Effect of rearing temperature on flesh quality in Arctic charr (*Salvelinus alpinus*)

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Running head: Improving sensory quality in Arctic charr

Keywords*:* Sensory quality, marketability, rearing temperature, Arctic charr

Abstract

Currently no information is available on the effect of progressively decreasing temperatures on the sensory quality of Arctic charr. The objective of this study was to investigate if and how different and progressively changing rearing temperatures affect the sensory quality of cooked and raw fillets of Arctic charr. The effects of rearing temperature on the sensory quality of Arctic charr (weight range 622-888 g) was investigated. Rearing temperature was changed during the experimental period as the fish were reared at constant or decreased temperature during October to April and subsequently reared at two constant temperatures from April to August establishing six different rearing temperature combinations. Significant differences were seen in all four main sensory attributes groups i.e. odour, appearance, flavour and texture. Freshness characteristics such as sweet odour and flavour, and metallic odour and flavour, increased with decreasing rearing temperature, whereas musty odour and flavour decreased. Rearing temperature had a clear effect on the colour of the fillets. Lower rearing temperature increased colour intensity substantially. Softness, juiciness and tenderness increased with decreased rearing temperature. A trend was seen towards more effect from final rearing temperature than initial temperature on the sensory attributes studied. Spoilage characteristics, i.e. sour and rancid odour and flavour, and off-odour and flavour were either very weak or not noticeable in all sample groups.

1 | INTRODUCTION

Arctic charr (*Salvelinus alpinus*) is a stenothermal cold-water species (Imsland, Gunnarsson, & Thorarensen, 2020a) that is well suited for farming in colder climates (Jobling, Jørgensen, Arnesen, & Ringø, 1993). It has a relatively high growth rate at low temperatures (Le François, Lemieux, & Blier, 2002; Gunnarsson et al., 2011; Siikavuopio, Foss, Saether, Gunnarsson, & Imsland, 2013). It can be reared at high densities (Jørgensen, Christiansen, & Jobling, 1993) and the flesh is perceived to be of high quality (Gines, Valdimarsdóttir, Sveinsdóttir, & Thorarensen, 2004; Gunnarsson et al., 2012).

Although Arctic charr grow well at low temperatures, the optimum temperature for growth of juveniles is between 12 and 18°C (Larsson et al., 2005; Gunnarsson et al., 2011; Siikavuopio et al., 2013; Imsland et al., 2020a). The rearing temperature for Arctic charr aquaculture varies widely depending on local condition (Sæther, Siikavuopio, Thorensen, & Brännäs, 2013) and this affects the production time and harvest size of the fish. However, there is limited information available on the effects of environmental factors, such as temperature and photoperiod, on the sensory quality of Arctic charr. Different environmental factors, such as rearing temperature and photoperiod, can affect the flesh quality of salmonids (Ytrestøyl, Struksnæs, Koppe, & Bjerkeng, 2005; Johnston et al., 2004). In Atlantic salmon, *Salmo salar*, seasonal variation in quality appears to be related to growth rate (Roth et al., 2005; Imsland et al., 2017). The results of Gines et al. (2004) have shown that rearing temperature affects flesh quality of Arctic charr with more intense colouration in fish reared at lower (10°C) than at higher temperature (15°C). Furthermore, the flesh of fish reared at the higher temperature scores higher values for hardness, gumminess, chewiness and fracture ability than fish reared at the lower temperature (Gines et al. 2004). Gunnarsson et al. (2012) has investigated several flesh quality parameters (fillet pH, fillet gaping and fillet colour) in Arctic charr reared under different photoperiods and has found no differences in relation to different photoperiod. In general sensory evaluations are of great importance in the process of developing new rearing methods for fish farmed for the consumptive market since it is dependent on consumer approval (Carlberg et al., 2018).

Long-term studies on the growth of Arctic charr have shown that the optimum temperature for growth of the fish is reduced as the fish grow larger (Gunnarsson et al., 2011; Siikavuopio et al., 2013; Imsland et al., 2020a). This may suggest that the growth of Arctic charr can be maximised by reducing the rearing temperature progressively as the fish grow. However, the results of Gunnarsson et al. (2011) have shown, that progressively reduced temperatures reflecting optimum temperatures for different sizes of the fish provides no long-term production gain for Arctic charr. While there is currently no information available on the effect of progressively decreasing temperatures on the sensory quality of Arctic charr. The objective of this study was to investigate if and how different rearing temperature regimes affect the sensory quality of cooked and raw fillets of Arctic charr.

2 | MATERIALS AND METHODS

2.1 | Experimental fish and rearing conditions

In October 2007, 2460 juvenile Arctic charr (mean weight (SD), 20.9 (3.3) g), of the Icelandic Hólar strain were randomly distributed into six 700 l rearing tanks. The experiment was divided in two periods: Phase I (5 October 2007– 22 April 2008) and phase II (23 April 2008– 26 August 2008) (see Table 1). In phase I three temperature treatments were created. Two groups reared at near constant temperatures (achieved by mixing ambient water with heated water from the local FW source (Skagafjardaveitur ehf, Iceland)) for the whole period i.e. groups called 9 (mean temperature 9.0 ºC SD 0.7 ºC), and 15 (mean temperature 14.7 ºC SD 0.7 ºC) and one so called temperature-step group i.e. 15-12 referring to the fish transferred from 15 to 12°C (mean temperature 11.9 ºC SD 0.7 ºC) in February 2008.

During phase II (April 2008 - August 2008) all the previous treatments were reared at either 12 ºC (called 12, mean temperature 12.0 ºC SD 0.8 ºC) or reared at near 7 ºC (called 7, mean temperature 7.0 ºC SD 0.5 ºC). Hence the following six experimental groups were established: 9-9-7, 9-9-12, 15-15-7, 15-12-7, 15-15-12, 15-12-12. Table 1 shows an overview of the different treatments during both phases. The transfer between temperature regimes in April was done gradually over a period of three days.

Fish were reared in six and four (phase I and II respectively) 1x1 m^2 square green fiber glass tanks with active rearing volume of 700 l. Initial stocking density in phase I was in the range of 7–8 kg m-3. Density was regularly adjusted by reducing number of fish in tanks and kept similar in all tanks throughout the study period. The fish were fed ad libitum using a series of one brand commercial formulated feeds (LAXÁ, Akureyri, Iceland, containing 45-50% crude protein, 11-12% crude fat, 6-8% crude ash, pellet size 1.8-4.0 mm) with the aid of automated feeders from 0800 to 2400. The pellet sizes were increased gradually during the experiment to fit the fish size in accordance to the feed producer recommendation. For further information about the experimental set-up and results from the growth trial see Gunnarsson et al. (2011).

2.2 | Sensory evaluation

At the end of the temperature trial, the fish were starved for 24 h before being killed with a blow to the head and a gill incision for exsanguination. They were kept in a small tank with iced water for 10 min until bleeding was completed, then gutted and kept on ice for 3–4 days prior to sensory evaluation. Sensory evaluation was conducted on 10-12 fish from each of the six experimental groups using the method of generic descriptive analysis (GDA method), where defined sensory attributes were evaluated to describe the appearance, flavour, odour and texture of Arctic charr (Lawless & Heymann, 2010). A trained sensory panel consisting of 10 members previously selected and trained according to ISO guidelines (2014), carried out the sensory evaluation. A previous list of attributes was used to describe Arctic charr (Gines et al., 2004) and the GDA method was applied as a basis for sensory training. The panellists together with the panel leader established descriptions of the 23 sensory attributes of Arctic charr (Table 2). For each sample, each sensory attribute was evaluated on a 15 cm line which in data analysis was transformed to numbers from 0 to 100.

The sensory evaluation was performed on samples (each 30-40 g) transversally cut from skinned fillets. Each sample was cooked in an aluminium box in a steam oven at 98°C for 5-6 min. Immediately after cooking, the boxes were covered and served to each panellist in a pre-heated glass bowl to avoid cooling. Each sample group was evaluated in duplicate. The evaluation was carried out in a sensory laboratory equipped with separate booths and a FIZZ sensory data recording system (FIZZ Network, Version 2.0, 1994-2000, Biosystemes, Couternon, France).

2.3 | Colour measurements

Fillet colour represented as CIE, L*, a*, b* values were measured in five fish from each experimental group at 3 locations along the fillet (anterior, mid, and posterior part) using a Minolta Chromameter CR-200 (Minolta, Osaka, Japan). The L*, a* and b* value represent lightness, redness (a+ = red, a- = green), yellowness (b+ = yellow, b- =blue), respectively.

2.4 | Gaping and shear force

After the storage period of 3-4 days, fillet gaping was evaluated visually by counting numbers of slits along the epaxial muscle (Andersen, Strømnes, Steinsholt, & Thomassen, 1994). Gaping was estimated in 12-16 fillets from each experimental group.

For shear force measurements, a standard muscle sample (70 × 30 mm) was sampled, starting 1 cm from the visceral cavity and along the loin from the blind side of the fish. A v-shaped blade with a thickness of 3.20 mm, height of 125 mm and width of 70 mm was assembled to the TA.XT2® Texture Analyser (Stable Micro Systems Ltd, Vienna Court, Surrey GU7 1YL, United Kingdom).The maximum peak force (N) required to shear through the sample was recorded as shear force. This method incorporates compression of fibres beneath the blade, tension in the adjoining fibres and shearing of the fibres (Bouton, Harris, & Shorthouse, 1975). The speed of the probe was set to 2.5 mm s^{-1} and measurement frequency set to 20 dots s^{-1}.

2.5 | Statistical methods

The sensory data was analysed using a two-way mixed model ANOVA, with treatment (temperature) as a fixed factor and panellist as a random factor, correcting for panellists´ use of the scale (Zar, 1996). For fillet colour, gaping and shear force data, a one-way ANOVA model was used to analyse, with treatment as fixed factor. In cases where the ANOVA indicated significant differences, multiple post hoc comparisons were made using Duncan's test. Possible correlation between fillet weight and shear force was tested with a Pearson correlation coefficient test (Zar, 1996). The statistical package used was NCSS 2000 (Number Cruncher Statistical Systems, Kaysville, UT 1998). Significance level was set at $P < 0.05$ unless otherwise stated. The multivariate structure of the sensory evaluation was analysed with a Principal Component Analysis (PCA) using the Unscrambler ® (Version 9.7, CAMO, Trondheim, Norway) program package.

3 | RESULTS

3.1 | Sensory and physical evaluation

Significant differences were seen in all four main sensory attributes: odour, appearance, flavour and texture (Duncan's test, $p < 0.05$, Table 3). In general, sweet and metallic odour and flavour increased with decreasing rearing temperature. On the other hand, musty odour and flavour increased with increasing rearing temperature (Table 3). It was well noticeable when comparing the lowest temperature group 9-9-7 and the highest temperature group 15-15-12. Group 9-9-7 had the most sweet and metallic odour but the weakest musty odour, but opposite results were seen for group 15-15-12. A trend was seen towards more effect from final rearing temperature than initial temperature on the beforementioned sensory attributes, with lower values on musty odour and flavour, but increasing values on sweet and metallic odour and flavour (Figure 1). Spoilage characteristics, i.e. sour and rancid odour and flavour, and off-odour and flavour were either very weak or not noticeable in all sample groups (Duncan's test, $p < 0.05$, Table 3).

Rearing temperature had a clear effect on the colour of the fillets. Lower rearing temperature increased colour intensity substantially (Duncan's test, $p < 0.05$, Table 3). No differences were seen in other appearance attributes. The optical measurements of colour attributes showed similar results as the sensory evaluation. The a* value (redness) and b* value (yellow) were significantly higher in the 9-9-7 group than in all other groups (Duncan's test, $p < 0.05$, Table 4). The a* values were lowest in the 15-15-7 and 15-15-12 groups and the b* values were lowest in the 15-12-12, 15-15-7 and 15-15-12 groups.

Softness, juiciness and tenderness of the fish increased with decreasing rearing temperature. The texture of fish from group 9-9-7 was quite different from other sample groups, being more tender and juicier (Duncan's test, $p < 0.05$, Table 3). The mechanical test for share force (Table 5) confirmed the results from the sensory evaluation. The share force was lowest in the 9-9-7 group and highest in the 15-15-7 and 15-15-12 groups (Duncan´s test, $p < 0.05$, Table 5). There was a highly significant correlation between shear force and fillet weight (Pearson's r = 0.6, $p < 0.001$, Table 5) as shear force increased with increased fillet weight. No differences in gaping were observed (Duncan's test, $p > 0.05$, Table 5).

3.2 | Principal Component Analysis

PC1 and PC2 together explained 93% of the variation in the sensory evaluation results between sample groups (Fig. 1). The six treatment groups were clearly separated in the PCA plot (Fig. 1A). PC1 explained 80% of the variation of the sensory evaluation data mainly due to difference in colour, juicy texture, and sweet and musty odour and flavour (Fig. 1B). PC2 explained 13% of the observed sensory variation mainly due to difference in sample colour, and musty odour and flavour (Fig. 1B).

4 | DISCUSSION

Previous studies on the effects of environmental factors, such as temperature, on aquaculture fish have mainly focused on their effect on fish growth (Imsland et al., 2020a). However, sensory quality is also very important for the marketability of the product (Carlberg et al., 2018; Imsland et al., 2020b) and the results of the present study show that temperature rearing regime affects the flesh quality in Arctic charr. Lower temperatures appear to promote better quality. In the present trial attributes connected with freshness, i.e. sweet/characteristic and metallic odour and flavour, increased with decreased rearing temperature. Increased rearing temperature, especially in phase II, resulted in stronger musty odour and flavour. Secondly, both the visual and instrumental evaluation showed that the flesh of fish reared at lower temperatures was more intense in colour than that of fish reared at higher temperatures. Finally, the results from the sensory evaluation and the mechanical measurement of shear force showed that the flesh of fish reared at lower temperatures is softer, juicier, and more tender than that of fish reared at higher temperatures. These results are in accord with those of another study (Gines et al. 2004) where Arctic charr were reared at either 10 or 15°C for about the same period of time as the fish in the present study. Gines et al (2004) found more intense flesh colour, as estimated by a sensory panel or optically at 10°C compared to 15°C. Moreover, the sensory panel found cooked fish reared at 15°C to be firmer than fish reared at 10°C. Similar to the present study, the hardness, gumminess and chewiness (measured mechanically) of raw fillets was also more at 15°C than at 10°C (Gines et al. 2004). This difference was, however, not observed when the fillets were cooked. In contrast to the present study, Gines et al. (2004) found no significant differences in odour and flavour of cooked fish. Taken together, these results show that lower rearing temperatures promote better quality of Arctic charr flesh. These differences can be quite large (Table 3) and be discernible by an untrained consumer. In the present study all groups had intense flavour and odour of fresh oil, whereas sensory characteristics describing spoilage such as sour and rancid odour and flavour were not found. Freshness characteristics such as sweet odour and flavour, and metallic odour and flavour increased with decreasing rearing temperature, whereas musty odour and flavour decreased. Softness, juiciness and mushiness increased with decreased rearing temperature.

The flesh pigmentation in cultured Arctic charr is influenced by dietary astaxanthin content (Olsen & Mortensen, 1997). Gines et al. (2004) found that rearing temperature exerted a clear influence on the colour of raw fillets with increased colour intensity found at 10°C compared to 15°C. Similar findings were detected by Olsen & Mortensen (1997), where Arctic charr reared at 8°C had a stronger fillet pigmentation than fish reared at12°C. In the present study sensory evaluation of cooked Artic charr indicates that the fillet colour became more intensively orange with decreasing temperature. Colour measurements on raw fillets showed that rearing temperature has no effect on the lightness of the fillets, whereas both yellowness and redness increased with decreasing rearing temperature. Sensory evaluation, thus, reflected the difference in intensity of red and yellow in the raw fillets seen in the instrumental evaluation.

Rearing temperature did not have an effect on fillet gaping, whereas shear force increased with increased rearing temperature. Both instrumental evaluation on raw fillets and sensory evaluation on cooked fillets showed similar results as the 9-9-7 group was softest and the 15-15-12 and 15-15-7 groups firmest. In fish, flesh texture is shown to be influenced by a number of different factors including, light regime (Hagen & Johnsen, 2016), temperature (Roth et al., 2005), feeding (Einen, Mørkøre, Rørå, & Thomassen, 1999), and season (Espe et al., 2004; Imsland et al., 2017). The findings of Imsland et al. (2017) indicate that harvesting Atlantic salmon during periods of high growth can have negative effect on flesh quality in the form of softer muscle tissue. Similar negative effect of fast growth on fillet softness in Atlantic salmon was also seen in the study of (Mørkøre & Rørvik, 2001), but there is limited knowledge on underlying causes of the correlation between fast growth and softness (Lysenko et al., 2015;

Moreno et al., 2016). Current findings are in line with these earlier findings on Atlantic salmon as the 9-9-7 group displayed the highest growth in the final rearing period of the temperature trial (Gunnarsson et al., 2011) and the 15-15-7 and the 15-15-12 the lowest, leading to corresponding differences in fillet softness.

The current study is a follow-up of the growth study by Gunnarsson et al. (2011) where sensory and instrumental evaluation was performed for selected groups after termination of the growth trail when all fish were slaughtered. The aim of the Gunnarsson et al. (2011) study was to evaluate the effect of rearing temperature on growth and maturation of Arctic charr. Arctic charr juveniles were reared for six months (phase I, October – April, size range 20-500 g) at constant 9 or 15 ºC and according to a temperature step group (T_{step}) i.e. fish transferred from 15 to 12 ºC. All the previous treatments were then reared at either 7 or 12 ºC for additional four months (phase II, size range 300-900 g) and then slaughtered in August 2008. Overall growth rate was highest at constant 15 ºC for the first six months of the trial with the fish in this group being 78% heavier than fish reared at constant 9 ºC. Arctic charr displayed a negative response in terms of growth rate when transferred from higher to lower temperatures especially for groups previously reared at 15 ºC. There was a trend for higher gonadosomatic index (GSI) values at the end of the experiment for females that experience higher rearing temperatures during juvenile phase i.e. 7.29% (±0.89), for the 15°C temperature group, compared to 2.49% (±0.74) for the 9 ºC group. No difference in GSI was found for males. The results suggest that for production of fish > 1000 g, moderate or low temperatures (e.g. 9 ºC) should be applied during the juvenile phase in order to reduce negative effects from maturation. Further, the current data on sensory and instrumental evaluation indicates that the use of low and moderate temperatures is preferable to improve the sensory characteristics and flesh quality of the slaughtered fish.

6 | CONCLUSION

In conclusion, rearing temperature during the juvenile phase had a significant effect on the sensory quality of the cooked fish. This was most apparent for colour, softness, juiciness and tenderness, as well as sweet, metallic and musty odour and flavour.

ACKNOWLEDGEMENTS

The present study was financed by the Icelandic AVS (R005 07) and Framleiðnisjóður landbúnaðarins. The authors would like to thank the technical staff at the Hólar aquaculture research station at Sauðárkrókur and at Matís for valuable assistance during sampling and analysing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests.

AUTHORS' CONTRIBUTION

AKI, SG and HT designed the study. AKI, SG, AG participated in the execution of study. SG, and AKI implemented the study and involved in sampling as well as testing. JA and AÓ were responsible for the sensory and instrumental evaluation. AKI, AÓ, SG and HT drafted the manuscript. All the authors read and accepted the final manuscript before submission.

ETHICAL APPROVAL

The whole experiment was conducted according to the guidelines established by the Icelandic Fish Health Authority.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article due to commercial restrictions.

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TABLE 1 Overview over temperature regimes (mean (SD)) of the different treatments during phase I and phase II in the trial.

	Rearing temperatures (°C)		
	Phase I		Phase II
Treatment	October-February	February-April	April-August
9-9-7	9 (0.7)	9 (0.7)	7 (0.5)
9-9-12	9 (0.7)	9 (0.7)	12 (0.8)
15-12-7	15 (0.7)	12 (0.7)	7 (0.5)
15-12-12	15 (0.7)	12 (0.7)	12 (0.8)
15-15-7	15 (0.7)	15 (0.7)	7 (0.5)
15-15-12	15 (0.7)	15 (0.7)	12 (0.8)

TABLE 2 Sensory attributes and attributes definition in a Generic descriptive analysis (GDA) for Arctic charr reared under different temperature regimes.

Sensory attributes	Short name	Scale anchors (0-100%)	Definition
Odour			
Sweet/characteristic	O-sweet	None || Much	Characteristic odour for cooked Arctic charr
Metallic	O-metallic	None || Much	Metallic odour
Fresh oil	O-oil	None || Much	Fresh unspoiled oil
Musty	O-musty	None || Much	Earthy or musty odour
Sour	O-sour	None || Much	Spoilage characteristic
Rancid	O-rancid	None || Much	Spoilage characteristic
Off-odour	O-off	None || Much	Off-odour, reminding of e.g. band aid or detergent
Appearance			
Colour	A-colour	White || Orange	Intensity of orange colour of sample surface
Discolouration	A-discol.	None || Much	Uneven colour distribution
Yellow liquid	A-yellow l.	Transparent || Yellow	Degree of yellow liquid present
Fat droplets in liquid	A-droplets	Small || Large	Quantity and size of fat droplets in the liquid
White precipitations	A-precipit.	None || Much	White precipitations on sample
Flavour			
Sweet/characteristic	F-sweet	None || Much	Characteristic flavour for cooked Arctic charr
Metallic	F-metallic	None || Much	Metallic flavour
Oily	F-oil	None || Much	Flavour of fresh oil
Musty	F-musty	None || Much	Earthy or musty flavour
Sour	F-sour	None || Much	Spoilage characteristic
Rancid	F-rancid	None || Much	Spoilage characteristic
Off-flavour	F-off	None || Much	Off-flavour
Texture			
Soft	T-soft	Firm || Soft	Evaluated in first bite
Juicy	T-juicy	Dry || Juicy	Evaluated when sample is chewed
Tender	T-tender	Tough || Tender	Evaluated when sample is chewed
Adherence	T-adhere.	None || Much	Adherence to teeth

TABLE 3 Average of sensory attributes (scale 1-100) for Arctic charr reared under different temperature regimes. Significant differences between experimental groups are indicated with superscripted letters (Duncan's test, $p < 0.05$).

Experimental group							
Sensory attributes	9-9-7	9-9-12	15-12-7	15-12-12	15-15-7	15-15-12	*p* value
Odour							
Sweet/characteristic	58^{a}	50^{b}	61^{a}	50^{b}	49	39^{b}	0.014
Metallic	39	37	40	35	35	26	0.076
Fresh oil	45	39	49	43	46	39	0.381
Musty	15^{b}	34^{a}	21^{b}	28^{a}	21^{b}	37^{a}	0.015
Sour	2	4	3	1	3	4	0.425
Rancid	2	4	3	3	6	5	0.716
Off-odour	1	7	3	2	6	6	0.547
Appearance							
Colour	64^{a}	49^{bc}	55^{ab}	41^{cd}	33^{d}	34^{d}	<0.001
Discolouration	33	38	34	34	34	28	0.659
Yellow liquid	41	44	37	49	37	42	0.168
Fat droplets in liquid	43	55	47	54	51	53	0.109
White precipitations	46	50	45	42	45	46	0.669
Flavour							
Sweet/characteristic	64^{a}	47^{bc}	58^{ab}	50^{bc}	53^{b}	41^{c}	0.006
Metallic	45^{a}	37^{ab}	45^{a}	38^{ab}	43^{a}	32^{b}	0.010
Oily	46	46	49	49	42	44	0.623
Musty	12^{b}	39^{a}	21^{b}	32^{a}	23^{b}	38^{a}	<0.001
Sour	3	5	3	3	4	3	0.715
Rancid	1	6	2	5	4	6	0.492
Off-flavour	3	3	1	3	1	5	0.184
Texture							
Soft	71	62	65	65	63	60	0.149
Juicy	71^{a}	61^{b}	61^{b}	57^{b}	56^{b}	51^{b}	0.007
Tender	71^{a}	65a	64^{a}	63^{a}	63^{a}	57^{b}	0.051
Adherence	46	50	50	55	48	58	0.145

TABLE 4 Mean colour (SD) values of Arctic charr reared under different temperature regimes. Significant differences between experimental groups are indicated with superscripted letters (Duncan's test, $p < 0.05$).

Colour value	9-9-7	9-9-12	15-12-7	15-12-12	15-15-7	15-15-12	*p* value
L-value	42	42	44	42	44	43	0.158
a-value	10^{a}	8^{c}	9^{b}	7^{c}	5^{d}	5^{d}	<0.001
b-value	22^{a}	19^{b}	20^{b}	13^{c}	15^{c}	13^{c}	<0.001

TABLE 5 Mean (SEM) weight, shear force (g) and muscle gaping of Arctic charr reared under different temperature regimes. Significant differences between experimental groups are indicated with superscripted letters (Duncan's test, $p < 0.05$). N=number of samples.

Experimental group	**Mean weight (g)**	**Shear force (g)**	**Gaping**	**N**
9-9-7	673 (45)^{b}	485 (32)^{d}	0.2 (0.4)	16
9-9-12	842 (56)^{a}	744 (32)^{b}	0.1 (0.3)	16
15-12-7	699 (35)^{b}	676 (35)^{c}	0.3 (0.5)	14
15-12-12	888 (45)^{a}	691 (32)^{c}	0.3 (0.6)	16
15-15-7	630 (47)^{b}	785 (37)^{a}	0.2 (0.4)	12
15-15-12	831 (57)^{a}	805 (32)^{a}	0.1 (0.3)	16

Figure legend

FIGURE 1 Principal component analysis of generic descriptive analysis (GDA) data from sensory evaluation. (A) Scores of sample groups. (B). Loadings of sensory attributes. Attributes with averages below 10, and/or contributed little to the variation of the data were excluded from the analysis.