, selection for increasing body weight can achieve increases both in the colouration and fat content of the flesh. Jobling and Johansen (2003) reported that a high-fat feed caused higher fat deposition in fillets and carcass of salmon compared with fish fed with a low-fat feed. Moreover, fat content of fillet were found to increase with the increasing rearing time and fish size. However, there is no published study that directly addresses how body weight or size of Atlantic salmon affects technological (e.g. gaping) and sensory quality (texture, flavour and odour) of Atlantic salmon fillets.

Quality properties vary among different sections within the same fillet of Atlantic salmon. Compared with the anterior region, the caudal fillet region is leaner (Aursand et al., 1994; Bell et al., 1998; Einen et al., 1998; Refsgaard et al., 1998) and firmer (Sigurgisladottir et al., 1999; Casas et al., 2006). Additionally, the fat content differs between the dorsal and ventral parts (Refsgaard et al., 1998). Although there are marked differences in price and preferences on body weight among salmon markets, there is lack of published results regarding consumer rating of sensory quality among different size classes of salmon. Moreover, specific portions of Atlantic salmon fillet have been developed to achieve substantial value as high quality products in salmon processing industry. However, consumer preferences of sensory quality properties caused by regional differences in Atlantic salmon fillet are remained to be explored. The purpose of the present work is to explore the effects of fish body weight and fillet parts on the sensory quality of Atlantic salmon and on the consumer preference using three categorized body weight of salmon fillets and two parts of fillets.

2 Literature review

2.1 Quality characteristics of salmon flesh

2.1.1 Colour

Astaxanthin (3,3’-dihydroxy-β,β-carotene-4,4’-dione) is the major carotenoid pigment used in farmed Atlantic salmon diets to achieve the distinctive red colour of the flesh. Salmon cannot synthesize carotenoids de novo, therefore carotenoids – including astaxanthin and canthaxanthin from dietary resources are deposited in salmon muscle. The retention of dietary astaxanthin in the flesh of salmonid fishes is approximately 1 to 18% (Torrissen et al., 1989; Storebakken and No, 1992). Approximately 55% of astaxanthin in salmon diets is excreted through the digestibility system and 50% of the absorbed astaxanthin is metabolized; hence less than 10% of the carotenoids are is retained in the salmon muscle (Torrissen et al., 1989; Storebakken and No, 1992; Bjerkeng and Berge, 2000).

Various factors influence the retention of carotenoids in salmon muscle, including intestinal absorption, transport capacity, deposition mechanism and metabolism in fish (Torrissen et al., 1989; Aas et al., 1999), dietary factors such as diet composition, source of carotenoid and carotenoid concentration, duration of feeding duration and genetic differences (Olsen et al., 2005). It has been suggested that the dietary factors such as lipid levels (Torrissen et al., 1989), cholesterol levels (Chimsung et al., 2014) and high levels of polyunsaturated fatty acids in certain fish oils (Bjerkeng et al., 1999) increase the absorption of carotenoids. Chimsung et al. (2013) found that dietary cholesterol plays a significant role for the astaxanthin transport in the blood. E.g. 2% cholesterol supplementation to the diet significantly increased the concentration of astaxanthin in fish plasma and very low-density lipoprotein (VLDL) as well as increasing plasma cholesterol; the protein-rich fraction was found to be the major carrier of astaxanthin in salmon plasma (Chimsung et al., 2013). There are some seasonal fluctuations in the pigment content in Atlantic salmon flesh since the muscle carotenoid level has been observed to increase from November to July during early spring and summer (Mørkøre and Rørvik, 2001; Nordgarden et al., 2003). Temperature and feed intake have been regarded as important factors resulting in these fluctuations (Ytrestøyl et al., 2005). Low temperature has a negative effect on the utilisation of astaxanthin since a reduced digestibility of astaxanthin by approximately 10% was reported with temperature decreasing from 12 °C to 8 °C (Ytrestøyl et al., 2005). Moreover, Quinton et al. (2005) reported positive genetic correlations between harvest body weight of Atlantic salmon and colour scores, carotenoid pigment deposition and fillet fat contents. The direct selection of broodstock for harvest body weight may obtain desirable responses of increased colour scores and carotenoid pigment deposition in salmon fillet. In addition, the variation of colour distribution within salmon fillet can be evaluated quantitatively by the method of LW-NIR hyperspectral imaging (Wu et al., 2012). They found the non-uniform distribution of colour constituents in salmon fillets; the belly flap area showed lighter with more red and yellow in colour compared with the dorsal part of the muscle.

2.1.2 Gaping

Gaping is a phenomenon in which the separation of the connective tissue between the muscle blocks causes undesirable holes or slits in raw fish fillets. Gaping can range from slight separation at the cut surface to complete separating fillets into pieces. The connective tissue of the fillet can break down and the blocks of muscle (myotomes) can fall apart easily when a fillet with gaping is cooked. Salmon fillets are downgraded due to the defects caused by gaping, mainly due to unappealing appearance, but also because of problems cutting slices of raw and smoked salmon with gaping (Lavéty, 1984). Hence fillets with severe gaping can only be processed into cheaper products like fish cakes or fish meal (Loye, 1973). Gaping also leads to rejection by consumers due to deteriorated (Pittman et al., 2013).

The biological mechanism of underlying gaping causes are not yet fully understood, but there are various recognized factors including harvest season, storage condition and handling (Loye, 1973; Lavéty, 1984; Pittman et al., 2013), handling stress (Pittman et al., 2013), and high temperature during rigor developments (Loye, 1973; Lavéty, 1984). Loye (1973) and Lavéty (1984) stated that physical damage of fish caused by rough handling may result in the fillet gaping, thus farmed fish should be handled gently during the process from harvesting to finished product. For example it is important not to bend fish that are stiff in rigor. Moreover, stress due to rough handling prior to and at slaughter process may lead to gaping and soft fillets (Roth et al., 2006; Bahuaud et al., 2010), which could be considered to be linked to a decrease in pH (Bahuaud et al., 2010). Acidic conditions lead to increasing activity of cathepsin L and B which are believed to degrade collagen in the muscle tissue and soften fillets (Bahuaud et al., 2010). Besides, gaping condition is believed to vary with season (Lavéty et al., 1988; Mørkøre & Rørvik, 2001; Espe et al., 2004). Farmed salmon harvested in summer are more likely to gape than those harvested in winter (Lavéty et al., 1988; Mørkøre & Rørvik, 2001), because the changes of chemical composition of the muscle occurs when the fish begin to feed actively in the spring (Loye, 1973; Lavéty, 1984). Increasing temperature of fish body can cause stronger muscular contraction and weaken the connective tissue in a whole fish during rigor, eventually resulting in gaping when the fish is filleted (Lavéty, 1984). In addition, cleaning intensity of the abdominal cavity may significantly affect fillet gaping, as salmon with body fluids and blood remained in the abdominal cavity during storage showed higher gaping scores (Jacobsen et al., 2017). There is few published study that directly addresses how body weight of Atlantic salmon and fillet section affects gaping degree of Atlantic salmon fillets.

2.1.3 Texture

"Texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetics" (Szczesniak, 2002). The definition of texture indicates that texture is a sensory property which is mainly perceived by the human being senses of touch and pressure; it's a multiple-parameter including tenderness, chewiness and other characteristics (Szczesniak, 2002). Moreover, it has been suggested that the empirical measurements and practical experience could be connected to sensory quality and consumer acceptance of a given product (Szczesniak and Bourne, 1969). Therefore, it is possible to detect and quantify the degree of specific physical characteristics indicating the sensory perception by texture testing instruments (Szczesniak, 2002).

The textural characteristics have been classified into three categories: mechanical properties, geometrical properties, and other properties relating to fat and moisture content (Szczesniak, 1963). Mechanical properties involve a series of reactions of the food to press, such as hardness, cohesiveness, viscosity, elasticity, and adhesiveness (Szczesniak, 1963). Geometrical properties of the texted sample are mainly the appearance reflection in size and shape (Szczesniak, 1963). Other properties relating to fat and moisture content of product are associated with the gustatory perception of the moisture and fat content of the product, which could be related to the lubricating properties of the product (Brandt et al., 1963; Szczesniak, 1963; Szczesniak, 1975).

Texture of fish muscle is influenced by various factors, including the species, age and size of the fish within the species, nutritional state, rate and extent of post-mortem muscle shortening (rigor mortis), and the rate and extent of proteolysis causing myofibril breakdown (Dunajski, 1980; Sigurgisladottir et al. 1997). Post-mortem factors influencing texture include glycolysis, rigor mortis, pH decline and the contraction of the muscle leading to the separation of muscle segments (Dunajski, 1980). Other parameters such as fat content, fatty acid composition, and distribution of fat in muscle tissue may influence fillet texture (Haard, 1992). Additionally, Hatae et al. (1990) stated that differences in firmness of muscle tissue observed among five fish species could result from differences in protein content (sarcoplasmic protein) and differences in the diameter and mobility of the muscle fibers; the heat-coagulating material between muscle fibers could prevent the fibers sliding under pression. Fish species with firm texture had smaller diameter and higher numbers of muscle fibers with considerable heat-coagulating material between muscle fibers; fish species with soft texture had larger diameter and lower numbers of muscle fibers with little heat-coagulating material (Hatae et al., 1990). Bahuaud et al. (2010) reported that cathepsin B and L activities could result in decreased firmness in Atlantic salmon muscle.

2.1.4 Flavour and odour

Flavour and odour are important sensory attributes for the assessment of freshness and quality of salmon flesh, and are commonly used in the salmon inspection services. Flavour and odour characteristics observed for salmon are described as fresh, slightly fish oily, bitter, metallic, nutty/buttery, and sour. Fresh salmon can be distinguished from spoiled salmon by the terms indicating positive sensory attributes and negative sensory attributes of odour and flavour, respectively (Sveinsdottir et al., 2003). Fresh raw and cooked salmon were positively described by seaweed, cucumber and sourish odour, and seaweed, sweetish, sourish, fish oil and mushroom flavour, while salmon at the end of the shelf life was characterized as sour with amine and rancid odour and flavour (Sveinsdottir et al., 2003). Additionally, it was suggested to use a descriptor of boiled potato odour for cooked salmon which could be distinguished from the cucumber odour of fresh fillets (Milo and Grosch, 1996; Hui, 2006).

It is revealed that flavour and odour of salmon flesh and cooked salmon fillet are mainly characterized by volatile compounds and their intensity. The volatiles resulting in the characteristic aromas of boiled salmon have been evaluated by aroma extract dilution analysis (AEDA) and gas chromatography olfactometry headspace (GCO-H) (Milo and Grosch, 1993). Raw salmon homogenates stored for 26 weeks at -60°C and -13°C showed the pleasant odour descriptors when boiled, such as sweet, buttery, biscuit-like, boiled potato-like, vegetable-like, green, cabbage like, mushroom-like, citrus-like, and cucumber-like (Milo and Grosch, 1993). (Z)-3-hexenal and fatty green (Z,Z)-3,6-nonadienal was suggested to cause the flavour defect in boiled salmon after being stored frozen for a long period; these two compounds are formed by the peroxidation of unsaturated fatty acids. Compared with the lean fish, salmon contains higher level of n-3 unsaturated fatty acids. Consequently, salmon could have a higher risk of off-flavour formation by peroxidation of unsaturated fatty acids (Milo and Grosch, 1993).

The off-flavour of salmon is mainly associated with components of low volatility. During the storage process of frozen salmon, there is a significant increase in intensity of rancid fish oil taste, bitterness, and metal taste which can be produced by compounds of low volatility, such as palmitoleic acid and linoleic acid, eicosapentaenoic acid, and docosahexaenoic acid containing high intensity of rancid fish oil, bitter and metallic taste (Refsgaard et al., 2000). Salmon fillets exhibited increasing intensity of train oil, metal, and bitter taste during storage at -10°C and -20°C, which indicated that frozen salmon became rancid after a long period of frozen storage (Refsgaard et al., 1998). Milo and Grosch (1993) suggested that rancidity in salmon could be described as fish oil taste and as fatty and train-oily odours. The rancid off-flavour of salmon is mainly caused by formation of volatile oxidation products such as aldehydes and ketones which have very intense odours and flavours. The compound associated with a cucumber odour is (E,Z)-2,6-nonadienal. (Z)-3-hexanal provides a green odour, while (Z,Z)-3,6-nonadienal contributes a fatty odour. Small concentrations of these volatile compounds can affect the sensory quality (Milo and Grosch, 1993).

2.2.5 Fat content

The content, distribution and composition of lipids are important quality characteristics for salmon fillets, which affect the nutritional and sensory quality including the taste, odour, texture and flavour (Sigurgisladottir et al., 1997). The lipid content of salmon fillets can be up to 18.4% (Ytrestoyl, et al., 2015), although this figure varies both within and between species. Salmon contain lipids in their tissues and in the belly cavity around the gut. However, lipid distribution of salmon fillet varies among sections of the same fillet (Aursand et al., 1994; Katikou et al., 2001). The fat content is highest in belly flap area, lowest in the middle and tail areas, and relatively high in dorsal part (Katikou et al., 2001). The variation in lipid content deposited in a number of tissues and organs were reported by Zhou et al. (1995) and Aursand et al. (1994). Zhou et al. (1995) reported that dark muscle of Atlantic salmon contained approximately 5.25 times more lipid than white muscle (3.8%). Most of lipids in whole dark muscle, up to 62.4% of total lipids were stored in the myosepta while 39.1% of total lipids in white muscle were deposited in the myosepta (Zhou et al., 1995). Aursand et al. (1994) analysed the fat content in the skin, red and white muscle, belly flap, dorsal fat depot, backbone, head, visceral tissue, and liver of commercial farmed Atlantic salmon. The highest fat content was found in the dorsal fat depot (38.4% of wet weight), red muscle (27.2%) and belly flap area (28.1%); white muscle contained 9.6% fat (Aursand et al., 1994). United States Department of Agricultural Research Service (2016) reported that salmon contains 3.05% saturated fatty acids, 3.77% total monounsaturated fatty acids and 3.886 % total polyunsaturated fatty acids.

The fat content of salmon fillets is positively influenced by high content of dietary lipid (Hillestad & Johnsen 1994; Hemre & Sandnes, 1999; Hamre et al., 2004). Lie et al. (1988) found a linear relationship between lipid intake and lipid retention in Atlantic salmon. However, the excess lipid were distributed in the viscera when Atlantic salmon was fed diets with high lipid content; thus there was no possibility of lipid contents in fillet and liver increasing above certain levels (Lie et al., 1988). Refstie et al. (2001) reported that Atlantic salmon fed the high-fat diets (40% protein and 39% lipid) gained 24% higher lipid than those fed the medium-fat diets (45% protein and 32% lipid), with higher fat contents of viscera and carcass and 10% wider myosepta stripes in the fillets.

Ackman and McLeod (1988) described farmed salmon containing approximately 8% fat in 1988 while the upper value can be between 18.3% (Ørnholt-Johansson et al., 2017) and 22% (Gjerde et al., 2007).

The lipid composition of salmon fillets affects the important sensory parameters including fattiness, juiciness and flavour (Waagbø et al., 1993; Thomassen and Røsjø, 1989). Waagbø et al. (1993) reported that vitamin E and n-3 PUFA contents cooperate to influence the rancidity of fillets. Salmon fed a high n-3 PUFA and low vitamin E diet has more intense rancid flavour compared with fillets from salmon fed higher vitamin E levels. It's well recognized that fatty acid composition of salmon fillets is significantly affected by the lipids composition of the fish diet (Hardy et al., 1987; Polvi and Ackman, 1992; Ackman and Takeuchi, 1986; Waagbø et al., 1993; Lie et al., 1988; Thomassen and Røsjø, 1989). Atlantic salmon fed a high omega-3 fatty acids or lipid substitution contains a desirably high level of fatty acids (Hardy et al., 1987; Polvi and Ackman, 1992; Ackman and Takeuchi, 1986).

2.2 Methods for sensory evaluation of Atlantic salmon

2.2.1 Quality Index Method

The Quality Index Method (QIM) has been suggested to be a rapid and reliable method used for estimating the freshness and quality of seafood. QIM scheme has been modified to be applicable for a number of fish species including Atlantic salmon (Sveinsdottir et al., 2003), Atlantic halibut (Guillerm-Regost et al., 2006), fresh herring (Nielsen and Hyldig, 2004; Mai et al., 2009), frozen cod (Warm et al., 1998), red fish (Botta, 1995), Atlantic mackerel, horse mackerel and European sardine (Andrade, Nunes, & Batista, 1997), octopus (Barbosa and Vaz-Pires, 2004), sea bass (Alasalvar et al., 2002), blackspot seabream (Sant'Ana et al., 2011) and gilt-head seabream (Huidobro et al., 2000).

QIM is based on a number of significant sensory parameters for a particular fish species and a grading system allocating scores to each attribute from 0 to 3 demerit points depending on the descriptions and state of the selected item (Ólafsdóttir et al., 1997; Sveinsdottir et al., 2003). The QIM scheme for fish consists of attributes including the appearance, odour and texture of eyes, skin and gills respectively. Demerit points are assigned to selected parameters according to the influence on the quality of the given product. According to the description of each parameter, scores of zero are assigned for very fresh fish while increasingly larger whole numbers are scored as fish deteriorate. For example, 0 demerit point for the appearance of the skin on farmed Atlantic salmon indicates pearl-shiny all over the skin on the freshly harvested salmon, while 2 demerit points are recorded when the appearance of the skin on the head is still pearl-shiny, but the rest part turns less bright and perhaps yellow (Sveinsdottir et al., 2003). An overall sensory score is obtained by summing the scores of each attributes, called Quality Index (QI). QIM for a particular seafood or fish species is developed by selecting appropriate attributes in order to observe a linear relationship between the QI and storage time (Sveinsdottir et al., 2003), which may be used to predict the remaining shelf life of fish (Luten & Martinsdottir, 1997; Sveinsdottir et al., 2003).

Table 2.1. The QIM scheme developed for farmed salmon to identify the fillet quality (Sveinsdottir et al., 2003)

Quality parameters	Description	Points
Skin		
Colour/appearance	Pearl-shiny all over the skin	0
	The head is still pearl-shiny, but the rest less, perhaps yellow	1
Mucus	Clear and not clotted	0
	Milky and clotted	1
	Yellow and clotted	2
Odour	Fresh seaweedy, cucumber	0
	Neutral to metal, dry grass, corn	1
	Sour	2
	Rotten	3
Eyes		
Pupils	Clear and black, metal shiny	0
	Dark grey	1
	Mat, grey	2
Form	Flat	0
	Little sunken	1

	Sunken	2
Abdomen		
Blood in abdomen	Blood light red/not present	0
	Blood more brown	1
Odour[a]	Neutral	0
	Corn	1
	Sour	2
	Rotten/rotten kale	3
Gills[b]		
Colour/appearance	Red/dark brown	0
	Light red/brown	1
	Grey-brown, grey, green	2
Mucus	Transparent	0
	Yellow, clotted	1
	Brown	2
Odour	Fresh, seaweed	0
	Metal	1
	Sour	2
	Rotten	3
Texture		
Elasticity	Finger mark disappears immediately	0
	Finger leaves mark over 3s	1
Quality Index Total 0–22		

[a] Turn the salmon and smell the skin on the other side.

[b] Examine the side that has not been cut through.

2.2.2 Quantitative Descriptive Analysis

Quantitative Descriptive Analysis (QDA®) developed by Stone et al. (1974) is one of main descriptive analysis techniques that uses descriptive panels to measure a product's sensory characteristics in sensory evaluation. Panellists are trained in multiple product evaluations to improve their skill in making relative judgments with a high degree of precision before participating in a sensory analysis of the targeted product. It is more difficult for humans to distinguish absolute differences than to evaluate relative sensory differences (Stone and Sidel, 2004). When establishing QDA® profiles, a group of ten to twelve panellists use their senses to identify perceived similarities and differences in products, and articulate those perceptions in their own words under the guidance of a panel leader (Stone and Sidel, 2004). During training, the panel leader encourages communication but keeps apart from involvement and interference with panel discussions. Panellists need to reach a consensus about the attributes describing the important quality characteristics of the given product. Therefore references play an important role in generating appropriate terms for descriptions of the quality characteristics, especially when puzzles and disagreements on sensory attributes occur during training sessions (Stone and Sidel, 2004). Then panellists are trained in determining sensory intensities for each of the attributes using a linear scale. There are word anchors of sensory intensities locating at 0.5 inch from each end on a 6-inch linear scale. The sensory intensities increase from left to right on the linear scale (Stone and Sidel, 2004). Panellists evaluate the sensory intensities independently in individual booths and use different parts of the scale to judge the sensory intensities based on their perceiving of sensory intensities instead of reference for intensities standards. Therefore, the differences among multiple products evaluated by QDA® will be relative results without the involvement of absolute scale value (Lawless and Heymann, 2010). Repeated measurements are conducted on product attributes to analyse the reliability of the panel tests (Stone and Sidel, 2004).

The QDA® methodology is efficient for collecting information on consumer preferences and identifying specific sensory characteristics related to consumer preferences (Sidel, Stone, & Thomas, 1994). It's clear that this method is suitable for the mapping of consumer preferences (Helgesen, Solheim, & Naes, 1997) and for relating sensory attributes of texture to instrumental measurements (Reyes-Vega, Peralta-Rodriguez, Anzaldua-Morales, Figeurosa-Cardenas, & Martinez-Bustos, 1998). Additionally, the QDA® method has been applied to the shelf life measurement of products. Sveinsdottir et al. (2003) estimated the maximum storage time of farmed Atlantic salmon by the sensory evaluation of cooked fillets using Quantitative Descriptive Analysis (QDA) and found the results applicable to a reference when developing QIM scheme for fresh fish. The maximum shelf life of a product can be determined by the storage time when spoilage attributes are detected by the panel or part of the panel, or tend to be identified with spoilage attributes descriptions (Sveinsdottir et al., 2003). It is valuable to provide accurate information on consumer concerns for quality control in food processing (Stone & Sidel, 1998).

The QDA® methodology is a reliable tool to analyse the important quality characteristics which are most concerned by consumers.

2.2.3 Consumer acceptance testing

Consumer preference is an important positive determinant for fish consumption intention (Verbeke & Vackier, 2005). It is difficult for many consumers to express their perceptions of specific attributes of a product and explain the detailed reason for their preference on one product, therefore the analysis of consumer sensory requirements may be difficult to interpret. Greenhoff & MacFie (1994) stated that the consumer preference may be related to the sensory characteristics of products by preference mapping. Preference mapping has been applied to the research on the consumer acceptability of various food products such as meat (Helgesen, Solheim, & Næs, 1997), beverages (Geel, Kinnear, & de Kock, 2005; Guinard, Uotani, & Schlich, 2001), fruits (Thybo, Kühn, & Martens, 2003; Daillant-Spinnler, MacFie, Beyts, & Hedderley, 1996), ice cream (Dooley et al., 2010; Cadena et al., 2012) and cheese (Westad, Hersleth, & Lea, 2004; Murray & Delahunty, 2000). Researches on the comparisons of consumer acceptability and sensory properties of different fish products have also been published. Sveinsdóttir et al. (2003) investigated preferences of Icelandic consumers and the sensory quality of fresh, thawed and cod fillets in MAP (Modified atmosphere packaging) of different storage time. They found that the thawed and modified atmosphere packed fillets were determined to be more dry and tough than fresh fillets when evaluated by a trained sensory panel. Moreover, differences between fresh and stored cod fillets (stored 2 and 10 days) were detected by the consumers, which indicated that consumers preferred the fresh fish.

Consumer acceptance testing measures consumer liking or preference expressing appeal of one product compared with others. Methods for acceptance testing in sensory analysis include the paired comparison test, the nine-point hedonic scale, ranking test and other methods based on the former methods (Stone and Sidel, 2004). The paired comparison method can be applied to determine the preference between two products by stating which one of two products is preferred. The nine-point hedonic scale allows for determining the degree of acceptability of one or more products by nine categories ranging from ‘dislike extremely’ to ‘like extremely’ and including a neutral midpoint (neither like nor dislike). Alternatively, a preference ranking test may be completed to indicate whether or not a detectable difference of preference exists between samples, when more than two samples are evaluated. Usually three to five samples are the most that can be efficiently ranked by a consumer. Consumer panelists are required to order the samples based on the degree of their preference on specified characteristics, with a ranking of '1' meaning most preferred. The paired comparison test and ranking test can determine consumer liking or acceptance in multi products while the scaling method can directly measure the degree of consumer liking or acceptance (Stone and Sidel, 2004).

3 Materials and Methods

3.1 Fish materials and sampling

Thirty Atlantic salmon (*Salmon salar*) in the weight classes of 4 kg, 5kg and 6kg were harvested from a farming facility in Radøy (Hjeltefjorden, Hordaland), the west coast of Norway on 1st April 2016. At the slaughter house of Sotra Fiskeindustri (Hordaland, Norway), 10 fish from each weight class – 4 kg, 5kg and 6kg were bled, gutted and packed on ice in styrofoam boxes. These 30 salmon were transported to Nofima (Ås, Norway) and stored on ice at 4ºC immediately after filleting on 7th April 2016.

Table 3.1. Biometric traits of Atlantic salmon (*Salmon salar L.*) for each of the weight classes of 4 kg, 5kg and 6kg, respectively.

	Weight class (kg)		
	4	5	6
Body weight[1] (g)	3991 ± 61^{c}	5005 ± 54^{b}	6013 ± 68^{a}
Gutted weight (g)	3542 ± 56^{c}	4465 ± 44^{b}	5388 ± 63^{a}
Body length (cm)	69.5 ± 0.50^{c}	74.5 ± 0.41^{b}	76.9 ± 0.41^{a}
Condition factor[2]	1.06 ± 0.02^{b}	1.08 ± 0.01^{b}	1.18 ± 0.02^{a}
Fillet weight (g)	2588.2 ± 46.7^{c}	3241.6 ± 34.2^{b}	3892.0 ± 47.3^{a}
Fillet yield (%)	73.1 ± 0.4^{a}	72.6 ± 0.5^{a}	72.2 ± 0.3^{a}

Different superscripts in the same row indicate significant variation ($P < 0.05$).

[1]Body weight were the body weight of bled salmon.

[2]Condition factor: (Gutted body weight (g) × fish length (cm)$^{-3}$) × 100.

3.2 Colour measurement

The flesh colour was visually compared with DSM SalmoFan™ (DSM, Kaiseraugst, Switzerland). The colour fan readings were conducted on the Norwegian Quality Cut (NQC) (NS 9401, 1994) which includes the region between the posterior end of the dorsal fin and the gut. The evaluation was performed under controlled conditions – indirect daylight and non-reflective surface, in order to eliminate the influence of adjacent colour and distracting reflections from the glossy surface of the salmon flesh. The scale of DSM SalmoFan™ ranges from score 20 to 34; score 20 for the palest and score 34 for the most intense colour.

3.3 Gaping measurement

Gaping measurement was conducted immediately after filleting. Based on the method described by Andersen et al. (1994), the gaping was determined by visually measuring the amount and size of slights in the fillet. A scale from score 0 to 5 was used; score 0 for fillets without slits, score 1 for fillets with less than 5 small slits (< 2 cm), score 2 for fillets with less than 10 small slits, score 3 for fillets with more than 10 small slits or some large slits (>2 cm), score 4 for fillets containing many large slits and 5 score for fillets containing extreme gaping or falling apart.

3.4 Digital image analysis of pigment and fat content

The pigment and fat contents of fillets were determined by analyzing the tissue surface of the NQC fillet section using digital photography, reported by Folkestad et al. (2008). The NQC cutlet was placed on the bottom plate in a light resistant aluminum box (800 mm × 830 mm × 955 mm) and photographed by a digital camera (Dolphin F145C, Allied Vision Technologies, Stadtroda, Germany) fixed on the top of the box. Four fluorescent bulbs (OSRAM Lumilux 55 W, OSRAM, Augsburg, Germany) providing standard spectrum illumination were installed in the upper areas of the box walls, 60 cm distant from the bottom plate. A diffuse plate was installed to eliminate the specular reflection of light on the bottom plate when the light passed through to illumine the fillet on the bottom plate. In order to correct nonuniform illumination, the bottom plate covered by a white plate was photographed as a reference image. QPcard 101 (QPcard AB, Gothenburg, Sweden) with neutral white, grey and dark grey patches was placed beside the tested fillet on the bottom plate and recorded in each image, which aimed at calibrating white balance. The camera recorded the visual Red-Green-Blue (RGB) images into 1280×960 pixels. Each pixel in an RGB image was represented by colour values R (red), G (green) and B (blue) ranging from 0 (dark) to 255 (light). Mean values of R, G, and B within NQC region were used for evaluation of pigment and fat contents in fillets by regression analyses.

3.5 Texture analysis

Texture analysis of raw salmon fillets were performed in the NQC and loin parts shown in Figure 3.1, using the Texture analyzer (TA-XT2, Stable Micro Systems Ltd., Surrey, England). A flat-ended cylinder probe (12.5 mm diameter, type P/0.5) was pressed into the fillets at a constant speed of 1 mm/s. The texture analyzer was equipped with a 30 kg load cell and the trigger force was 9 g. The breaking force in Newton, required for the probe to puncture the surface of the fillet, was recorded from the force-time graphs by a computer. The breaking force is defined as the sensory determination of firmness.

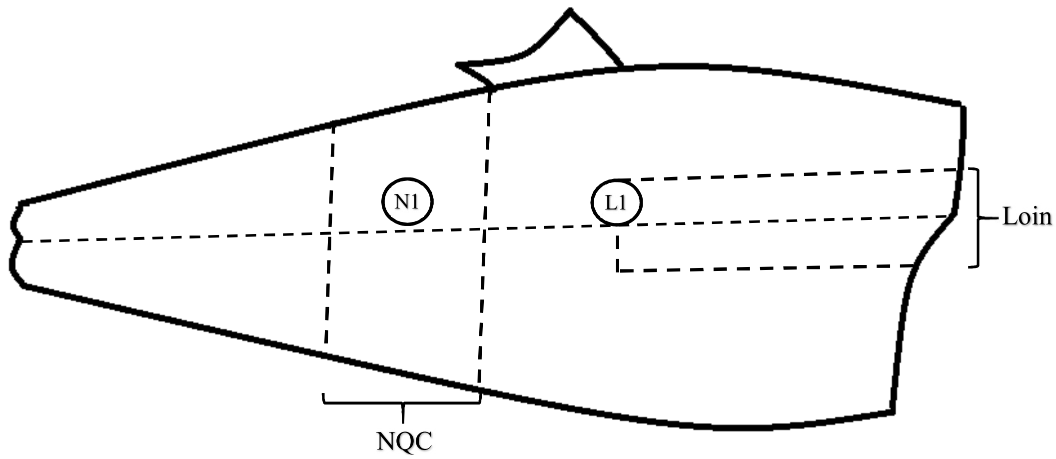

Figure 3.1 The loin and Norwegian Quality Cut (NQC) parts of fillets of farmed Atlantic salmon, respectively. The loin fillet is the midline cut between the dorsal and ventral parts. According to the Norwegian standard procedure – NS 9401 (1994), Norwegian Quality Cut (NQC) is described as the region of Atlantic salmon from the end of the dorsal fin backward to the anus. The texture analysis was conducted on N1 and L1, respectively. Fillet colour, pigment concentration and fat content were analyzed in the NQC area. Loin and NQC fillets were baked and evaluated by consumer assessors.

3.6 Sensory evaluation of cooked fillets

A consumer sensory test was carried out to evaluate the acceptance of sensory characteristics of salmon fillets. Fillets of all 30 salmon samples were evaluated by 30 consumer panelists. Two different fillet parts – loin and NQC shown in the Figure 3.1 were used for consumer sensory evaluation. The fillet parts were stored in plastic bags at -40ºC until 20th September 2016, then thawed at -4ºC for 24 hours. After thawing at 4ºC, the skin was removed and each fillet part (left and right part) was cut into cubes (20 mm × 25mm × 30mm for loin pieces, 30mm × 25mm × 25mm for NQC pieces). The cubes were soaked in 5% salt solution before they were baked without additives at temperature of 102 °C in a preheated oven for 12 minutes. The internal temperature of baked cubes was up to 69°C. Three pieces of each size (4kg, 5kg and 6kg) of salmon fillets were randomized and served simultaneously to participants in clean plastic petri dishes marked with 3-

digit codes to distinguish between the two types of fillet part and three types of sizes. Water and crackers without additives were offered between samples.

The salmon samples were subjected to a consumer evaluation (n = 30) of untrained participants. All consumer panellists were recruited from volunteer students and staff at Norwegian University of Life Sciences and Nofima. There were 17 female and 13 male assessors, aged from 20 – 50 years old (Table 3.1). Each panelist was asked to complete a questionnaire determining their preference of the taste and the appearance of the product. Their opinions regarding monthly fish consumption and preference were asked. Samples from all 3 batches of fish size – 4kg, 5kg and 6kg were randomly given to consumers. The taste and appearance evaluations were measured on a 6-point scale, where 1 = dislike extremely, 3 = neutral and 6 = like extremely (Table 3.2). Communication between assessors was avoided during the process of tasting and filling the questionnaire.

Table 3.2. Characteristics of participants in the consumer sensory analysis

	Number	Percentage (%)
Gender		
Female	17	56.7
Male	13	43.3
Age		
20-24	13	43.3
25-29	11	36.7
30-50	6	20.0
Nation		
Asia	15	50.0
Europe	13	43.3
North America	1	3.3
South America	1	3.3
Education		
Bachelor	5	16.7
Master	23	76.7
PhD	2	6.7
Fish consumption frequency		
Once per month	6	20.0
Once every two weeks	6	20.0
Once per week	15	50.0
⩾2 times per week	3	10.0

Table 3.3. Scoring system used by the assessors to assess the sensory quality of cooked salmon fillets.

Sensory properties	Scores					
	1	2	3	4	5	6
Colour	Dislike	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
Odour	Dislike	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
Flavour	Dislike	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
Firmness	Dislike	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely
Juiciness	Dislike	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

3.7 Data analyses

Summary statistics (mean, standard deviation, standard error, minimum, maximum), analysis of variance, Duncan multiple range tests and bivariate correlations were performed using IBM SPSS Statistics Version 22 software (IBM, New York, USA). Categorical data (sensory scores and gaping) were analysed by Wilcoxon/Bonferroni Multiple Comparisons in the SAS 9.4 computer software (SAS Institute Inc., Cary, NC, USA; www.sas.com). The significant statistical level was set at $p < 0.05$.

4 Results

4.1 Quality of raw fillets

4.1.1 Fillet colour

The mean values of visual colour evaluated by SalmoFan™ and pigment content of raw NQC fillets are shown in Figure 4.1. The average colour scores of 4kg, 5kg and 6kg salmon are 26.1, 26.2 and 25.7, respectively. There were no significant differences in either colour score or pigment content between groups of 4kg, 5kg and 6kg salmon.

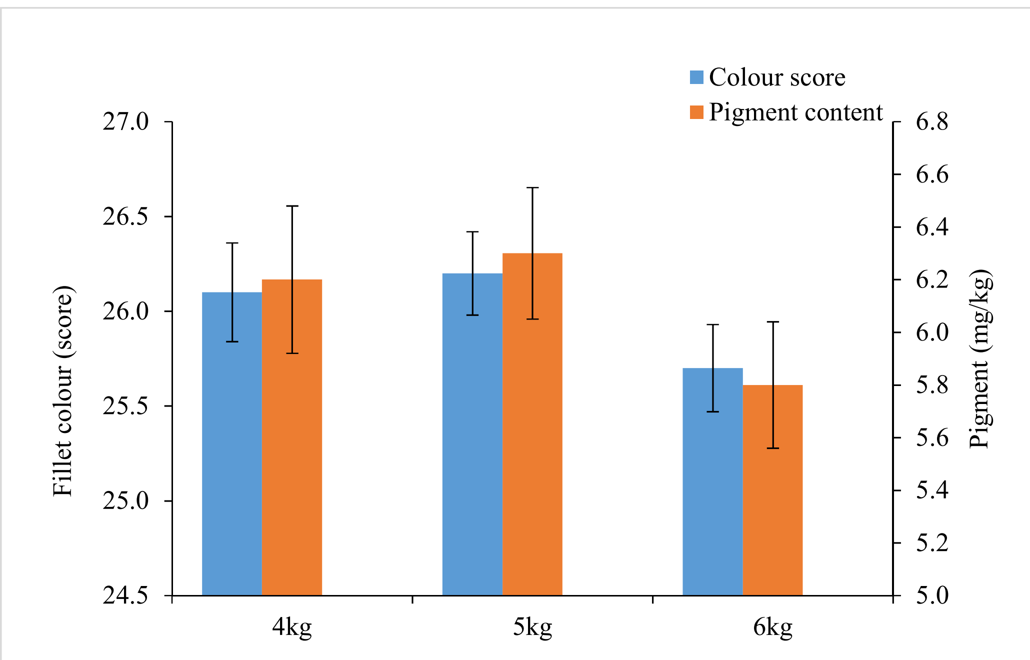

Figure 4.1 Colour score evaluated by SalmoFan™ and pigment content of raw NQC fillets. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively (n = 10 per fish group).

4.1.2 Gaping

The mean gaping score of raw fillets is shown in Figure 4.2. Gaping score of raw fillets showed no significant differences between groups of 4kg, 5kg and 6kg salmon (on average values of 0.6, 0.8 and 0.5, respectively).

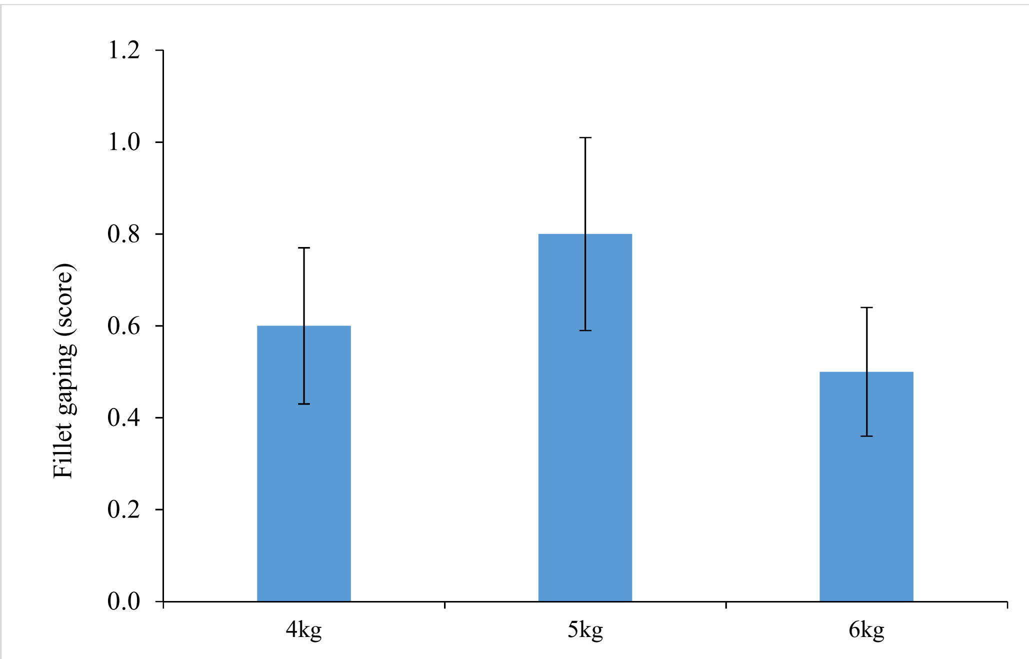

Figure 4.2 Gaping score of raw salmon fillets. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively (n = 10 per fish group).

4.1.3 Fillet thickness and firmness

Figure 4.3 illustrates that thickness of both the loin and NQC increased significantly with increasing body weight (4kg, 5kg and 6kg). Firmness of the loin part was significantly higher in the 6kg salmon compared with the 4kg and 5kg salmon. There were no significant differences in firmness of raw NQC fillets between groups of 4kg, 5kg and 6kg salmon (Figure 4.3). The loin part was significantly thicker and firmer than the NQC part.

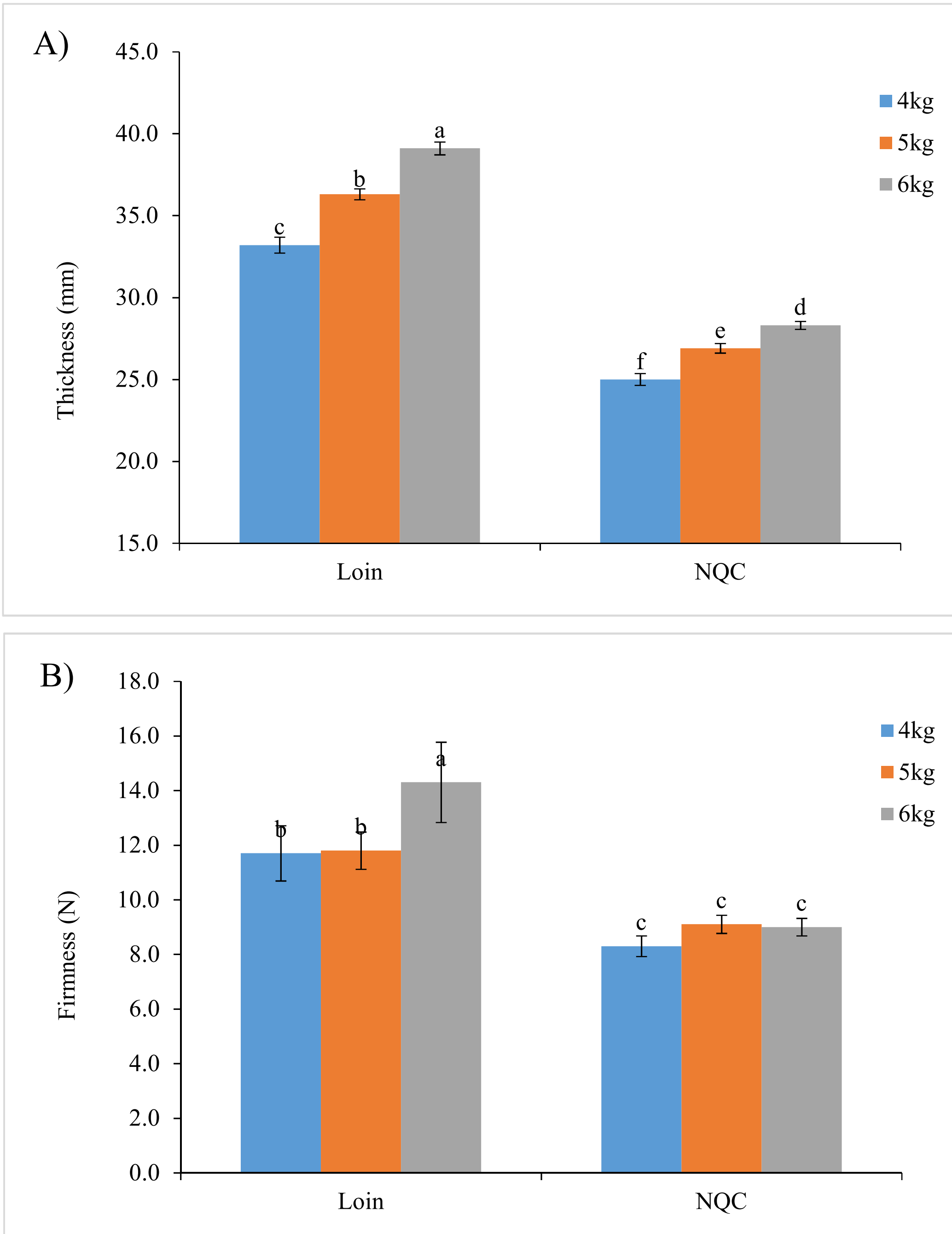

Figure 4.3 Thickness (A) and firmness (B) of raw loin and NQC fillet parts of 4kg, 5kg and 6kg Atlantic salmon. Different superscripts above the SE-bars indicate significant differences ($P < 0.05$) between size groups. Results are presented as mean $\pm$ SE (n = 10 per fish group).

4.1.4 Fillet fat content

The fillet fat content was significantly lower in the 4kg salmon (14.2%) compared with the 5kg (15.3%) and 6kg salmon (16.3%). No significant differences in fillet fat content were found between the 5kg and 6kg salmon (Figure 4.4).

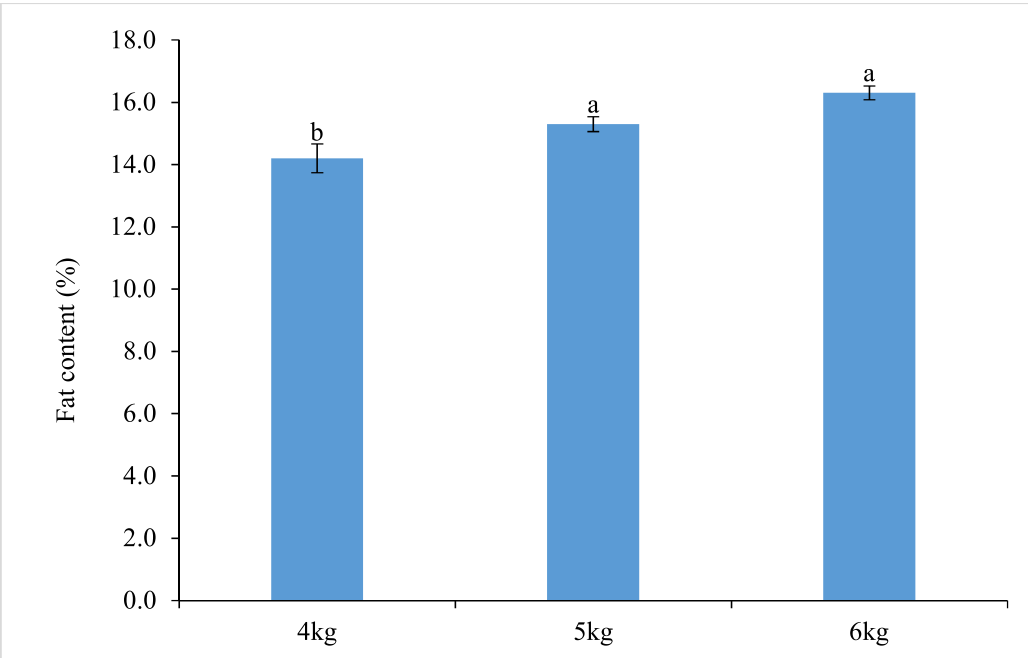

Figure 4.4 Fat content of raw NQC fillets. Results are presented as mean ± SE (n = 10 per fish group) for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

4.2 Effect of salmon body weight on consumer preference

Figure 4.5 shows that the flavour score of 5kg salmon (4.2) was significantly higher than that of 4kg salmon (3.7), while the juiciness scores of 5kg (4.1) and 6kg salmon (4.0) were significantly higher than that of 4kg salmon (3.4). The scores of colour, firmness and odour showed no significant differences between the fish groups. Scores of overall preference ranking of 5kg and 6 kg salmon were significantly higher than that of 4kg salmon (Figure 4.6).

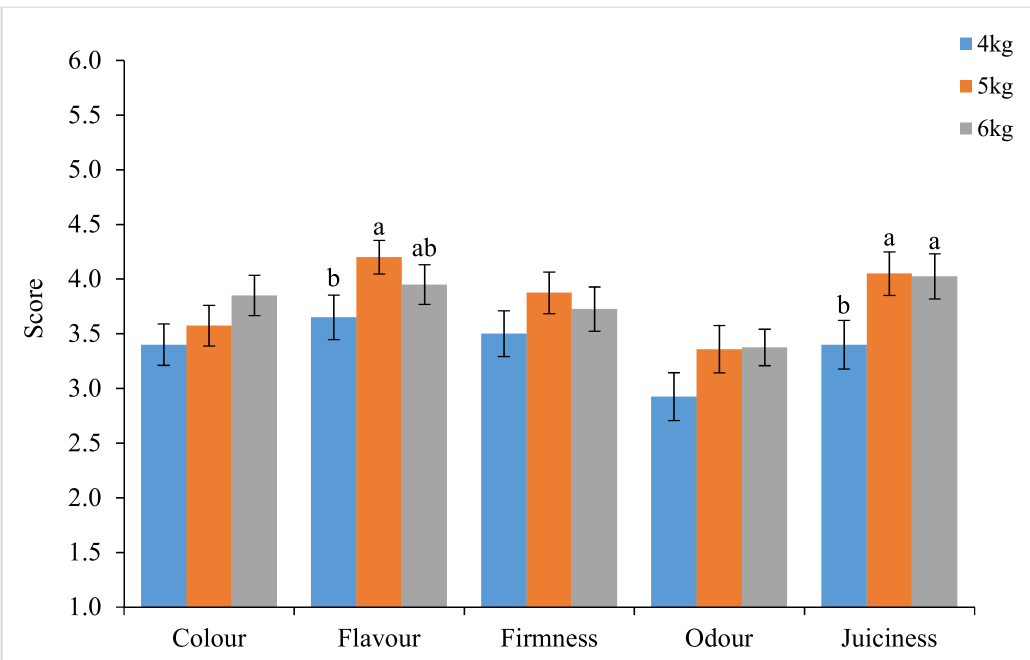

Figure 4.5 Colour, flavour, firmness, odour and juiciness scores of cooked fillets evaluated by 30 assessors. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

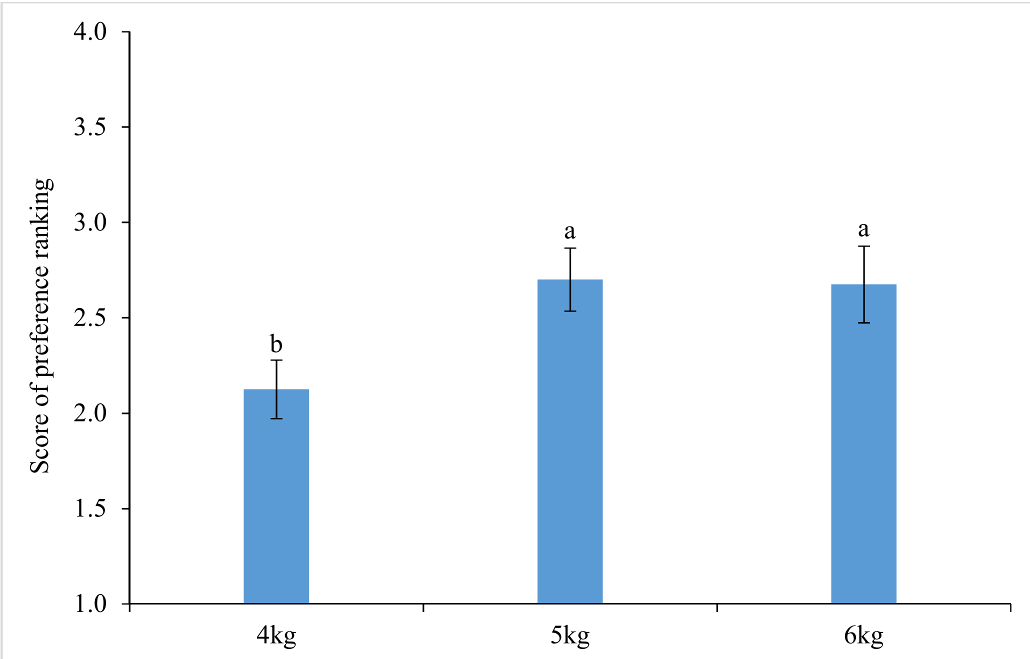

Figure 4.6 Score of preference ranking of cooked fillets evaluated by 30 assessors. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

4.2.1 Differences between female and male assessors

Figure 4.7 shows female assessors scored the colour of 6kg fish significantly higher than that of 4kg fish; the scores of flavour, firmness, odour and juiciness rated by female and male groups showed no significant differences between the fish groups. Scores of overall preference ranking of 4kg, 5kg and 6kg fish showed no significant differences among female assessors, while 5kg fish were preferred significantly more than 4kg fish among male assessors (Figure 4.8).

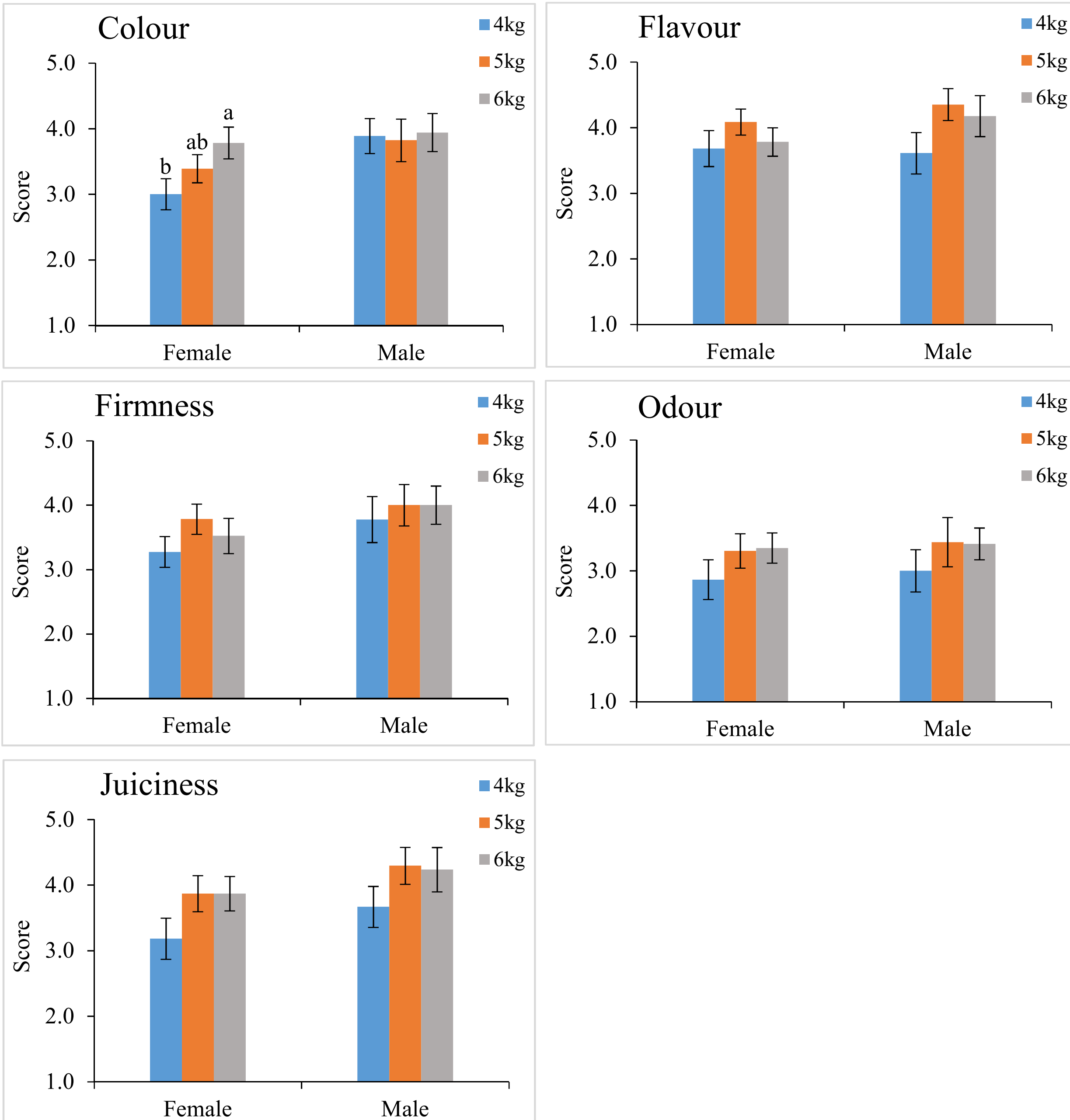

Figure 4.7 Colour, flavour, firmness, odour and juiciness scores of cooked Atlantic salmon fillets evaluated by female and male assessors. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

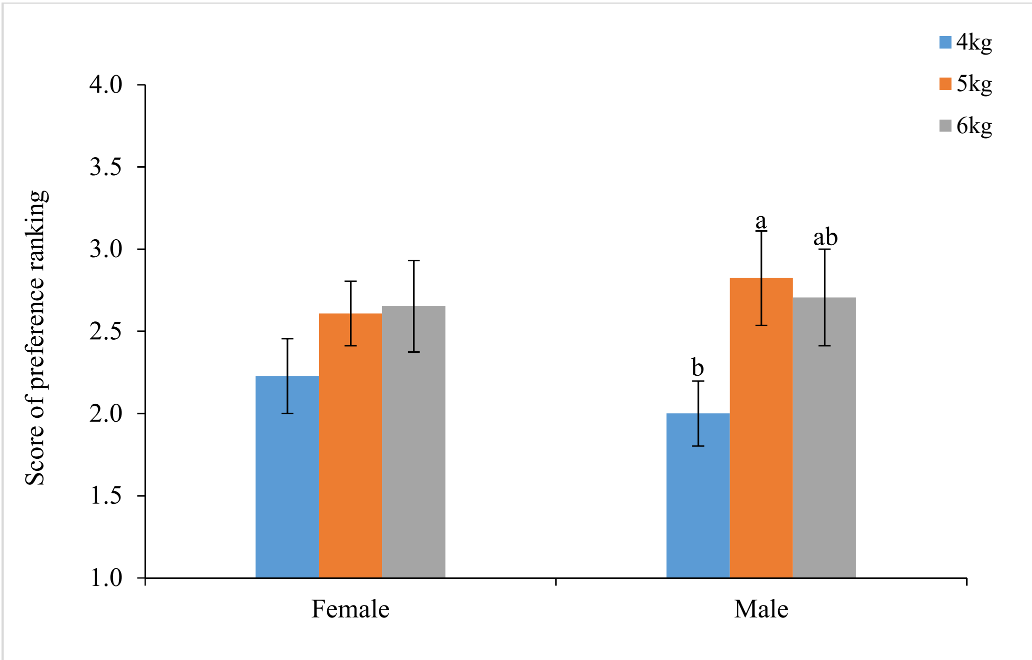

Figure 4.8 Scores of overall preference ranking of cooked fillets evaluated by female and male assessors respectively. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

4.2.2 Differences between age groups

For assessors aged 20-24 years, the flavour and juiciness of 5kg and 6kg fish were scored significantly higher than those of 4 kg fish (Figure 4.9). For assessors aged 30-50 years, the flavour of 5kg fish was scored significantly higher than those of 4kg and 6kg fish (Figure 4.9). For 25-29 years old assessors, no significant differences in the scores of colour, flavour, firmness, odour and juiciness were found between groups of 4kg, 5kg and 6kg fish (Figure 4.9).

Figure 4.10 shows the score of overall preference ranking of 6kg fish was significantly higher than that of 4kg fish among the youngest (20-24 years) age group; there were no significant differences in the score of overall preference rank of between fish groups among assessors aged 25-29 years and 30-50 years.

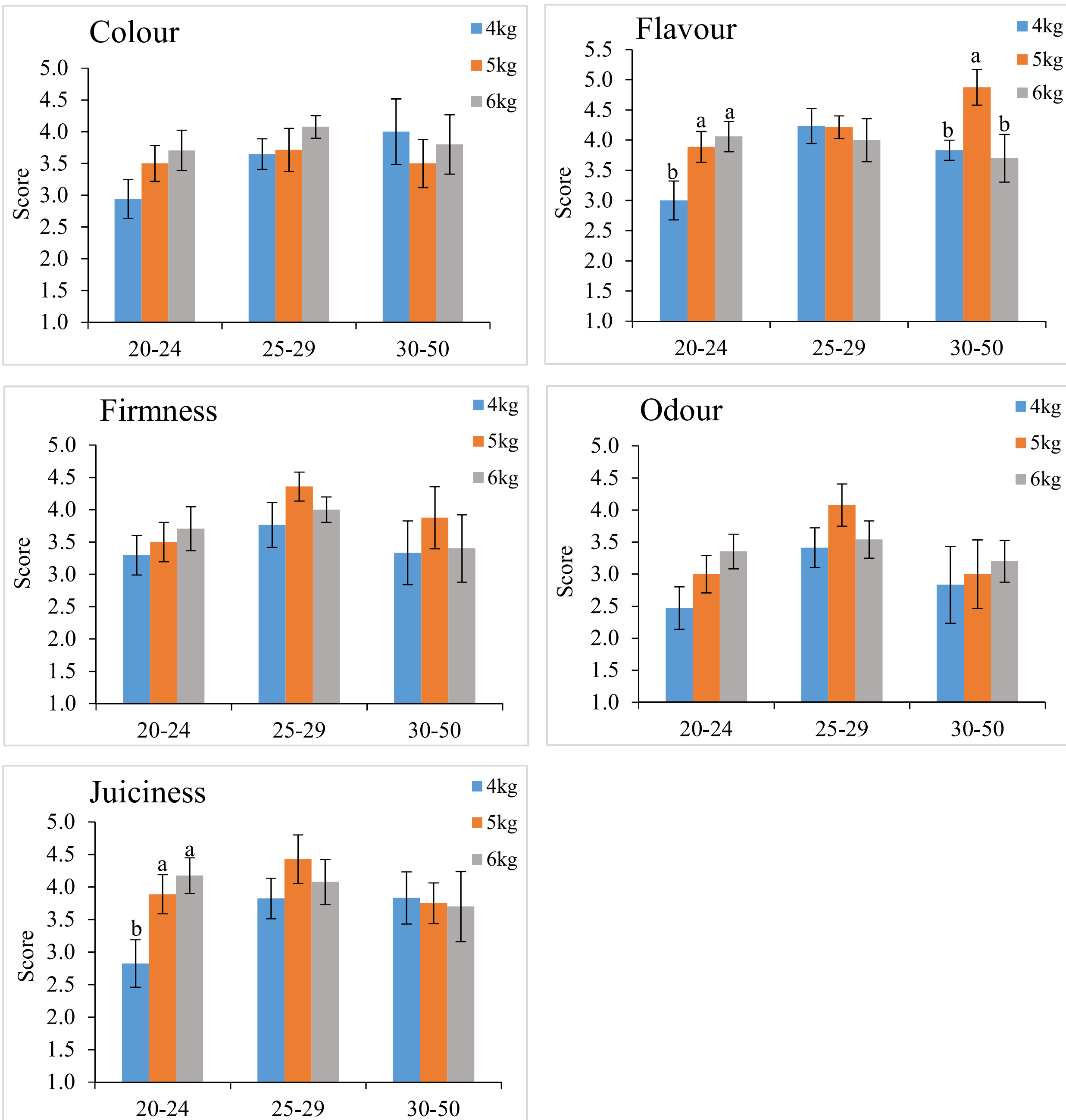

Figure 4.9 Colour, flavour, firmness, odour and juiciness scores of cooked fillets evaluated by groups of assessors aged 20-24 years, 25-29 years and 30-50 years. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

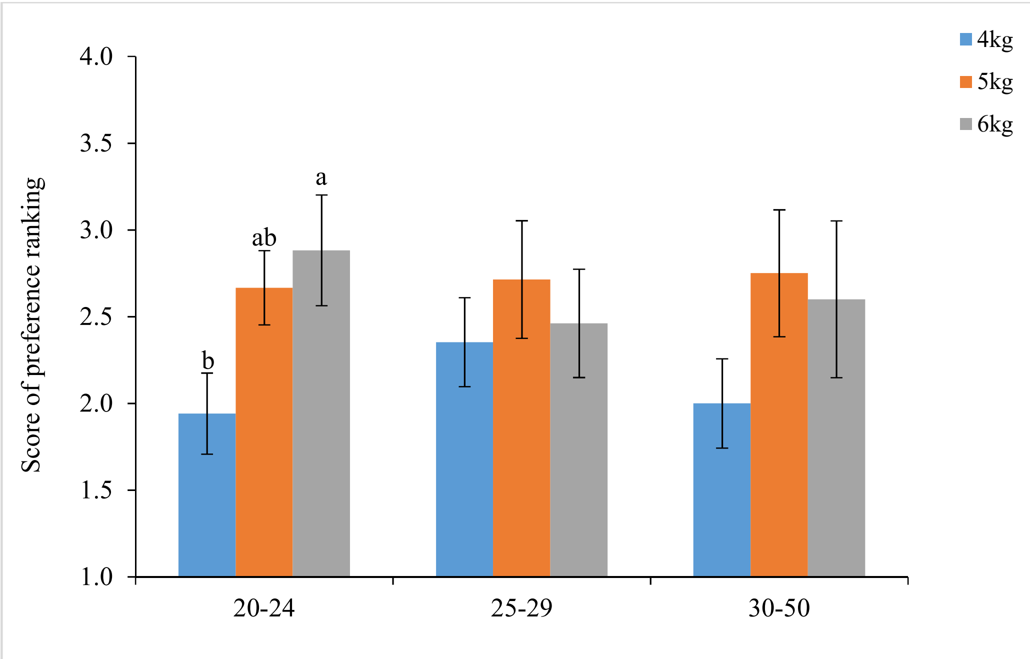

Figure 4.10 Score of overall preference ranking of cooked evaluated by groups of assessors aged 20-24 years, 25-29 years and 30-50 years. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

4.2.3 Differences between nationality groups

For the Asian assessors, the juiciness of 5kg fish was scored significantly higher than that of 4kg fish; for the European assessors, the flavour of 5kg fish was scored significantly higher than those of 4kg and 6kg fish (Figure 4.11).

Figure 4.12 shows no significant differences in the score of overall preference ranking were observed between 4kg, 5kg and 6kg fish among Asian and European assessors.

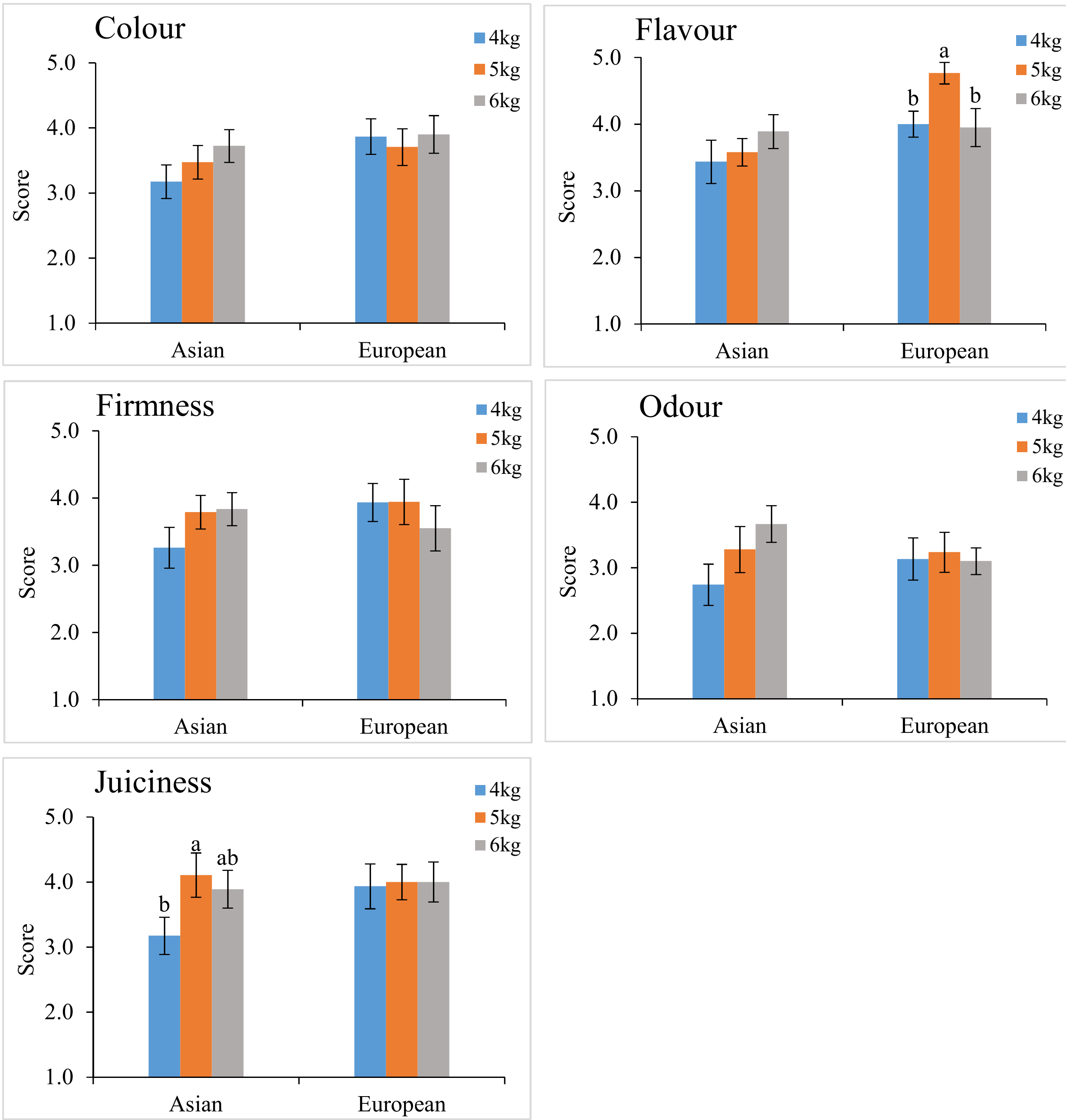

Figure 4.11 Colour, flavour, firmness, odour and juiciness scores of cooked fillets evaluated by Asian and European assessors. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

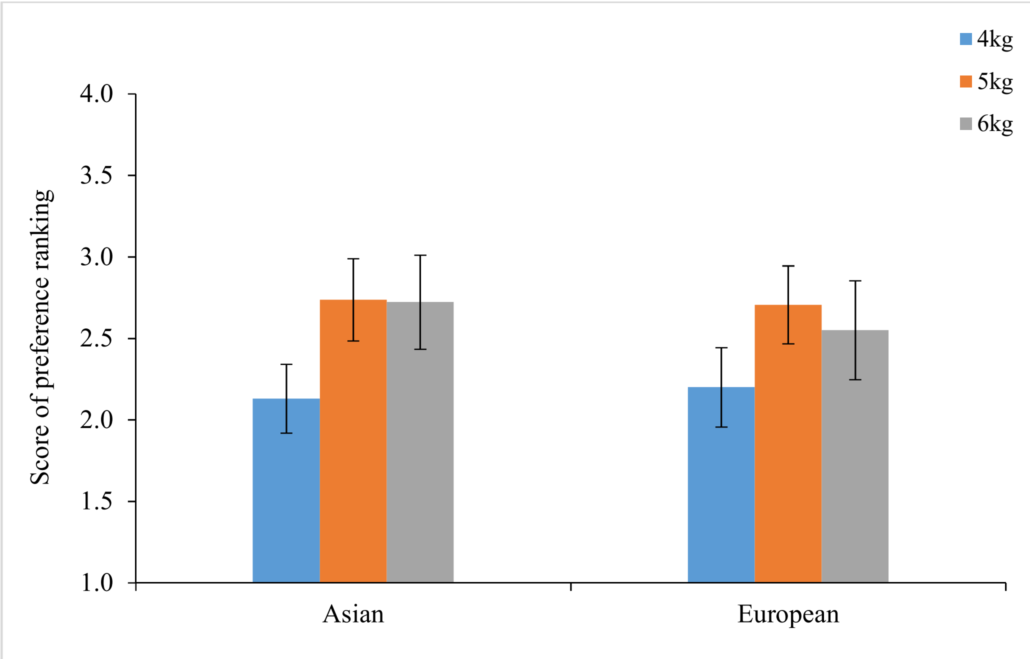

Figure 4.12 Scores of overall preference ranking of cooked fillets evaluated by Asian and European assessors. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. No significant differences on the scores of preference ranking were observed between 4kg, 5kg and 6kg fish.

4.2.4 Differences between groups of monthly fish consumption frequency

Assessors were grouped according to the average monthly frequency of fish consumption – once per month, once every two week, once per week and more than 2 times per week.

For assessors consuming fish once per week, the juiciness of 5kg fish was scored significantly higher than that of 4kg fish. There were no significant differences in the scores of colour, flavour, firmness and odour between 4kg, 5kg and 6kg fish among all these groups of assessors.

For assessors consuming fish once every two week, the score of overall preference ranking of 5kg fish was significantly higher than that of 4kg fish. There were no significant differences in the scores of overall preference ranking between 4kg, 5kg and 6kg fish among assessors consuming fish once per month, once per week and more than 2 times per week.

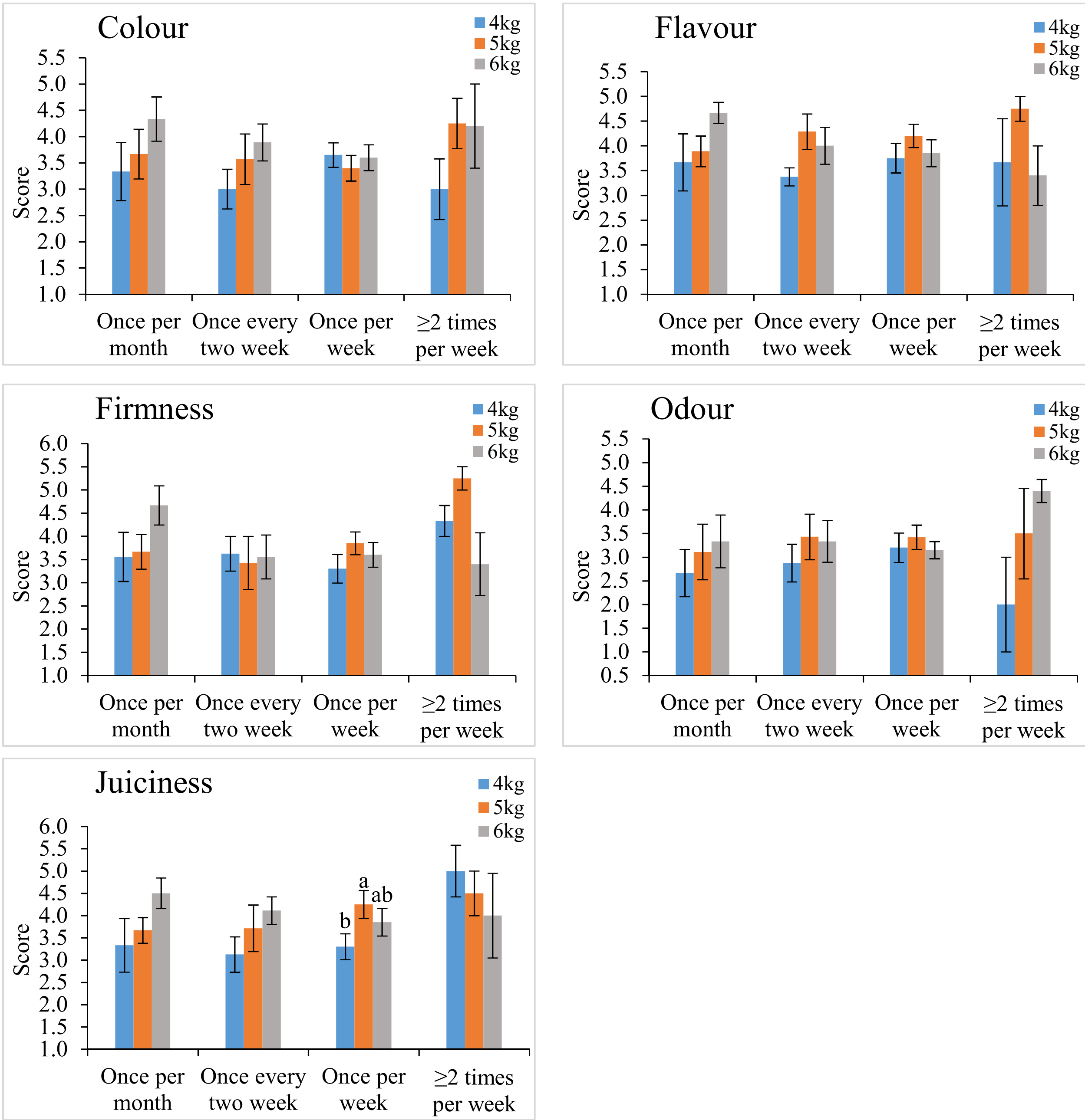

Figure 4.13 Colour, flavour, firmness, odour and juiciness scores of cooked fillets evaluated by assessors consuming fish once per month, once every two week, once per week and more than 2 times per week. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

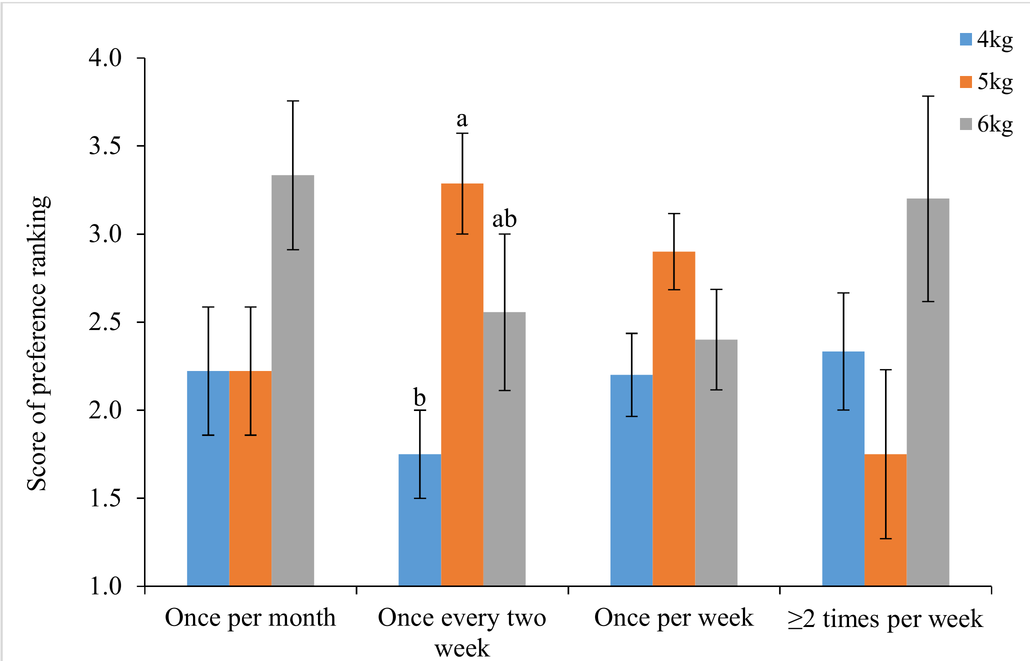

Figure 4.14 Score of overall preference ranking of cooked fillets evaluated by assessors consuming fish once per month, once every two week, once per week and more than 2 times per week. Results are presented as means ± SE for salmon groups of 4kg, 5kg and 6kg, respectively. Different superscripts indicate significant differences ($P < 0.05$) between groups of 4kg, 5kg and 6kg fish.

4.3 Effect of fillet parts on consumer preference

Colour and juiciness of the loin part were scored significantly higher than those of the NQC part (Figure 4.15). There were no significant differences in the scores of other sensory properties – flavour, firmness and odour between the loin and NQC parts (Figure 4.15). Moreover, there were no significant differences in the scores of overall preference ranking between the loin and NQC parts (Figure 4.16).

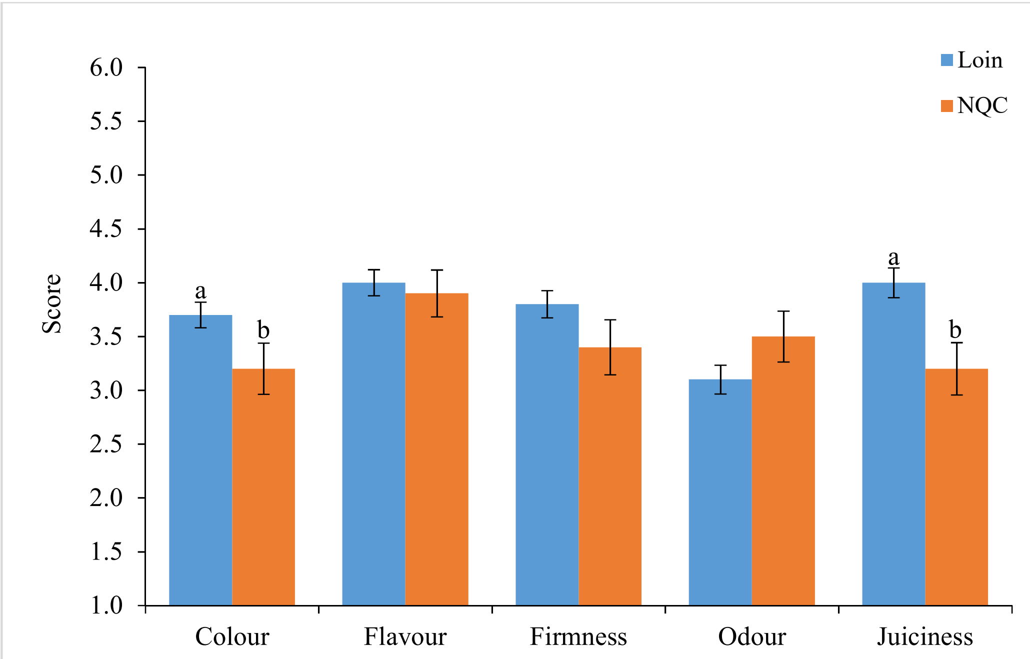

Figure 4.15 Colour, flavour, firmness, odour and juiciness scores of cooked loin and NQC fillets evaluated by 30 assessors. Results are presented as means ± SE. Different superscripts indicate significant differences ($P < 0.05$) between groups of the loin and NQC fillets.

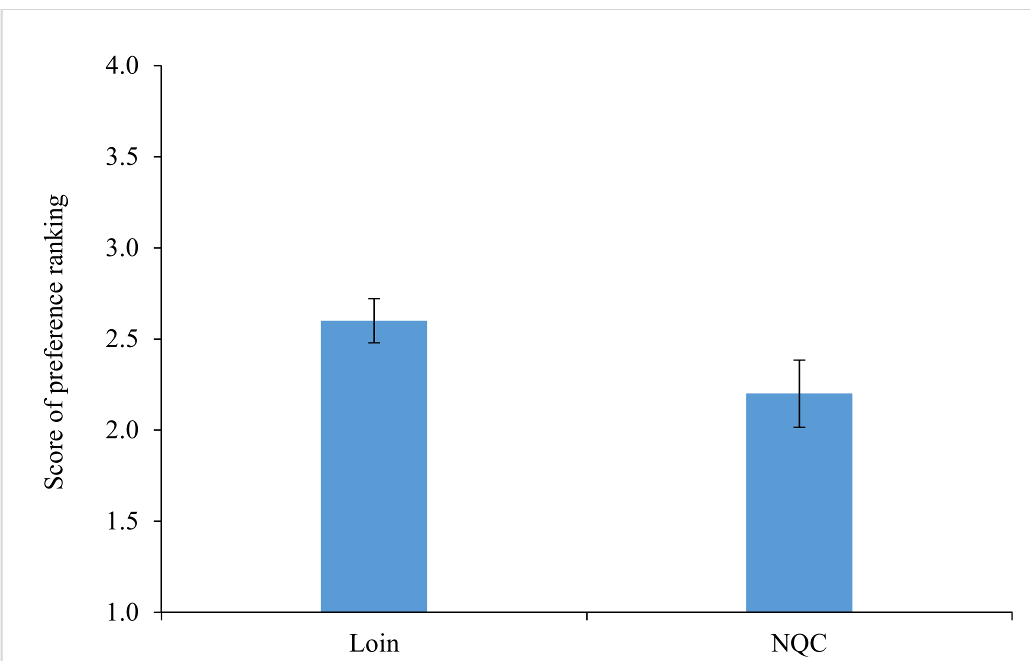

Figure 4.16 Score of overall preference ranking of cooked loin and NQC fillets evaluated by 30 assessors. Results are presented as means ± SE.

4.4 Correlation between sensory properties and preference ranking

4kg salmon showed significant positive correlations between the scores of odour, flavour, firmness and juiciness and the overall preference ranking score; 5kg salmon had significant positive correlation between the juiciness score and the preference ranking score (Table 4.1). For 6kg salmon, both the flavour and juiciness scores were significantly positively correlated with the preference ranking score (Table 4.1). The colour scores, however, were not significantly correlated with the corresponding ranking score among the different size of salmon.

Table 4.1 Correlation between the colour, odour, flavour, firmness and juiciness scores and overall preference ranking score of cooked fillets of 4kg, 5kg and 6kg salmon from the sensory evaluation

		Ranking Score		
Fish weight	Property	4kg	5kg	6kg
4kg	Colour	0.289	0.058	-0.014
	Odour	0.410**	-0.069	-0.087
	Flavour	0.550**	-0.156	-0.024
	Firmness	0.452**	-0.168	-0.038
	Juiciness	0.602**	-0.056	-0.112
5kg	Colour	-0.042	0.207	-0.026
	Odour	0.254	0.165	-0.172
	Flavour	-0.192	0.214	0.201
	Firmness	-0.008	-0.010	0.074
	Juiciness	0.037	0.441**	-0.150
6kg	Colour	-0.279	-0.080	-0.086
	Odour	-0.299	0.198	0.151
	Flavour	-0.040	-0.141	0.462**
	Firmness	-0.054	-0.006	0.307
	Juiciness	-0.266	0.156	0.468**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5 Discussion

5.1 Fillet quality and fish size

Colour of salmon fillet is an important quality parameter that can be predicted by the method used in the present study (Sigurgisladottir et al., 1997). SalmoFan^{TM} is a well-recognized colour reference standard for visual judging the colour of salmon fillet in the salmon production industry and trade. The colour score of tested sample depends on the degrees of salmon flesh pigmentation perceived by the human eyes. Alfnes et al. (2006) found that the consumer prefer the salmon fillets with colour score of R25, R27, and R29 to those with R23. The colour of farmed salmon fillet sold in Norway most commonly ranges from R25 and R27 (Carle and Schweiggert, 2016 p. 272-273). Hence, the average level of fillet colour of all weight groups in the present study were in the range of commonly acceptable colour scores for commercially traded salmon. There were no significant differences in colour score between the different body weight groups. It is in accordance with the result of Alfnes et al. (2006) that no significant differences in consumer preference of fillet colour were found between R23, R25, and R27.

Data on the gaping score shows only small and few slits on the raw fillets in three body weight groups of salmon, which indicates that the raw fillets are in the acceptable range. The post-mortem storage time and temperature can affect the fillet texture (Dunajski, 1980) and gaping (Loye, 1973; Lavéty, 1984). The post-mortem storage time and temperature in the present study was similar for fillets of all salmon groups. Thus, the gaping in the raw fillets was most probably related to the de novo conditions of salmon. Moreover, the present study reveals that the loin fillets were significantly thicker and firmer than NQC fillets. The distribution and diameter of the muscle fiber have been found to affect the texture of muscle tissue among five fish species (Hatae et al. 1990). Hence the greater firmness in the loin fillet might be related to differences in fiber density.

The present study shows that the 5kg and 6kg salmon had significantly higher fillet fat content than the 4kg salmon. As for an individual salmon, a curve-linear relationship between body weight and fat content of salmon is reported, differences in body weight contribute only 27.1% of the variation in fat content of salmon with the body weight greater than 2kg (Mørkøre & Rørvik, 2001). because the fat content was either stable or slightly declining during winter and spring, although the weight was increasing. Fat content in salmon fillets higher than 18% is unfavorable (Gjedrem 1997). The average fillet fat content of all size groups in the present study was below 18%, ranging from 14.2% to 16.3%, which indicates that the fillets could be sold at premium to the demanding market.

5.2 Fish size and consumer preference

In the present study, both the 5kg and 6kg salmon were most preferred whereas the 4kg salmon was least preferred. On average, none of the three body sizes of salmon had very high or low acceptability. Colour, texture, flavour and fat content of salmon products are regarded as important quality parameters for consumer preference (Gormley 1992; Sigurgisladottir et al., 1997; Anderson 2000; Steine et al., 2005). Differences in overall preference for these groups of salmon might be explained by differences in sensory properties evaluated by consumer assessors. There were no significant differences in the preferences of colour, firmness and odour among all size groups, however, the significantly preferred flavour and juiciness were reflected on the 5kg salmon when consumers preferred the 5kg salmon to the 4kg salmon. It's suggested in the present study that the preference for odour, flavour, firmness and juiciness of the 4kg salmon were positively correlated to the overall preference ranking while the juiciness of 5kg salmon and the overall preference ranking were positively correlated. Hence, consumer preferred the 5kg salmon to the 4kg salmon due to their liking the flavour and juiciness of the 5kg salmon. As for the 6kg salmon, the juiciness preference was significantly higher than that of 4kg salmon while preferences of other sensory properties were not significantly different from those of the 4kg salmon. Both the flavour and juiciness of the 6kg salmon were positively correlated to the overall preference ranking. Thus, preference for the juiciness might contribute to consumer preference on the 6kg salmon rather than the 4kg salmon.

Preference differences might result from consumers differed with regard to gender, age, countries and fish consumption frequency. Differences in the sensory characteristics and overall preference for salmon fillet were observed among consumers with different background. Both female and male consumers had high preferences for the 5kg and 6kg salmon, whereas only male consumers significantly preferred the 5kg salmon to the 4kg salmon. The high preferences for the bigger size of salmon could be reflected by the high scores of the colour, flavour, firmness, odour and juiciness on these salmon. Female consumers significantly preferred the fillet colour of the 6kg salmon to that of the 4kg salmon while male consumer had high preferences for the fillet colour of all groups of salmon. It could be explained by the differences in the visual perception of colour between female and male (Jain et al., 2010). However, the liking for fillet colour was not correlated to the overall preference among all size groups of salmon. Hence, the flavour, firmness, odour and juiciness might be the important factors influencing female and male consumer preference.

There were also preference differences in the sensory characteristics of three groups of salmon between consumers differed in age. Both the youngest consumers (20-24 years old) and consumers aged 30-50 years had high preferences for the 5kg and 6kg salmon, while consumers aged 25-29 years showed high preferences for the 5kg. The youngest consumers significantly preferred the 6kg salmon to the 4kg fish, which might result from the considerably high preference for the colour, firmness and odour of the 6kg salmon, and the significantly higher preference for the flavor and juiciness of the 6kg salmon over those of the 4kg fish. For consumer aged 25-29 years, the high preference for the 5kg salmon of might result from the high preference for the firmness, odour and juiciness. The preference for the 5kg salmon among consumer aged 30-50 years might be explained by the better preference for the firmness, relatively high preference for the juiciness and significantly preferred flavour. Consumer in age groups claimed their preferences for the bigger size of salmon based on their liking for different sensory characteristics of salmon fillet.

In addition, Asian consumers who had their likings for the 5kg and 6kg salmon showed the high preference for the colour, flavor, firmness, odour and juiciness. There was a significant preference for the juiciness of the 5kg salmon over that of 4kg salmon. The likings for the 5kg salmon among European consumers could be observed in the high preference for the firmness, juiciness and the significantly preferred flavour. Moreover, people consumed fish once per week had their liking for the 5kg salmon and significantly preferred to the juiciness of the 5kg salmon. Consumers differed in gender, age, countries and fish consumption frequency claimed their preferences for the bigger size of salmon focusing on different sensory characteristics of salmon fillet, such as flavour, firmness, odour and juiciness.

Mouth-feeling of juiciness is a common sensory characteristic which influences the overall preference of salmon fillet among consumers differed in gender, age, countries and fish consumption frequency. Einen et al. (1999) suggested a positive correlation between mouth-feeling of juiciness and fat content in smoked salmon. The present study reveals that the 5kg and 6kg salmon contain higher fillet fat content than the 4kg salmon, which could be responsible for the consumer preference for juiciness of the 5kg and 6kg salmon.

5.3 Fillet part and consumer preference

Data in the present study reveals that consumers tended to prefer the loin fillet than NQC parts. Preference for firmness of the loin fillet than that of the NQC parts suggests that consumers prefer a firmer texture of the loin fillet. Consumers also showed significantly higher preference for colour and juiciness of the loin fillet to those of the NQC part. Moreover, Consumers claimed relatively high preference for flavour of both the loin fillet and NQC part and higher acceptability for odour of the NQC part. It could be concluded that differences in firmness, colour and juiciness between the loin fillet and NQC part of salmon could be perceived by consumers and contribute to consumer preference.

6 Conclusions

The present experiment demonstrated that fillet quality related characteristics of Atlantic salmon could be affected by body weight and fillet parts. The increasing body weight, increased fillet yield, fillet thickness and fat content in salmon indicate that these quality characteristics can be altered by extended growth period before harvest. Likewise, the bigger body weight of salmon, such as the 5kg and 6kg salmon obtained higher consumer preference than the 4kg salmon. Odour, flavour, firmness and juiciness of cooked salmon fillet were improved by increased salmon body weight, although fillet colour and pigment content showed no significant differences. Fillet colour in all body weight groups of salmon were well accepted by consumer assessors. In addition, different fillet parts caused differences in sensory texture characteristics in raw and cooked fillet. The raw loin fillet parts were thicker and firmer than the NQC part, and the sensory score for firmness and juiciness of the cooked loin part were higher compared with the NQC. Hence the sensory characteristics evaluated showed that the loin part appeared to be more favourable compared with the NQC part. Tendency that younger consumers (20-24 years) discriminated the fish group more significantly than older consumers (25-50 years). Frequency of fish consumption and origin of the assessors (Asian and European) showed no significant effect on sensory assessment. Although a certain demographic effect on sensory parameters, preferences should be conduced with a higher number of assessors.

Bigger body size before slaughter and the loin fillet can be associated with potential positive changes in quality characteristics of raw and cooked salmon. However, the extension of harvest to obtain bigger fish size may lead to potential additional costs which will result in higher market prices. The present data can be used for optimizing production in relation to cost of production, marketing and quality characteristics of gutted salmon or salmon fillet products.

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