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Original scientific paper

Sensory evaluation of cold-smoked trout packaged in vacuum and modified atmosphere

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A b s t r a c t: The aim of the study was to investigate the influence of different packaging methods on the sensory properties of cold smoked trout fillets stored at 3°C during six weeks. Cold smoked trout fillets were vacuumed packaged or packaged in one of two modified atmospheres with a gas ratio of 50% CO_2:50% N_2 or 90% CO_2:10% N_2. Before and after storage, fillets underwent sensory analysis for colour intensity, odour and taste of smoke intensity, tenderness and overall acceptability (on days 0, 7, 14, 21, 28, 35 and 42 of storage). Colour intensity, odour and taste of smoke intensity and overall acceptability of all examined groups of cold smoked trout fillets decreased during storage, while tenderness of the fish fillets remained virtually unchanged. Cold-smoked trout fillets packaged in the modified atmospheres had higher average sensory scores compared to vacuum packaged cold-smoked trout fillets.

Keywords: *trout, smoking, packaging, storage, sensory properties.*

Introduction

Proper nutrition has primary importance in good life quality. For this reason, fish meat, due to its nutritional value, occupies an important place in the human diet. Throughout human history, fish meat has been a significant food source, important for survival and human development. Fish has always been appreciated in coastal areas, especially those with deficient conditions for agricultural development. Fish as a food, in addition to the favourable content of proteins, minerals and vitamins, seems particularly attractive to the consumer because it is a very rich source of essential fatty acids, which play a role in the prevention of many human diseases (*Cvrtila and Kozacinski,* 2006; *Baltic et al.,* 2010).

Food preservation, and therefore smoking, as one of the oldest methods of meat preservation, dates back to prehistoric times, while today, the process of fish smoking in developed countries is applied primarily to improve fish sensory characteristics and conveniently market an assortment of fish meat and products (*Vasiliadou et al.,* 2005; *Foucat et al.,* 2008; *Gomez-Guillen et al.,* 2009). In accordance with the standard for smoked fish, smoke-flavoured fish and smoked dried fish *(Codex Alimentarius,* 2013*)*, cold-smoked fish is produced by treating fish with smoke using time/temperature combinations that will not cause significant coagulation of the proteins in the fish meat, but will cause some reduction of the water activity. Salting, packaging and storage processes are also defined in this standard. In the literature, there are numerous data relating to the factors important for the smoked fish quality. Special attention is dedicated to the shelf life of smoked fish (bacteriological status, physical, chemical, sensory properties), particularly with regard to the packaging method, which aims to extend the shelf life of smoked fish (*Salama and Ibrahim,* 2012; *Loncina et al,* 2013; *Daramola et al.,* 2014; *Rizo et al.,* 2015). The finished product is usually vacuum packaged and refrigerated or frozen and consumed as a ready-to-eat food. The shelf life of cold-smoked fish is three to six weeks at temperatures below 5°C. The consumption of smoked fish has grown significantly in the last decade in many European countries (*Cardinal et al.,* 2001; *Foucat et al.,* 2008). In Serbia, the most commonly consumed smoked fish is cold-smoked trout (*Baltic et al.,* 2006).

Appearance, texture, colour, odour and perhaps taste of fish meat and fish products are analysed at purchase/consumption using human senses (*Olafsdottir et al.,* 2005). ISO standards in the field

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of sensory analysis, adopted in the past 20 years, have contributed to the objectification of sensory analysis (*Baltic and Karabasil,* 2010). Sensory properties of cold-smoked fish depend on numerous factors (nutrition, primary treatment, the brine composition, condition and quality of smoke, packaging method) (*Franco et al.,* 2010*; Ghouaiel et al.,* 2013*; Ameko et al.,* 2016).

The aim of this study was to investigate the influence of different packaging methods on the sensory properties of cold-smoked trout stored at 3°C during 42 days.

Material and methods

Cold-smoked trout samples preparations

Salmon trout (*Oncorhynchus mykiss*) weighed about 1 kg and originated from the Bocac Fish Farm, owned by Tropic, Banja Luka, Republic of Srpska. All salmon trout were grown and fed under the same conditions. The live fish were transported from the fish farm to the processing plant in specialized vehicles with liquid oxygen under controlled temperature conditions. Trout were placed in outdoor open pools that had the conditions necessary for fish survival (a constant water flow, adequate temperature), and were not fed. Trout were primarily processed (stunning, bleeding, evisceration) in the manner usual for this industrial plant. After primary processing, the spine was removed by cutting parallel to it, whereby the left and right halves were obtained. Trout halves were rinsed with water and immersed in barrels with brine (wet salting) with a 9% salt concentration. Rosemary (*Quantum satis*), was added to the brine according to the principles of good manufacturing practice. Fish were brined for 24 hours at 4°C. After brining, fish were drained for one hour at 20°C and then smoked for eight hours in an automated smoke chamber at 28°C. Smoke was produced by combustion of beech sawdust in a generator separated from the smoking chamber. After smoking, fish were cooled at 2°C for ten hours, then residual parts of the ribs were removed and fish halves were sliced from the medial carcass side, into thin fillets, up to 0.5 cm thick, each weighing about 75 g.

Cold-smoked trout fillet packaging

Cold-smoked trout fillets were split into three groups. The first group was vacuum packaged (group I), the second was packaged in a modified atmosphere with 50% CO_2 and 50% N_2 (group II), and the third was packaged in a modified atmosphere with 90% CO_2 and 10% N_2 (group III).

Modified atmosphere packaging was conducted using a Multivac machine (Multivac C350, D-87787 Wolfertschwenden, Germany). The packaging foil was OPA/EVOH/PE (oriented polyamide/ethylene vinyl alcohol/polyethylene, UPM-Kymmene, Walki Films, Finland) with low gas permeability (degree of permeability to oxygen 5 $cm^3\ m^{-2}\ day^{-1}$ at 23°C, nitrogen 1 $cm^3\ m^{-2}\ day^{-1}$ at 23°C, carbon dioxide $cm^3\ m^{-2}\ day^{-1}$ at 23°C and water vapour 15 $g\ m^{-2}\ day^{-1}$ at 38°C). Packages were filled with commercial gas mixtures (Messer Tehnogas, Serbia). The ratio of gas:fish in the packages was 2:1.

After packaging, all three groups of fish fillets were stored at 3°C for six weeks.

Selection of assessors and sensory evaluation

Samples for sensory analyses were taken on day 0 and on days 7, 14, 21, 28, 35 and 42 of storage. Before evaluation, fish fillets were kept at room temperature for 20 min. Fourteen assessors participated in sensory evaluation and were selected according to Serbian/ISO standard (*SRPS*, 2015; *SRPS* 2012a). The evaluation was conducted in a sensory laboratory designed according to Serbian/ISO standard (*SRPS*, 2012b), using quantitative descriptive analysis (*SRPS*, 2001). Four parameters, colour intensity, odour and taste of smoke intensity, tenderness and overall acceptability, were evaluated. The highest score was 5, and the lowest 1, with exception of the tenderness intensity evaluation, where the optimal score was 3.5 (score 5 was for the firmest meat and score 1 the most tender meat).

Chemical composition

The basic chemical composition was determined in fish fillets on day 0. Chemical analyses to determine protein, water, fat and mineral content were conducted according to standard methods (*AOAC,* 1990).

Statistical analysis

Statistical analyses of the results were conducted using the software GraphPad Prism version 6.00 (GraphPad Software, San Diego, California USA, www.graphpad.com). The results were expressed as mean ± SD and are reported in tables and figures. The effects of different packaging treatments were appraised during storage period by one-factor analysis of variance – ANOVA – with Tukey's multiple comparison test at 99% or 95% confidence levels (differences were considered significant if p<0.01 or p<0.05).

Results and Discussion

Basic chemical composition of cold-smoked trout fillets

The basic chemical composition of our cold-smoked trout fillets was similar to that reported for this type of fish (*Kilibarda*, 2009). The average water content in the cold smoked trout fillets at the beginning of the study was 71.00±2.43%, the average protein content 8.21±1.03%, the average fat content 2.08±0.46%, the average ash content 4.38±0.92%. The average sodium chloride content was 3.27±0.72. The sodium chloride content of smoked salmon in Norway is 2 to 4% (*Albarracin et al.*, 2011; *Almli and Hersleth,* 2013).

Colour intensity of cold-smoked trout fillets during storage

On day 0, colour intensity, odour and taste of smoke intensity and overall acceptability scores were 5, while tenderness scores were 3.5 for all groups of trout fillets.

The colour intensity of all groups of cold-smoked trout fillets decreased during storage (Table 1; Figure 1). However, the colour intensity of groups I and III drastically decreased. In contrast, *Kolodziejska et al.* (2002) and *Leroi et al.* (2001) showed that colour intensity of vacuum packaged cold-smoked fish did not significantly change during three weeks of storage at 4°C. Likewise, the colour intensity of smoked salmon packaged in vacuum and modified atmosphere stored for 35 days did not change (*Bugueno et al.,* 2003).

Table 1. Sensory evaluation of colour intensity of packaged cold-smoked trout during storage

Group	Day of Storage					
	7	14	21	28	35	42
I	4.81^{AB}±0.37	4.31^{A}±0.26	4.19^{aA}±0.26	3.25^{A}±0.27	3.31^{A}±0.26	2.19^{A}±0.37
II	3.25^{AC}±0.38	3.50^{AB}±0.27	3.69^{ab}±0.37	3.49^{B}±0.04	3.13^{a}±0.35	3.56^{AB}±0.42
III	4.19^{BC}±0.26	4.06^{B}±0.18	3.19^{Ab}±0.37	2.69^{AB}±0.26	2.56^{Aa}±0.32	2.63^{B}±0.52

Same letter within a column indicates a significance difference $^{A–C}$ p<0.01; $^{a, b}$ p<0.05

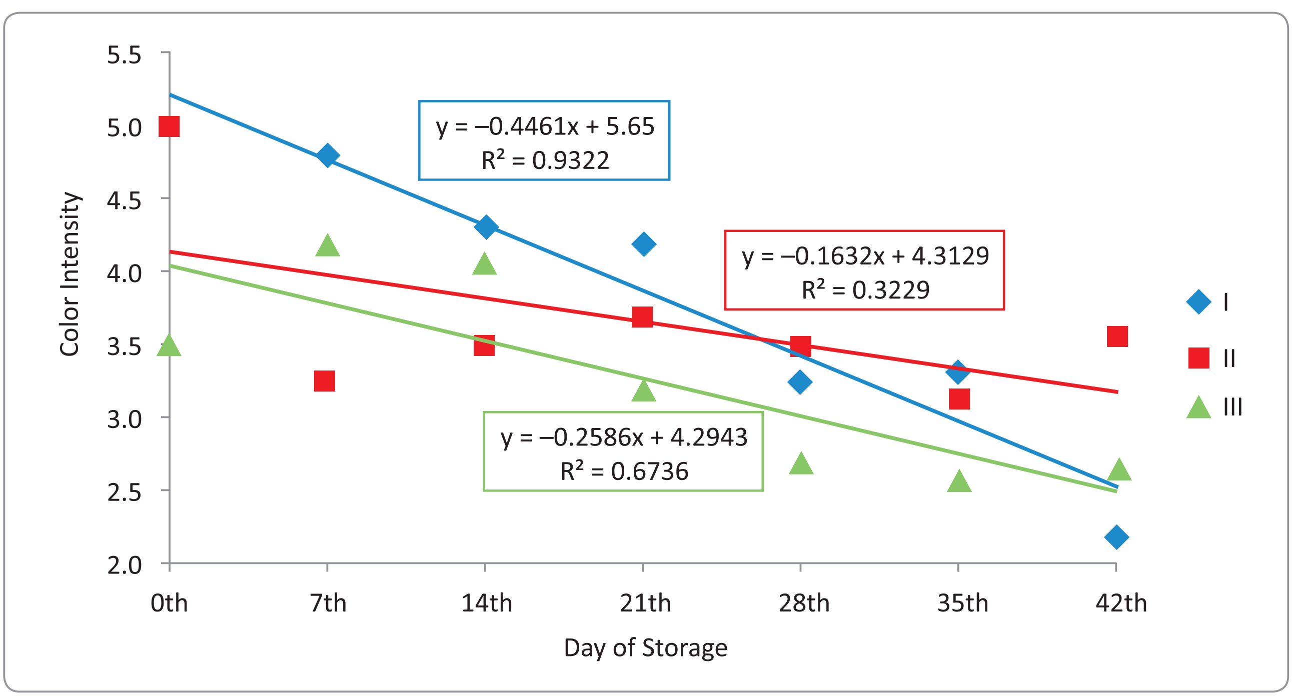

Figure 1. Sensory evaluation of colour intensity of packaged cold-smoked trout during storage

The colour intensity change of group III trout fillets during storage could be attributed to the large proportion of CO_2 in the modified atmosphere packaging. *Masniyom et al.* (2002) examined the sensory properties of fresh sea bass and mackerel packaged in modified atmosphere and also concluded that high CO_2 concentrations caused adverse colour changes. *Choubert and Baccaunaud* (2006) observed that salmon trout had a more intensive colour when it was packaged in a modified atmosphere with a lower content of CO_2 and in combination with N_2, compared to modified atmosphere packaging with higher CO_2 levels.

Numerous studies in the European Union showed that the colour of smoked products (particularly smoked fish) is a primary parameter that leads the consumer to buy a particular type of food (*Espe et al.,* 2004*; Schubring,* 2008). *Johnston et al.* (2000) and *Lakshmanan et al.* (2005) emphasise that undesirable colour, as one of the most important cold-smoked salmon quality parameters, greatly reduces the cost of this product on the market.

Salmon discoloration, as a result of pigment loss, was noted by *Partmann* (1981), when salmon was packaged in a modified atmosphere with 100% CO_2, and by *Barnett et al.* (1982), with salmon, packaged in a modified atmosphere with 90% CO_2. The less intensive colour of trout fillets packaged in modified atmospheres should not result from changes in smoke constituents (although these compounds give smoked fish its characteristic colour), but are likely due to the loss of fish pigments, which give fish its specific, initial colour, as result of CO_2 effects. *Poli et al.* (2006) point out that the reason for decreasing fish colour intensity after packaging in modified atmospheres could be muscle and pigment protein denaturation, as the result of carbonic acid formation. CO_2 dissolving in fish tissues under modified atmosphere packaging leads to acidification and decrease of the meat pH, which causes changes in the fish colour (*Torrieri et al.,* 2006).

Odour and taste of smoke intensity of cold-smoked trout fillets during storage

The odour and taste of smoke intensity of all groups of cold-smoked trout, although high, decreased during storage (Table 2).

The high scores for odour and taste of smoke intensity were not surprising, given the importance this quality has for cold-smoked fish quality (*Jonsdottir et al.,* 2008*; Olafsdottir and Kristbergsson,* 2006). Although odour and taste of smoke intensity scores decreased during the storage period, they remained the highest in group III trout fillets, compared to the other two groups (Figure 2). *Truelstrup Hansen and Huss* (1998) and *Leroi et al.* (1998) in their examination of vacuum packaged cold-smoked trout, also found that during storage, the odour and taste of smoke intensity decreased, and became milder or almost neutral.

Volatile substances that are usually produced by bacteria are the cause of undesirable odours in smoked fish (*Olafsdottir et al.,* 2005*; Dondero et al.,* 2004). These substances include trimethylamine, the volatile sulphur compounds, aldehydes, ketones, esters, hypoxanthine, and other low molecular weight substances. The substrates for the formation of these volatile compounds are trimethylamine oxide, sulphur-containing compounds, carbohydrates (ribose and lactate) nucleotides (inosine monophosphate, inosine), and other non-protein nitrogen compounds. Trimethylamine is responsible for the typical sharp "fishy" odour, indicator of spoilage.

An interesting result of the current study is the intense odour and taste of smoke discerned in group III trout fillets during whole storage period. Currently, we are unable to explain this phenomenon, and therefore, it is very interesting as a subject for future research. *Leroi et al.* (1996) produced similar observations during the examination of vacuum packaged cold-smoked salmon, which they attributed to yeast inhibition because of the high CO_2 concentration, and which reduced an undesirable acidic smell. It is also possible that the dissolved CO_2, with consequent decrease in pH, stimulated or accelerated some reactions responsible for forming the odour and

Table 2. Sensory evaluation of odour and taste of smoke intensity of packaged cold-smoked trout during storage

Group	Day of Storage					
	7	14	21	28	35	42
I	$4.00^{aA}\pm0.27$	$4.13^{A}\pm0.26$	$3.31^{AB}\pm0.46$	$3.31^{AB}\pm0.26$	$1.94^{AB}\pm0.50$	$1.31^{aA}\pm0.26$
II	$4.50^{a}\pm0.38$	$3.81^{B}\pm0.46$	$4.38^{A}\pm0.23$	$3.94^{AC}\pm0.18$	$3.31^{AC}\pm0.37$	$1.00^{aB}\pm0.00$
III	$4.75^{A}\pm0.27$	$4.81^{AB}\pm0.26$	$4.63^{B}\pm0.69$	$4.56^{BC}\pm0.18$	$4.31^{BC}\pm0.26$	$3.25^{AB}\pm0.27$

Same letter within a column indicates a significance difference $^{A–C}$ $p<0.01$; ^{a} $p<0.05$

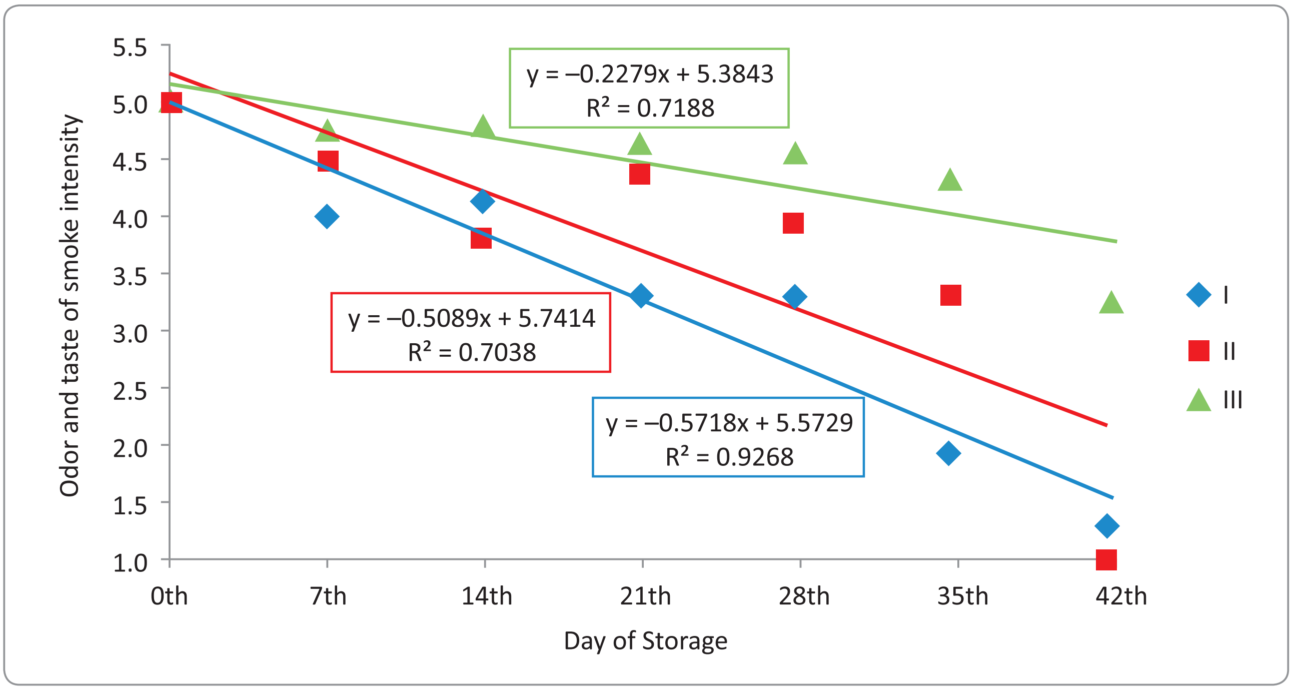

Figure 2. Sensory odour and taste of smoke intensity evaluation of packaged cold-smoked trout during storage

taste of smoke. Phenols are mostly responsible for forming the odour and taste of smoke (*Kostyra and Barylka-Pikielna,* 2006). As well, functional groups of low molecular weight carbonyl compounds (aldehydes, ketones) can affect odour and taste of smoke in smoked products (*Gomez-Guillen et al.,* 2006*; Kostyra and Barylka-Pikielna,* 2006).

Although the high average odour and taste of smoke intensity scores of group III trout fillets in the present study had a positive impact on the overall acceptability of these fillets, it could also have masked, for example, the odour of amine, an initial sign of fish spoilage (*Lyhs,* 2002*; Cardinal et al.,* 2004).

Tenderness evaluation of cold-smoked trout fillets during storage

Average tenderness scores of all groups of cold-smoked trout fillets during the storage period remained essentially unchanged (Table 3; Figure 3).

Cardinal et al. (2004) found a positive correlation between texture and colour intensity of cold-smoked fish (firmer fish had more intense colour) while in the current study, a negative correlation occurred between these two parameters. Also, our group III fish fillets, which had the less intense colour, had a slight decrease of tenderness during storage. The reason for our data disagreeing with literature data could be that colour intensity in the salmon trout we studied depended on smoke, but perhaps also on fish nutrition.

The texture of cold-smoked fish has great importance for product quality (*Lakshmanan et al., 2005*). Autolytic processes play the most important role in changes to fish meat structure during storage, and therefore, for the quality of fish meat. Autolytic degradation can cause undesirable fish softening at the very beginning of storage, even when the microbiota which usually causes spoilage is still not sufficiently developed to do so (*Olafsdottir et al.,*

Table 3. Sensory evaluation of tenderness of packaged cold-smoked trout during storage

Group	Day of Storage					
	7	14	21	28	35	42
I	$3.81^{aA}\pm0.26$	$3.50^{Aa}\pm0.38$	$3.75^{A}\pm0.46$	$3.13^{A}\pm0.23$	$3.75^{ab}\pm0.27$	$4.19^{A}\pm0.26$
II	$4.25^{aB}\pm0.38$	$4.06^{AB}\pm0.18$	$3.25^{a}\pm0.38$	$4.00^{AB}\pm0.27$	$3.38^{a}\pm0.23$	$3.94^{B}\pm0.18$
III	$3.25^{AB}\pm0.27$	$3.00^{aB}\pm0.27$	$2.75^{Aa}\pm0.38$	$3.38^{B}\pm0.23$	$3.31^{b}\pm0.26$	$3.44^{AB}\pm0.32$

Same letter within a column indicates a significance difference ^{A,B} $p<0.01$; ^{a,b} $p<0.05$

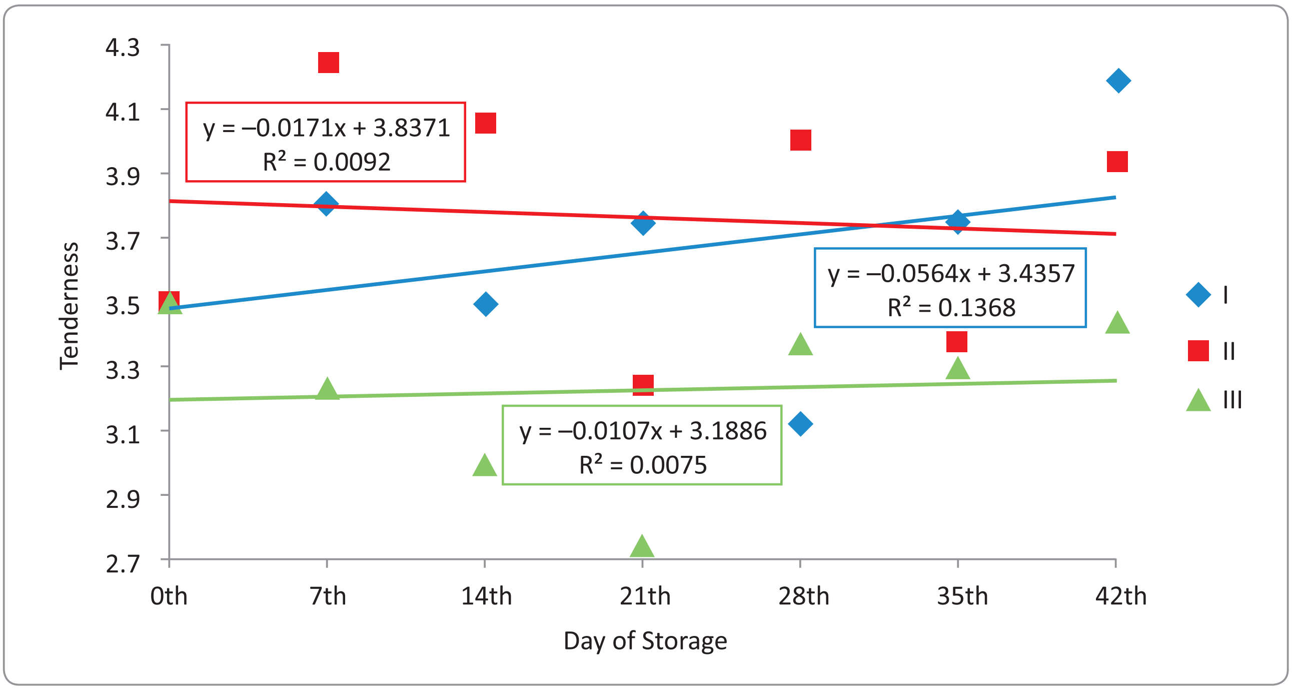

Figure 3. Sensory evaluation of tenderness of packaged cold-smoked trout during storage

2005*; Dondero et al.,* 2004*; Truelstrup Hansen et al.,* 1996).

One study showed that the reasons for fish meat softening include the manner of handling the raw material prior to slaughter, and the fat composition and storage conditions, which can lead to changes such as disintegration of the extracellular matrix and collagen fractions. This more likely occurs as a result of autolytic processes in fish tissue, rather than being a consequence of microbial activity (*Lund and Nielsen,* 2001). Also, dissolution of CO_2 in the tissues leads to acidification and decreases the pH of cold-smoked fish in modified atmospheres and consequently, changes the meat texture (*Torrieri et al.,* 2006).

The reason the tenderness intensity of group III fish fillets remained almost unchanged during storage could be due to this dissolution of CO_2 in the tissue, decreasing the pH. This would lead to protein changes, meaning the protein had less ability to bind water. Therefore, the consequent water loss resulted in the fish meat becoming firmer or not changing, even if it was affected by autolytic changes from microbiological activity (*Goulas and Kontominas,* 2007b).

Overall acceptability of cold-smoked trout fillets during storage

Average total acceptability scores of the three groups of cold-smoked trout fillets are shown in Table 4, and these decreased during storage. Similar findings were published by *Ibrahim et al.* (2008), *Pantazi et al.* (2008), *Goulas and Kontominas* (2007b)*, Cakli et al.* (2006), *Goulas and Kontominas* (2005), *Dondero et al.* (2004) and *Kolodziejska et al.* (2002). All these authors found that fish, fresh or smoked, packaged in different atmospheres, showed better overall acceptability scores, and thus, had

Table 4. Sensory evaluation of overall acceptability of packaged cold-smoked trout during storage

Group	Day of Storage					
	7	14	21	28	35	42
I	3.94^{AB}±0.18	4.21±0.27	3.00^{AB}±0.38	3.06^{A}±0.32	1.75^{AB}±0.27	1.00±0.00
II	4.44^{AC}±0.18	4.07±0.53	4.13^{Aa}±0.23	3.31^{B}±0.26	3.13^{AC}±0.23	1.00±0.00
III	4.94^{BC}±0.18	4.43±0.35	4.44^{Ba}±0.18	4.00^{AB}±0.27	3.88^{BC}±0.23	1.19±0.26

Same letter within a column indicates a significance difference $^{A–C}$ $p<0.01$; ^{a} $p<0.05$

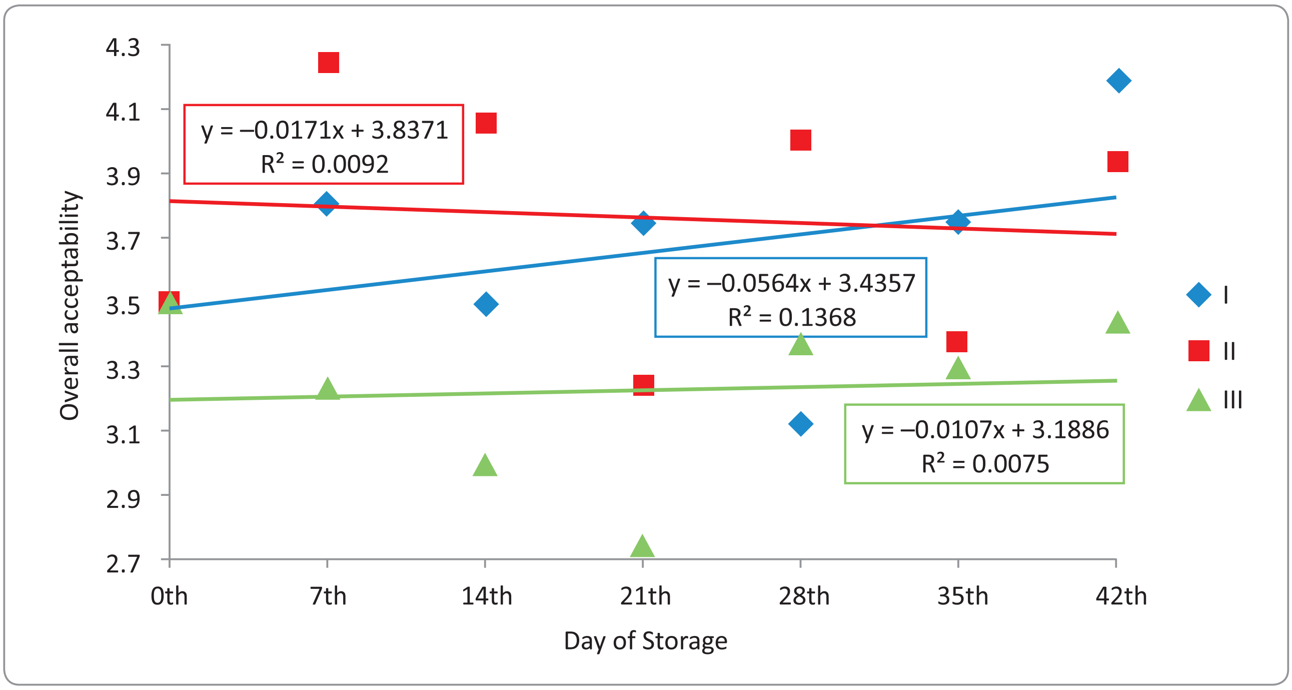

Figure 4. Sensory evaluation of overall acceptability of packaged cold-smoked trout during storage

longer shelf lives, as compared to fish stored in air or under vacuum.

Results of the present study show that significantly the highest average overall acceptability scores were determined for fish fillets packaged in the modified atmosphere with 90% CO_2 and 10% N_2 (group III). Group II fish fillets (modified atmosphere with 50% CO_2 and 50% N_2) had slightly lower overall acceptability scores, and vacuum packaged fish fillets (group I) achieved the lowest score (Figure 4). *Ibrahim et al.* (2008) examined smoked mullet packaged in modified atmosphere and vacuum, and found similar results. One explanation for this could be the fact that food packaged in modified atmosphere retains a more natural appearance than food packaged in a vacuum (*Murcia et al.,* 2003).

Conclusions

Colour intensity, odour and taste of smoke intensity and overall acceptability of cold-smoked trout decreased during storage, while fish fillet tenderness underwent very little change. Cold-smoked trout fillets packaged in modified atmosphere had higher average sensory scores compared to vacuum packaged cold-smoked trout fillets.

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