Grading of correlated quality traits for added market value in Atlantic salmon (*Salmo salar* L.) - A model with example data

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Abstract

The quality of the Atlantic salmon (Salmo salar L.) at the time of harvest affects the economic value and is in addition to body weight generally determined by the body composition and carcass quality traits, such as fillet colour and fat content. However, the method of grading on the basis of these quality traits is limited due to the lack of implemented technology. Currently, fish are therefore being graded according to their gutted body weight although different quality grade of pigment and fat content along with body weight are possible. Hence, the objectives of the study were (I) to determine the effect of present body weight based grading system on the frequency distribution of the quality traits fillet fat and fillet colour,(II) to study the effect on the frequency distribution of different quality classes of grading with respect to both body weight, fillet fat and fillet colour and (III) To study the added value if some premium could be fetched for grading fish in to top quality classes. Data were requested from SalmoBreed AS, Norway representing their 2001 year class. Total numbers of fish were 5316. Among them, 4331 (81.5%) fish were sexually immature and 985 (18.5%) were maturing. The sexual maturing fish were omitted from the data. The samples of 2634 of the non-maturing fish (1074 males and 1560 females) were used for the study. The traits recorded at harvest were sex, length (cm), round body weight (gm), gutted body weight (gm), pigment (ppm) and fillet fat content (%).The mean round body weight of the males was only 3.1% heavier than the females and average gutted body weight of males was 3.4% greater than females. The average fat and pigment content of male fish were only marginally higher than of the females. The mean value of gutted body weight, fillet pigment and fat content were found 2.89 kg, 6.74 ppm and 12.6% respectively in the sampled population. Fish with increasing body weight showed increasing value of pigment (r=0.51), fat (r=0.41), and increasing filet fat was associated with increasing pigment (r=0.55). A model was formulated to grade the Atlantic salmon in different quality groups based on fillet fat and pigment content and three models were given to calculate some anticipated premium for different quality grades based on fat content, pigment and gutted body weight. They were Revenue 1 (Rev 1), Revenue 2 (Rev 2) and Revenue 3 (Rev 3). In Rev 1, quality grading was not practiced. In Rev 2, grading on fillet fat and fillet pigment and in Rev 3, body weight, fillet fat and pigment were considered. For Rev 2 and 3, two alternatives were used. Different alternatives represent the different level of threshold value and premium percentage. Average revenue per kg fish for Rev 2 was 1.2% (Alt 1) and 1.0% (Alt 2) higher than Rev 1 whereas average revenue per kg *fish for Rev 3 (Alt 2) was 1.22% higher than Rev 3 (Alt 1). When quality grading based on fillet fat and pigment content, the worst quality fish (HF.LP) got 25% less price whereas the best quality fish (LF.HP) got 30% extra price per kg gutted body weight than the medium quality (MF.MP). Moreover, when the grading based on fillet fat content, pigment and body weight, the best quality group (LF.HP) fetch 33.4% more price while worst quality group (HF.LP) got 29.7% less price as compared to the medium quality (MF.MP) fish. Both producers and consumers could be benefited if grading is conducted on the basis of these quality traits. However, at present there is no implemented technology to prove such grading with respect to different quality traits. When technology is available it is possible to offer different quality classes and answer will be acquired on the premium that can be achieved.*

Key words: *Atlantic salmon, fillet fat, fillet pigment, body weight, grading, added value*

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1. Introduction

Atlantic salmon (*Salmo salar* L.) is one of the most established and economically important species within aquaculture. Important traits of aquaculture species are manipulated through selective breeding schemes that are employed to maximize the genetic gain in addition to controls over diet and culture environment, harvesting procedures and timing of the product delivery to the market (Paterson et al. 1997). Understanding the interactions between the economically important traits is of particular importance if we are to control the product quality in terms of body composition and flesh quality in addition to body weight. The main quality traits of Atlantic salmon include fat content, fat distribution pattern, body shape, texture, colour and appearance (Gormley 1992; Koteng 1992).

Growth rate until the desired marketing size has been the trait assigned the highest importance in terrestrial livestock selection programmes and this is also the same for Atlantic salmon (Quinton et al. 2005). The quality of the product at the time of harvest affects the economic value of the fish and is generally determined by the body composition and carcass quality traits, such as fillet colour and fat content. The importance of product quality means that most breeding programs for salmonid species should incorporate quality traits along with growth rate as selection criteria (Gjedrem 1997; Gjedrem 2000).

The market considers flesh colour as an indicator of salmon quality and retailers downgrade or even reject a product with insufficient colour. Alfnes et al. (2006) reported that consumers willingness to pay increased at higher colour intensities, in particular up to score 25 on the SalmoFan scale. Presented salmon fillets with colour scores less than 23 were difficult to sell at any price, corresponding with pigment level of approximately 3-4 mg/kg fish. In most markets, pigment level 6 mg per kg is considered as acceptable but certain markets want even higher value, for example Japan (Mørkøre 2010). The distinctive pink-red coloration of the flesh is caused by carotenoid pigments that salmonids are unable to synthesize. Thus the use of a feed with appropriate pigment content is regarded as the most important management practice for the production of farmed salmon (Moe 1990). Atlantic salmon fed a diet supplemented with astaxanthin accumulate caretonoids in the flesh as they grow and this process does not stop until they become sexually mature (Bjerkeng et al. 1992). Wild salmon obtain these from a diet of amphipods and crustaceans; however, such diet is not available or hard to get for farmed salmon. So, for farmed salmonids pigments are usually added to their feed in the form of astaxanthin (3,39-dihydroxy-b,b-carotene-4,49-dione) and canthaxanthin (b,b-carotene-4,49-dione) (Powell et al. 2008; Shahidi et al. 1998). Astaxanthin is the predominant carotenoid of wild Atlantic salmon (Schiedt et al. 1986). Astaxanthin and canthaxanthin have also been regarded as vitamins and have a positive effect on growth of salmon larvae. Therefore it is recommended that all fish feed should contain at least 10 mg/kg feed of these carotenoids (Torrissen & Christiansen 1995). Carotenoid feeding is expensive, although indispensable for Atlantic salmon farming, and the cost of supplements may amount to approximately 15- 20% of total feed costs (Torrissen 1995; Ytrestøyl et al. 2004). Therefore to minimize costs, producers want animals that most efficiently absorb and retain these pigments in the flesh. Flesh pigmentation has thus become a trait of interest for breeding programmes. The number of studies in salmonids have reported positive genetic correlations between body weight and colour, both measured at the fixed age, indicating that selection for increased body weight will result in an increase in the desirable coloration of the flesh (Johnston et al. 2006; Norris & Cunningham 2004; Quinton et al. 2005). However, no estimate is available in salmonids of the genetic correlation between growth rate and colour, both recorded at a fixed body weight.

Another quality trait of increasing interest is fillet fat content because fat content is one of the most important quality criteria of Atlantic salmon. It is important not only from a nutritional point of view, but also due to its sensory and functional properties (Haard 1992; Skonberg et al. 1993). According to Fjellanger et al. (2000), the fat content of Norwegian salmon fillets ranges from 11% to 19%. The European markets are becoming more concerned with quality and demand mainly salmon with low fat content (below about 12%) (Midtvedt 1995), while as a general rule fillet fat percentage greater than 18% is considered undesirable (Gjedrem 1997). An excessive amount of fat in muscles is thought to have a detrimental effect on meat texture as well as affects smoking processes and quality traits such as coloration (Powell et al. 2008). There is evidence of an unfavorable genetic correlation between fat content and body weight. This implies that the direct selection for increased harvest body weight measured at a fixed age results in unfavourable correlated responses in fat content, as heavier fish have a greater fillet fat percentage (Gjerde & Gjedrem 1984; Quinton et al. 2005; Rye & Gjerde 1996). If breeding programmes are going to maintain the quality of their product, they will need to utilize methods, such as restricted selection indices (Cameron 1997) in order to prevent the expected increase in fat percentage.

Chemical methods for fat determination such as ethyl acetate extraction are reliable but highly destructive, relatively costly and time-consuming (Folkestad et al. 2008). Computerized X-ray tomography (CT) is a non-destructive imaging technique that can be used for determination of gross chemical composition of several fish species, including salmonids (Rye 1991). Fat determination by CT is much faster than by chemical extraction methods, but the cost of the equipment has confined the method from being largely used in the commercial aquaculture industry. Near-infrared spectroscopy (NIR) has proven with sufficient accuracy (about ±0.8%) in the laboratory studies to determine the fat content in salmon fillets (Isaksson et al. 1995; Wold et al. 1996). Estimation of fat content by measurements of whole fish is a much more challenging job. The skin of the fish absorbs and reflects electromagnetic radiation heavily in the NIR region and makes it difficult to obtain representative measurements from the interior of the fish muscle. However, promising results have been obtained when measuring fat content in whole and live salmon with NIR spectroscopy (Solberg et al. 2003; Wold & Isaksson 1997).The NIR systems were designed for lab studies and not yet optimized to meet the requirements of a commercial salmon industry. Nuclear magnetic resonance (NMR) is also an interesting method for non-invasive fat determination in whole salmon (Veliyulin et al. 2005), but substantial development remains before an NMR system is affordable and fast enough for industrial purposes. A rapid, low-cost and nondestructive method of estimating pigment and fat content in whole fish (live or slaughtered) or gutted fish with sufficient accuracy would provide salmon industry with the opportunity to sort fish with different pigment level and fat content according to market requirements and product specifications (Folkestad et al. 2008).

Alike other products, the price of salmon is primarily determined by the relationship between demand and supply and the price is also somewhat influenced by the product quality. Different market may have different requirement for pigment and fat content which is also affected by condition factor. It is often difficult to delineate one set of coveted quality standard because quality depends on regional preferences, attitude of customers and the methods of handling, preservation and consumption. In any case, important quality traits of

Atlantic salmon are associated with safety, nutrition, texture, appearance and suitability of the raw material for processing and preservation (Haard 1992).

Normally, the whole salmon is graded according to the body weight before marketing. But if the grading be conducted based on additional quality traits like fillet color and fillet fat content, consumer can choose the product according to ones' preference. Moreover, products could be directed towards markets with different demand. For example the smoking processing industry has high demands on colour intensity and fat content (Mørkøre 2010).
Grading of salmon could result in added value if some price premium could be fetched for satisfying quality specifications from demanding costumers. However, the method of grading on the basis of these quality traits is limited due to lack of appropriate technology. Hence, the objectives of the study were:

I. To determine the effect of present body weight based grading system on the frequency distribution of the quality traits fillet fat and fillet colour.
II. To study the effect on the frequency distribution of different quality classes of grading with respect to both body weight, fillet fat and fillet colour.
III. To study the added value if some premium could be fetched for grading fish in to top quality classes.

2. Materials and Methods

2.1 Fish population

Data were requested from SalmoBreed AS, Norway. SalmoBreed AS is a breeding company with a family based breeding program, which develops a genetic material suitable for future production of Atlantic salmon and rainbow trout (http://www.salmobreed.no). The data represents their 2001 year class. Fish were started to feed in March/April, 2001 and kept in freshwater until May, 2002 at Nofima Marin, Sunndalsøra. Afterwards, they were transferred to the sea cages in May/June, 2002 at Nofima Marin, Averøy, and harvested in September, 2003. Data were recorded from 308 full-sib families. Total numbers of fish were 5316. Among them, 4331 (81.5%) fish were sexually immature and 985 (18.5%) were maturing. The sexual maturing fish were omitted from the data. The random samples of 2634 of the non-maturing fish (1074 males and 1560 females) were used for this study.

2.2 Traits recorded at harvest

The traits recorded at harvest were sex, length (cm), round body weight (gm), gutted body weight (gm) and fillet weight (gm). Colour, pigment (ppm) and fillet fat content (%) were measured above the lateral line between the posterior part of the dorsal fin and the gut (frequently termed as the Norwegian Quality Cut, NQC) *)* using the equipment provided by PhotoFish AS (Folkestad et al. 2008). Condition factor was calculated by using the following formula.

$$\text{Condition factor (K)} = \frac{\text{Round body weight (gm)} * 100}{(\text{Length, cm})^3}$$

The structure of data is given in Appendix 1.

2.3 Data analysis and calculations

A model is designed to grade the Atlantic salmon in different quality groups based on Fillet fat and pigment content. There are 9 different quality grade combinations of the two quality traits (Table 1). In addition, the price per kg body weight varied according to the body weight of the fish (Table 2).

Table 1. Different quality grade combinations of Atlantic salmon based on pigment (ppm) and fat content (%).

	Fat		
Pigment	**Low (LF)**	**Medium (MF)**	**High (HF)**
Low (LP)	LF.LP	MF.LP	HF.LP
Medium (MP)	LF.MP	MF.MP	HF.MP
High (HP)	LF.HP	MF.HP	HF.HP

Table 2. The price [Free Carrier (FCA) Oslo] per kg fresh gutted superior Atlantic salmon.

Body weight classes, kg	Price (NOK) per kg
1-2	31.35
2-3	36.37
3-4	40.84
4-5	41.34
5-6	41.78
6-7	42.38
>7	42.38

Source: (*Akvafakta, Week 15* 2010)

Three models are formulated to calculate some anticipated premium for different quality grades based on fat content, pigment and gutted body weight. They are Revenue 1 (Rev 1), Revenue 2 (Rev 2) and Revenue 3 (Rev 3). In Rev 1, quality grading is not practiced. Average body weight price is taken to calculate per kg revenue of Atlantic salmon.

In Rev 2, grading on fillet fat and fillet pigment is considered. Threshold levels are defined for different quality grades for pigment and fat content. Two different premium alternatives are used to calculate the revenue of fish (Table 3).

Table 3. Revenue 2 with threshold levels for the two different premium alternatives. The premium (%) is relative to a price of NOK 40 per kg.

	Threshold level[1]		**Premium, %**		
Alternative 1	Low	High	Low	Medium	High
Fat percentage	- 1*SD	+ 1*SD	+15	0	-5
Pigment (ppm)	- 1*SD	+ 1*SD	-20	0	+15
Alternative 2					
Fat percentage	- 1*SD	+ 0.842*SD	+10	0	-10
Pigment (ppm)	- 1*SD	+ 0.842*SD	-20	0	+20

SD = Standard deviation.
[1]Individuals above or below a threshold value of SD=1 represent 15% of the population, while those above or below a threshold value of SD=0.842 represent 20%.

In Rev 3, threshold levels are defined for different quality grades for pigment and fat content in addition to body weight. Alternative 1 is used to calculate the revenue based on gutted body weight only whereas alternative 2 is used to calculate the revenue based on fillet fat, fillet pigment and gutted body weight (table 4).

Table 4. Revenue 3 with threshold level and premium percentage for alternative 2.

Alternatives	**Quality grading**	**Threshold level**		**Premium %**		
		Low	**High**	**Low**	**Medium**	**High**
Alternative 1	Gutted body weight only	-	-	-	-	-
Alternative 2						
	Fat percentage	-1*SD	+1*SD	+15	0	-5
	Pigment (ppm)	-1*SD	+1*SD	-20	0	+15
	Gutted body weight	-	-	-	-	-

Profit per farm or per kg fish produced is equal to revenue minus cost of production (Profit = Revenue - Costs). In this study only revenue is considered, and costs for per kg fish production is assumed same for all quality classes.

The data were analysed by descriptive statistics, regression analyses and Pearson‘s correlation coefficient using SAS 9.1 (SAS Institute Inc.) and Minitab 15 (Minitab 2006).

3. Results

3.1 Phenotypic means and variation

Phenotypic mean, standard deviations (SD), coefficient of variance (C.V.), minimum and maximum values of carcass traits of Atlantic salmon were given in Table 5. The mean round body weight of the males was only 3.1% heavier than the females and average gutted body weight of males was 3.4% greater than of females. The average fat and pigment content of male fish were only marginally higher than of the females. So that in the further statistical analysis the sex of the fish was not considered.

Table 5. Phenotypic means, standard deviations (S.D.), coefficients of variation (C.V.), minimum (Min) and maximum (Max) value of carcass traits of males and females Atlantic salmon.

Sex	Traits	Mean	S.D.	C.V.	Min	Max
Males	Round body weight (kg)	3.22	0.78	24.2	1.57	6.59
N=1074	Gutted body weight (kg)	2.95	0.72	24.4	1.45	6.02
	Fillet fat %	12.8	1.43	11.1	6.3	17.1
	Pigment (ppm)	6.80	0.74	10.9	3.52	8.97
Females	Round body weight (kg)	3.12	0.67	21.5	1.46	6.22
N=1560	Gutted body weight (kg)	2.85	0.61	21.4	1.34	5.70
	Fillet fat %	12.5	1.44	11.6	5.4	16.8
	Pigment (ppm)	6.69	0.74	11.1	2.44	8.77

The frequency distribution of the gutted body weight, pigment and fat content of the sampled population was shown in Figure 1, 2 and 3 respectively. The mean value of gutted body weight, fillet pigment and fat content were found 2.89 kg, 6.74 ppm and 12.6% respectively in the sampled population.

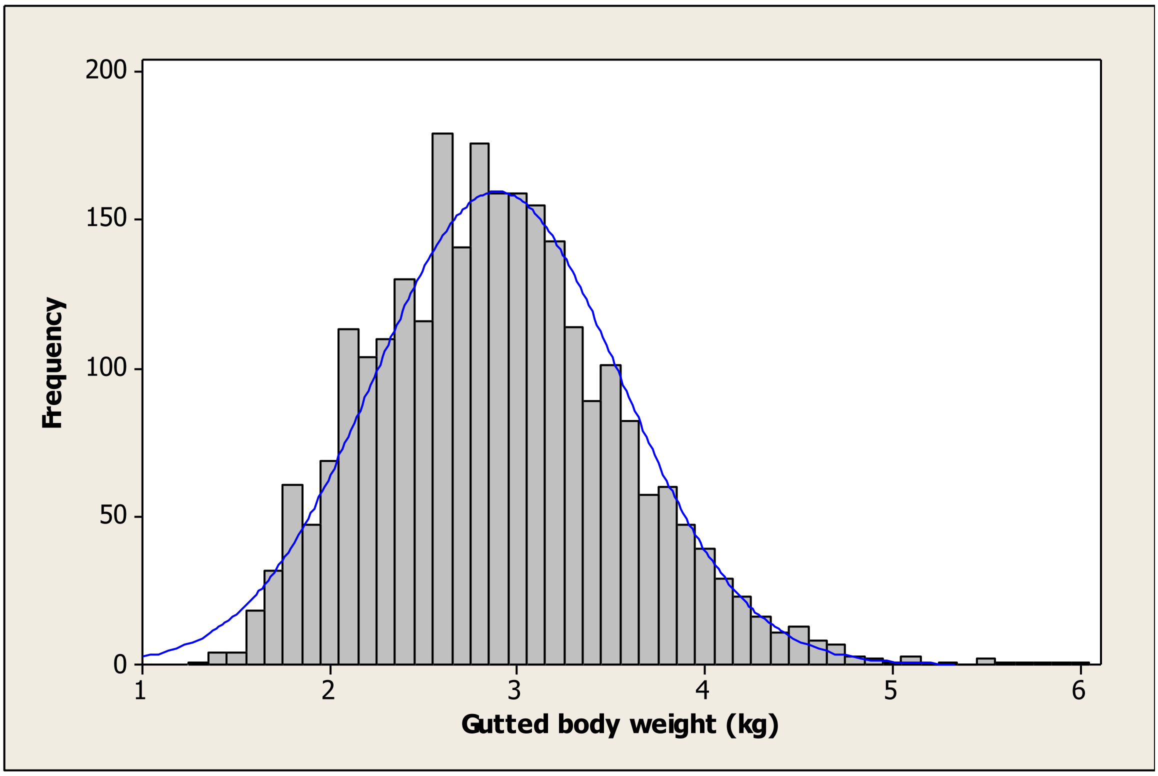

Figure 1. Frequency distribution of gutted body weight (kg) of Atlantic salmon (N=2634).

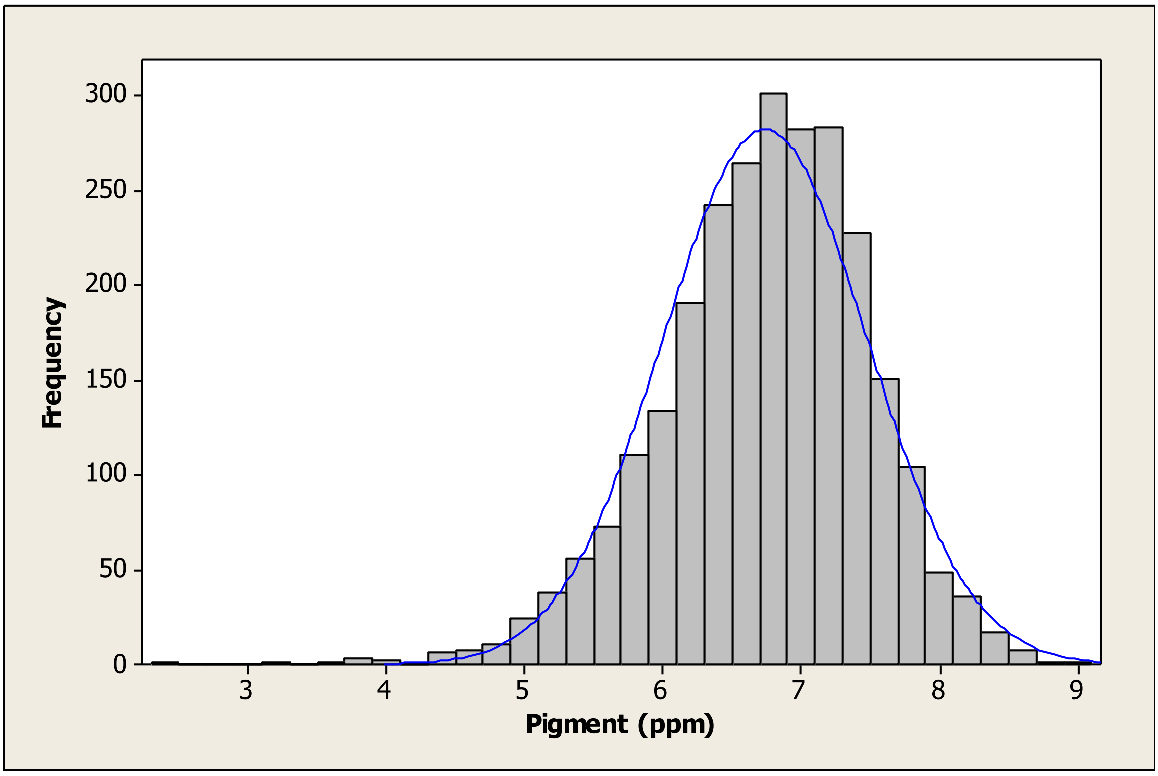

Figure 2. Frequency distribution of fillet pigment of Atlantic salmon (N=2634).

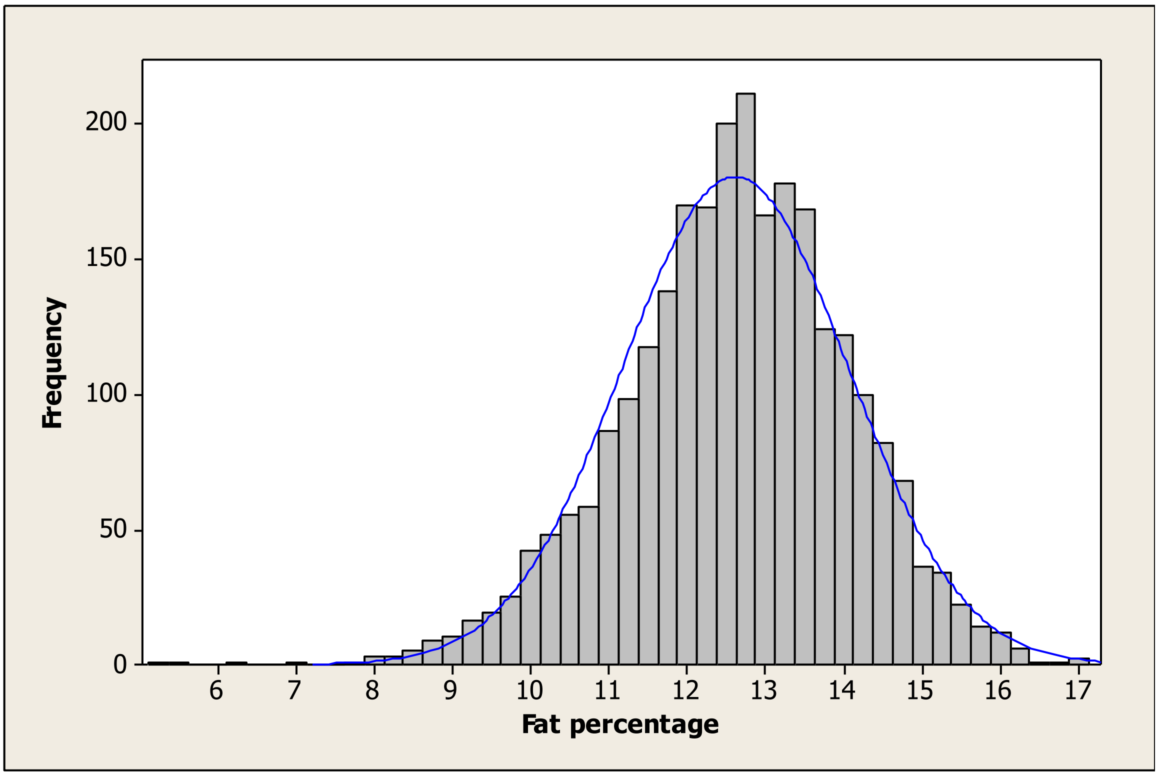

Figure 3. Frequency distribution of fillet fat percentage of Atlantic salmon (N=2634).

3.2 Regression and correlation of different quality traits

The regression analysis of fillet pigment and fat content on gutted body weight are shown in Table 6. For both traits the relationship was curve linear with a decreasing increase in each of the quality traits with increasing body weight. These relationships are shown in Figure 4 and 5.

Table 6. Intercept and regression coefficients of fillet pigment and fat on gutted body weight.

Traits	**Intercept**	**b_1 ± S.E.**	**b_2 ± S.E.**	**R^2*100**
Pigment (ppm)	3.61	1.572±0.115	-0.161±0.018***	28.7
Fat %	7.52	2.588±0.240	-0.272±0.038***	19.0

SE = Standard Error
**** = P<0.001*

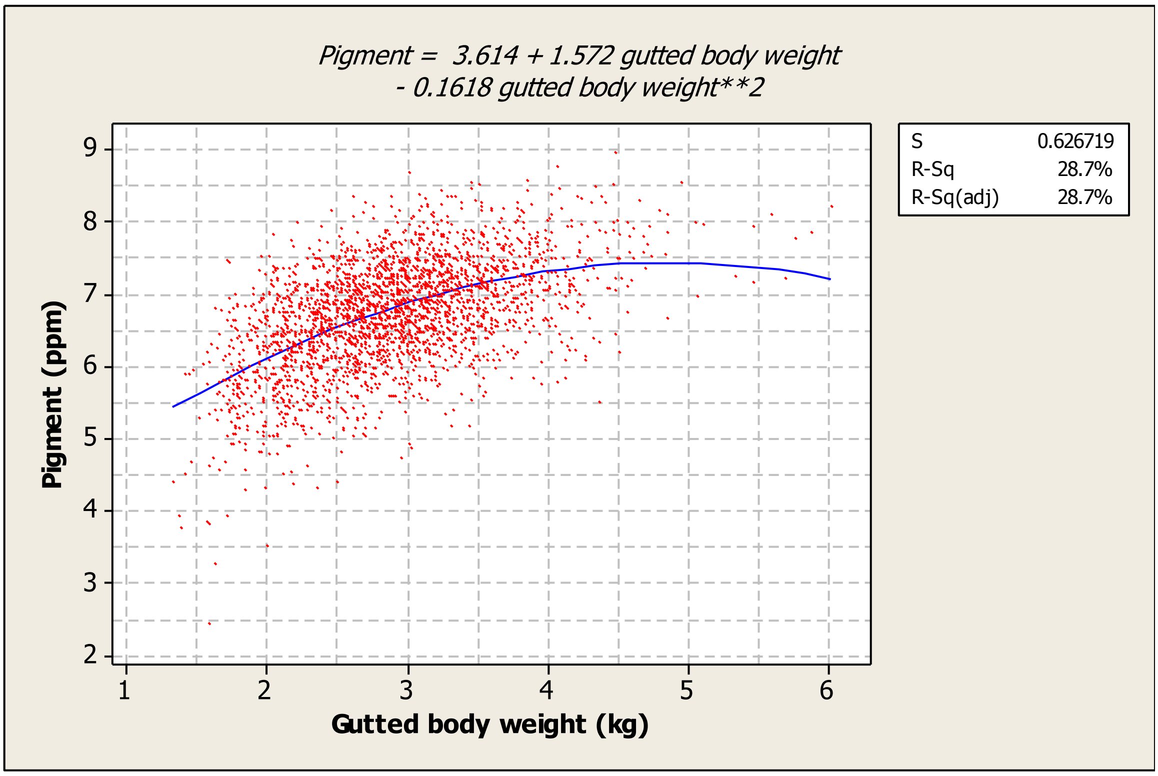

Figure 4. Regression of fillet pigment on gutted body weight of Atlantic salmon (N=2634).

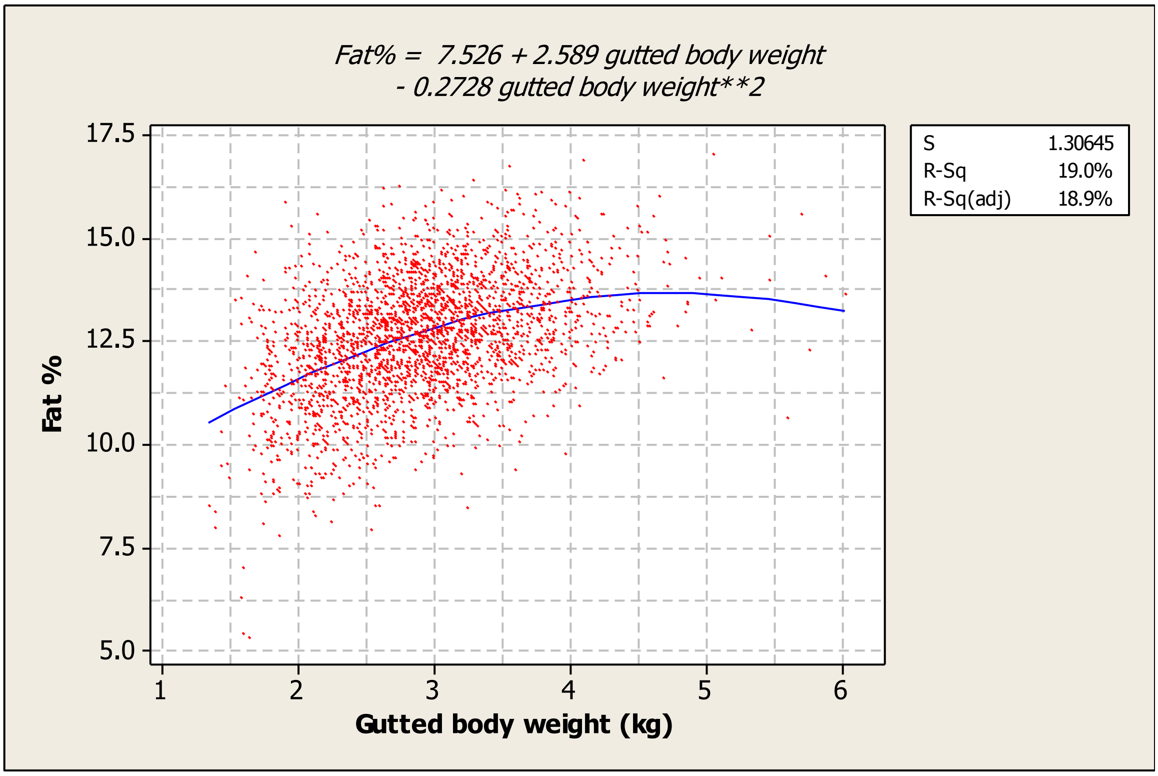

Figure 5. Regression of fillet fat % on gutted body weight of Atlantic salmon (N = 2634).

The correlation coefficient among gutted body weight, fillet pigment and fat percentage are given in Table 7. The correlations were all positive and of medium magnitude.

Table 7. Correlation coefficient among gutted body weight (kg), pigment (ppm) and fillet fat percentage of Atlantic salmon. All correlations (r) = p<0.001.

	Pigment	**Fillet fat**
Gutted body weight	0.51	0.41
Pigment		0.55

3.3 Mean quality traits for Atlantic salmon of different body weight and quality classes

Table 8 shows the average pigment, fat content in the fillet and condition factor for fish of different weight classes. Fish with increasing body weight showed increasing value of pigment, fat and condition factor. The results are shown graphically in Figure 6. Difference between weight classes 1-2 kg vs. 5-6 kg was 1.8 ppm for pigment, 2.58 % for fat and 0.16 for condition factor.

The result presented in table 9 showed that the high fat with low pigment (HF.LP), considered as worst quality fish, represents 0.15% where as low fat with high pigment (LF.HP), considered as best quality fish, represent 0.34% of total sampled population. Fish with medium fat and medium pigment (MF.MP) were found 52.7% in the sampled population.

Table 8. Mean ± S.E. fillet pigment (ppm), fat content (%) and condition factor for Atlantic salmon of different gutted body weight classes.

Weight (kg)	**N**	**Pigment**	**Fat**	**Condition factor**
1-2	201	5.83±0.06	11.34±0.12	1.14±0.01
2-3	1340	6.60±0.02	12.37±0.04	1.20±0.00
3-4	942	7.04±0.02	13.09±0.04	1.25±0.00
4-5	129	7.36±0.06	13.61±0.10	1.30±0.01
5-6	10	7.63±0.13	13.92±0.57	1.30±0.03
>6	1	8.22	13.67	1.39

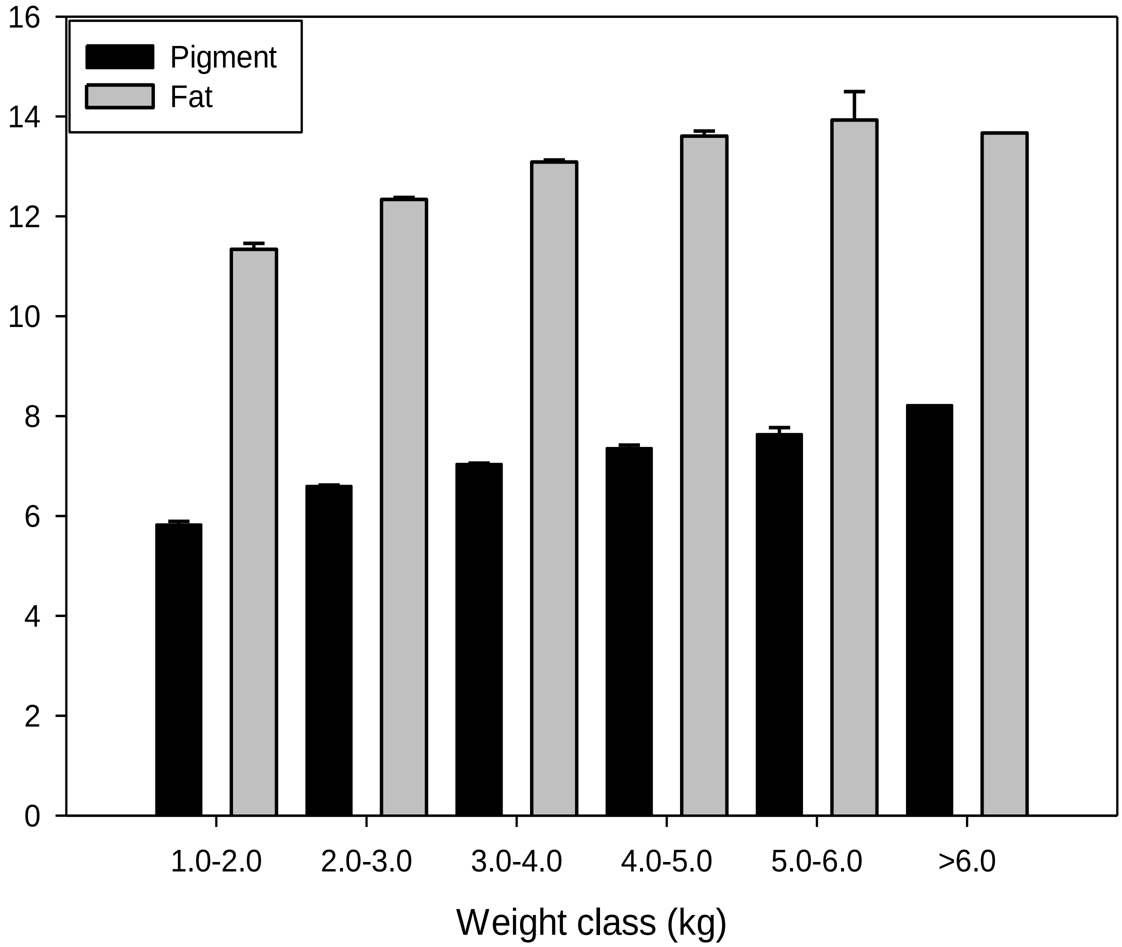

Figure 6. Comparison of mean pigment (ppm) and fat content (%) for different weight classes of gutted Atlantic salmon (N=2634).

3.4 Revenue for different quality classes

Average revenue (NOK/kg) for the different quality classes of Atlantic salmon has also been calculated in table 9 and figure 7. While considering the quality grading based on fillet fat and pigment content, the worst quality fish (HF.LP) got 25% less price whereas the best quality fish (LF.HP) got 30% extra price per kg gutted body weight than the medium quality (MF.MP) Atlantic salmon.

Moreover, when the quality grading based on fillet fat, pigment content and body weight is taken into account, the best quality group (LF.HP) falls under the weight class (3-4) kg gutted body weight which fetch 33.4% more price while worst quality group (HF.LP) which fall under the weight class (2-3) kg body weight got 29.7% less price than the medium quality fish (MF.MP).

Table 9. Mean ± S.E. fillet pigment (ppm), fat content (%) and gutted body weight (kg) for the nine different combinations of fat and pigment quality classes and its average revenue (NOK/kg) of Atlantic salmon. Assumed is a threshold value of ±1SD between the three classes of each trait.

Quality class		**N**	**Mean ± S.E.**			**Revenue[1]**	**Revenue[2]**
Fat	**Pigment**		**Fat, %**	**Pigment (ppm)**	**Weight (kg)**	**(NOK/kg)**	**(NOK/kg)**
LF	**LP**	219	10.1±0.07	5.4±0.04	2.26±0.03	38.01	33.64
	MP	182	10.5±0.04	6.6±0.03	2.59±0.04	46.00	43.29
	HP	9	10.5±0.26	8.0±0.11	3.32±0.30	52.00	51.37
MF	**LP**	182	12.2±0.05	5.6±0.02	2.41±0.04	32.00	28.29
	MP	1389	12.7±0.02	6.8±0.01	2.91±0.02	40.00	38.50
	HP	244	12.9±0.04	7.8±0.02	3.31±0.04	46.00	45.72
HF	**LP**	4	14.3±0.12	5.7±0.14	2.72±0.41	30.00	27.06
	MP	276	14.7±0.03	7.0±0.02	3.11±0.04	38.00	37.09
	HP	129	14.9±0.06	7.8±0.03	3.67±0.06	44.03	44.36

[1]Revenue is calculated based on different fillet pigment and fat content with average revenue (40 NOK/kg) for different gutted body weight classes.
[2]Revenue is calculated based on different fillet pigment, fat content and gutted body weight classes. Per kg price for different weight classes is taken from table 2.

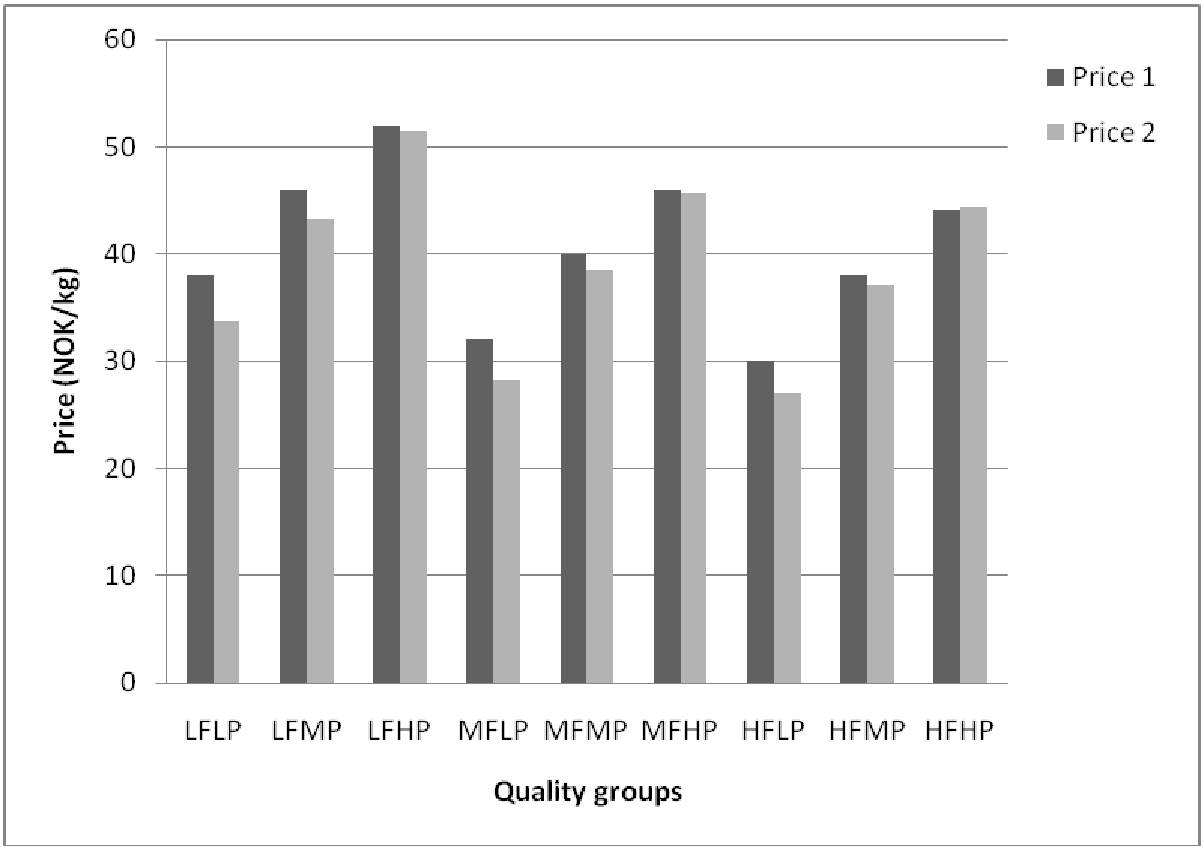

Figure 7. Comparison of per kg price of Atlantic salmon.
Price 1 is calculated by quality grading based on fat content (%) and pigment (ppm) only.
Price 2 is calculated by quality grading based on fillet fat content, pigment and gutted body weight (kg).

The revenues for Rev 1, Rev 2 and Rev 3 with alternative 1 and 2 are summarized in Table 10. Average revenue per kg fish where quality grading was based on fillet pigment and fat content, Rev 2; alternative 1 gave on average 1.2% and alternative 2 gave 1% higher revenue per kg fish produced than Rev 1 based on no quality grading.

Average revenue per kg fish where quality grading was based on fillet pigment, fat content and gutted body weight, Rev 3; alternative 2 gave 1.22% higher revenue per kg fish produced than alternative 1 based on gutted body weight only.

Table 10. Overall revenue (NOK/kg) of Atlantic salmon for the different alternatives (N=2634).

Alternatives	**Quality grading**	**Threshold level**		**Revenue (NOK/kg)**
		Low	**High**	
Revenue 1	No grading	-	-	40
Revenue 2				
-Alt. 1	Fat and pigment	-1*SD	+1*SD	40.50
-Alt. 2	Fat and pigment	-1*SD	+0.842*SD	40.40
Revenue 3				
-Alt. 1	Gutted body weight	-	-	38.41
-Alt. 2	Fat, pigment and Gutted body weight	-1*SD	+1*SD	38.88

4. Discussion

In the analysed data the correlation between body weight and fillet fat percentage was positive (0.41). Thus increased body weight will result in increasing fat percent of the fillet which is unfavourable as high fat content in fillet represents inferior quality in Atlantic salmon. This unfavourable relationship has also been found in other studies on Atlantic salmon (Gjerde & Gjedrem 1984; Rye & Gjerde 1996) and coho salmon (Neira et al. 2004).

A positive correlation of pigment with body weight (0.51) and fat percentage (0.55) was found. Thus an increase in body weight will result in favourable increases in pigmentation and in agreement with earlier reports in Atlantic salmon (Quinton et al. 2005; Rye & Gjerde 1996) and rainbow trout (Gjerde & Schaeffer 1989; Iwamoto et al. 1990). However, the positive correlation between pigmentation and fat percentage estimated here is undesirable, as it implies that a decrease in the fat percentage of the fillet will indirectly cause a reduction in the colouration of fillet.

At present, gutted salmon that fetch a minimum value for quality traits like fat and pigment are graded according to their body weight only. Therefore, consumers are not offered a product that is graded according to e.g. fillet fat content and/or colour of fillet and producers have not the possibility to obtain added values through different pricing of different quality classes. However, due to the positive correlation between body weight, fillet fat and pigment, choosing bigger fish will imply that consumers will get on average a fish with higher fat and pigment content than the average value in the actual population. In contrast, if they choose a small fish there is a high possibility to get a fish with low fat and pigment content in the fillet. So the present grading system which is based on body weight only results in a body weight classes with different levels of the quality traits fillet fat and pigment.

In this study the average fat and pigment content of males were only marginally higher than of females and the mean gutted body weight of males only 3.4% greater than females (table 5). Therefore, grading on sex only will have no significant effect on mean values of these quality traits. The mean value of gutted body weight, fillet pigment and fat content were found 2.89 kg, 6.74 ppm and 12.6% respectively in the sampled population. To enable supply of Atlantic salmon of different combinations of fillet fat and pigment in addition to body weight, new technologies is required that can provide such grading on the slaughter and processing line.

The quality grading was conducted based on fat content and pigment along with gutted body weight. If some premium could be obtained for different quality grades, producers could obtain higher revenue than grading on gutted body weight only. The potential and magnitude of such premium is not known. Therefore a model for such an added market value is presented together with some results based on some anticipated premium for different quality grades of fillet fat and pigment.

High fat percentage in the fillet is considered undesirable, also due to its negative effect on other fillet quality traits. Gjedrem (1997) reported that fat content greater than 18%, resulting from very high energy diets, may have a detrimental effect on the texture and processing characteristics of the fillet. In the presented model, a premium is added to the fish which has low fat and penalty to fish with high fat.

High pigment content of fillets of Atlantic salmon is desirable and increases the consumers' willingness to pay for the product (Alfnes et al. 2006). Hence, in this study a premium is added to high pigment and a penalty to low pigment.

For the two studied alternatives the additional revenue was on average marginal. Average revenue per kg fish where quality grading was based on fillet pigment and fat content, Rev 2; alternative 1 gave on average 1.20% and alternative 2 gave 1% higher revenue per kg fish produced than Rev 1 based on no quality grading. Average revenue per kg fish where quality grading was based on fillet pigment, fat content and gutted body weight, Rev 3; alternative 2 gave 1.22% higher revenue per kg fish produced than alternative 1 based on gutted body weight only.

However, differences in revenue for the different quality grades were substantial thus clearly indicate the potential for quality grading. To some extent the positive correlation between pigment and fat cancel each other in the premium as high fat is negative but high pigment is positive with respect to revenue. Producers and consumers of Atlantic salmon would get justice on price equity and favored quality if the grading of salmon is practiced based on this quality grading and revenue calculation model. The cost of the production for all quality fish was same to the studied sampled population.

This is only an example of the potential of quality grading of Atlantic salmon for the benefit of both producers and consumers. At present, the potential is limed due to lack of implementation of appropriate grading technologies. When grading technology is installed and implemented, it is possible to offer different quality classes and first then we get the information on the magnitude of premium that can be obtained for different quality grades.

5. Conclusion

The most important quality parameters of Atlantic salmon are fillet fat content and colour, in addition to body weight. The biological variation in these traits can be utilised through a quality grading given implementation of appropriate technology and thus offer different quality grades in a more quality sensitive and conscious market.

Currently, Atlantic salmon are being graded according to their gutted body weight and exterior appearance, although quality grade combinations based on pigment and fat content along with body weight are possible. Both producers and consumers could be benefited if grading is conducted on the basis of these quality traits. Producers could get an added value and consumers could get desirable quality (fillet fat content and colour according to their demands). The models are developed to grade the Atlantic salmon based on fillet fat and pigment content in addition to body weight and to calculate the revenue for different quality grades. However, at present there is no appropriate technology to prove such grading with respect to different quality traits. When technology is implemented it is possible to offer different quality classes and we will get the answer on to which extent a premium can be achieved.

6. References

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7. Appendix

7.1 Appendix 1. Structure of data

Year class-Sex-Maturity	Individual Id	Length, cm	Round body weight, gm	Gutted body weight, gm	Colour score	Pigments, ppm	Fat Percent
200110	2001000002	69	3895	3645	28.07	7.31	15.63
200120	2001000003	60	2745	2505	28.35	7.34	13.59
200110	2001000004	69	4045	3665	29.66	8.06	14.13
200110	2001000005	68	3690	3450	29.2	7.7	12.07
200120	2001000006	65	3450	3145	28.83	7.65	13.23
200120	2001000007	60	2680	2355	25.63	5.59	11.78
200120	2001000008	70	4100	3775	29.88	8.2	13.1
200110	2001000011	59	2150	1990	26.05	6	12.78
200110	2001000012	66	3525	3235	27.95	7.01	11.24
200110	2001000015	72	5025	4675	28.98	7.6	11.65
200120	2001000017	66	3690	3375	27.81	7.02	13.31
200120	2001000021	71	4360	4000	29.47	8.03	14.58
200120	2001000027	60	2415	2200	25.46	5.3	10.05
200120	2001000029	67	3455	3205	27.54	7.01	16.03
200110	2001000033	58	2315	2215	28.6	7.44	12.27
200120	2001000034	69	3980	3655	28.6	7.7	14.72
200110	2001000035	69	4080	3750	28.33	7.37	14.6
200120	2001000036	64	3525	3250	29.07	7.82	13.65
200120	2001000042	64	2895	2655	27.05	6.48	12.66
200120	2001000044	61	2805	2565	27.59	7.12	15.32
200110	2001000046	64	3690	3385	26.53	6.36	14.77
200120	2001000048	62	2830	2580	28.08	7.08	11.72
200110	2001000049	58	2245	2060	26.3	5.9	11.28
200120	2001000051	58	2315	2080	27.18	6.56	12.31
200120	2001000052	68	4030	3685	29.08	7.62	12.22
200120	2001000055	64	2860	2660	27.83	7.04	14.3
200120	2001000056	63	3065	2800	27.41	6.59	11.87
200120	2001000058	64	3105	2845	28.23	7.33	14.37
200110	2001000059	71	4440	4025	26.81	6.21	11.91
200120	2001000060	68	3920	3565	27.86	6.97	11.97
200120	2001000061	65	3345	3040	29.28	8.08	16.22
200120	2001000062	62	3110	2760	26.48	6	10.58