CHANGES IN MICROBIOLOGICAL QUALITY AND SAFETY OF VACUUM-PACKED COLD-SMOKED SALMON (*Salmo salar*) DURING STORAGE

Aya A. El-Bahnasawy, H.I. Abdelfattah, Howaida M. Abdelbasit and S.A. Mahgoub[*]

Agric. Microbiol. Dept., Fac. Agric., Zagazig Univ., Egypt

ABSTRACT: The first aim of this study was to assess the microbiological quality and safety of ten different brand samples of vacuum-packed cold-smoked salmon, CSS (n=50) from supermarkets of two cities in Egypt. The second aim of the current study was to study the changes in the microbiological quality and safety of CSS (*Salmo salar*) that obtained from one factory located in 10th Ramadan City after their directly production. Samples from the factory were stored at 5 and 0°C and then examined after 0, 7, 14, 21, 28 and 35 days of storage. For all samples, microbiological parameters [total bacterial counts (TBC), total lactic acid bacteria (LAB), lactobacilli count, *Pseudomonas* group and *Enterobacteriaceae* count] were performed at the same time. Pathogenic microorganisms (*Staphylococcus aureus* and *Listeria* spp.) were examined in all samples. These pathogenic bacteria were not detected in all factory samples tested and during the time of storage. The TBC, LAB, lactobacilli count, *Pseudomonas* group and *Enterobacteriaceae* family showed a significant increase with storage time and temperature regimes. Shelf lives of smoked salmon stored at 0 and 5°C were 26 and 8 days, respectively. *Lactobacillus* spp. and *Pseudomonas* spp. were dominant in terms of deterioration in quality.

Key words: Smoke salmon, safety, quality parameters, microbiological evaluation, pathogenic microorganisms.

INTRODUCTION

Smoking is besides drying one of the oldest methods of preserving fish. There are fundamentally three stages of cold smoke processing which contribute to the preservative effect: salting, dehydration, and smoking. Salting and dehydration (the latter is a direct effect of smoking) lower the water activity (a_W), thereby inhibiting the growth of bacteria and mold, which generally cannot grow at a_W lower than 0.86 in the presence of soluble salt (**Sperber, 1983; Løvdal, 2015**). In addition, the chlorine ions are toxic to some microorganisms. **Anonymous (2001)**. The bacteriostatic effect of smoke is mainly due to phenols. Drying times, after salting, range from 1 to 6 hr., at 20-28°C, smoking parameters at a maximum of 30°C ranges from 3 to 6 hr., and the recommended

smoke chamber temperature combinations must not exceed 32°C for more than 20 hr., and 10°C for more than 24 hr., (**Anonymous, 2001; Muñoz et al., 2020**). In addition, cold smoked salmon (CSS) is characterized by specific chemical properties, *i.e.,* lipid <18% (*W/W*), water content <74%, a NaCl concentration between 2.5 and 3.5% (*W/W*), and smoke treatment corresponding to 0.6 mg of phenol per 100 g of product (**Leroi et al., 2000, 2001**). CSS is therefore classified under lightly preserved fish products which include fish products preserved with low levels of salt (<6% NaCl (*W/W*) in the water phase) and the addition of preservatives such as sorbate, benzoate, NO_2, or smoke for some products. These products have a high pH (>5.0), they are often packed under vacuum and must be stored and distributed at cool temperatures (5°C). pH in CSS varies

* Corresponding author: Tel.: +201099341197
E-mail address: mahgoubsamir@gmail.com

between 6 and 6.3 **(Gram, 2001).** CSS is considered a delicacy commonly consumed as a 'ready-to-eat' (RTE) product without heat treatment **(Gram and Huss, 1996; Chan *et al.,* 2020).** The production and consumption of cold smoked salmon have been increasing in the last decade; for example, Spain represents the sixth highest European country in terms of consumption of smoked salmon **(IRI, 2015).** CSS, like other cold smoked fish products, is often consumed as RTE with no heat treatment, although it is also suitable as a cooking ingredient in, for example, various casserole dishes.

Anyway, the absence of thermal treatment makes the parameters salting and smoking utmost important in order to minimize the risk of foodborne hazards and spoilage. Salting and drying (also as an effect of smoking) are crucial steps to achieve the ideal water phase salt (WPS) level. Salt can be applied in dry form (dry salting), as brine, or by injecting brine. When liquid smoke (LS) is utilized as an alternative to traditional generated wood smoke, this is normally injected, sometimes combined with the brine, to achieve smooth and even colouring of the product. At the same time, processors of smoked salmon have made efforts to adapt their production parameters to this raw material in order to respect the market demand and to satisfy their requirements for profit. The choice of the processes used (salting techniques, drying and smoking procedures, type of equipment) is large and for each step of the process, the choice of control parameters such as time of salting, the concentration of brine, or smoking temperature allows specific finished product characteristics to be reached **(Indrasena *et al.,* 2000; Rizo *et al.,* 2017)**. The knowledge of raw material characteristics is an important factor to control in order to obtain the required product quality and many studies have shown their effects on final characteristics and yield **(Beltran and Moral, 1991; Rora, *et al*., 1998; Cardinal *et al.,* 2001)**. Also, the wide range of raw salmon characteristics as well as the many salting and smoking techniques used by different processors gives rise to a wide range of smoked salmon characteristics available in the market. All year rounds there are wide selection of products available to consumers. However,

consumers have great difficulties in identifying criteria in order to be able to choose a product according to their preference. Often, the only information available which can help consumers to make their selection are the appearance (*e.g.,* the colour) of the product, the brand name, processing references *e.g.,* dry salting, the shelf life of the product, and of course the price. Recent French market surveys on smoked salmon products, published by consumer review point out a general decrease in quality of smoked 3 salmon on the market **(Maleysson and Bonneff, 2001; Anonymous, 2002; Pedro and Nunes, 2019).**

However, the main criticisms on the quality of the product refer to the appearance, the texture related to fat content, the level of salt and the taste. A study performed on the Italian market reveals that the hygienic quality of the smoked salmon is poor at the expiry date **(Vergara *et al.,* 2001)**. Quality is one of the most frequently used words relating to food. However, it is exceptionally difficult and complicated to define quality in terms that are widely understood **(Meiselman, 2001).** Smoked salmon is a ready-to-eat food, normally vacuum packed, with a refrigerated shelf-life of 3-8 weeks **(Rørvik, 2000).** Cold smoked fish is usually consumed without any further cooking **(Eklund *et al.,* 1995; Gudmundsdóttir *et al.,* 2005)**, and salmon has a high lipid content which may protect microorganisms from a possible thermal treatment or from freezing. The production of smoked salmon includes several technological steps, such as filleting, salting (dry-salting or brine microinjection), drying, smoking, trimming and packaging, that require a lot of handling by workers **(Rørvik, 2000).** The spoilage bacteria depends on the type of processing. The microflora in spoiled CSS also varies widely between different processing plants and smokehouses **(Hansen and Huss, 1998; Hansen *et al.,* 1998)**. The aim of the present study was to describe the smoked salmon characteristics sold on the Egyptian markets by microbiological analyses and physical measurements (colour, expressible liquid), chemical analyses (pH values) in order to get an objective overview of the quality of the smoked salmon.

MATERIALS AND METHODS

Materials

Sampling from supermarkets

Samples of commercial smoked salmon products were collected from supermarkets of two cities, Egypt. Supermarkets were chosen as a favorite market for most consumers. Samples of sliced vacuum-packed cold-smoked salmon (*Salmo salar*) were purchased during January, February, and March 2019, sent to Agricultural Microbiology Laboratory in refrigerated truck. In total, 50 samples were received: 25 samples (A-E=25) from Tenth of Ramadan City (these products were produced in this city) and 25 samples (F-J=25) from El-Obour City. Altogether the sampling corresponded to different producers in Tenth of Ramadan City.

Sampling from industry

Samples of smoked salmon were then ordered directly from one factory named A in Tenth of Ramadan City. This was done in order to control our experimental design according to the shelf life of the product. All the samples were vacuum packed and evaluated after 0, 7, 14, 21, 28 and 35 days of storage at 0°C and 5°C in order to include the effect of the shelf life in the study.

Methods

Microbiological analysis

Total bacterial counts (TBC), Total lactic acid bacteria count (LAB), lactobacilli count (LC), *Enterobacteriaceae* count (ENT), staphylococci count (SC), *Staphylococcus aureus*, psychrotrophic count (TPC), *Listeria* spp. and *Pseudomonas* spp., were determined as described by US Food and Drugs Administration (**FDA, 1992**). In briefly, after 30 min at room temperature for resuscitation, when sensory evaluation was carried out, three packages per sample were opened and a 10 g portion of each bag, representing all the slices, was stomached in 90 ml buffered diluents (0.85% NaCl and 0.1% peptone) for two min in a stomacher 400 (Lab. Blender, London, UK). Ten-fold serial dilutions were spread or poured on selective agar media for count of different microorganisms.

For the first experiment (Microbiological analyses of market samples of smoked salmon), total bacterial count (TBC) was counted on plate count agar (PCA; Merck, 1.05463) incubated at 25ºC for 72 hr. Spread plates of modified Long and Hammer's medium (**Van Spreekens 1974**) incubated at 15°C for 5 days were used to determine the total psychrotrophic count (TPC).

Total lactic acid bacteria (LAB) was enumerated on spread plates of Nitrite Actidione Polymyxin agar (NAP, **Davidson and Cronin, 1973**) at pH 6.8 and lactobacilli on MRS (ROG, Biokar, Beauvais, France) at pH 5.5 as suggested by **Leroi *et al.* (2000)**. NAP and ROG plates were incubated at 20°C in anaerobic conditions (Anaerocult A, Merck, Darmstadt, Germany). At least 10 colonies grown in NAP and Rogosa agar with different morphologies were phenotypically characterized according to the Bergey Manual of Systematic Bacteriology, 8th edition. The colonies were classified according to their shape, colour, edge and size, and at least 10–15 colonies per plate were picked up and purified by plate-streaking technique, to detect the dominant bacteria in CSS. Presumptive LAB (Gram+ and catalase -) colonies were transferred into MRS broth (Merck) containing 40% (*V/V*) sterile glycerol (Merck) solution and stored at −25°C until identification and used in the other research. *Enterobacteriaceae* counts were determined in pour plates of CASO agar (Merck) overlaid by Violet Red Bile Glucose agar (Oxoid), incubated at 30°C for 2 days. Assuming that non-typical colonies could also belong to the Enterobacteriaceae family, all the colonies growing in the plate were enumerated after 48 hr. of incubation at 30°C. Staphylococci were counted on Baird Parker agar (Biolife, Milano, Italy) supplemented with egg yolk incubated at 37ºC for 48 hr. *Staph. aureus* was detected by examining the plates for typical black colonies, convex colonies, with a light halo, and these were tested for positive coagulase reaction (Bactident Coagulase Biolife, Milano, Italy). Enumeration of *Pseudomonas* spp. was performed by spread plate method on *Pseudomonas* agar base media (Biolife, Italy) and incubated at 25°C for 48 hr. *Listeria* spp. were determined by surface plating on polymyxin-acriflavin-lithium chloride-ceftazidime-aesculin-mannitol agar (PALCAM, Biolife,

Italy) and the plates were incubated at 30°C for 48 hr.

For the second experiment (Microbiological changes in smoked salmon during storage), total bacterial count (TBC), *Enterobacteriaceae* counts, total lactic acid bacteria (LAB) and *Pseudomonas* spp. were determined according the procedures above.

Sensory and pH evaluation

A descriptive test with conventional profiling **(Stone and Sidel, 1985)** was carried out in industry samples to evaluate the sensory characteristics of smoked salmon. All samples were scored by twenty panelists belonging to the Agric. Microbiol. and Food Sci. Depts. Fac. Agric., Zagazig Univ. staffs and trained on sensory descriptors for smoked salmon. The descriptors related to the appearance, odour, flavour and texture of smoked salmon slices. An experimental design was constructed in order to balance various parameters, the characteristics of products presented within a session (it was decided to present samples that had previously identified as samples belonging to different groups at the same session), the company of production of the product and the remaining shelf life.

According to the package weight (100g or 200g), seven to fourteen packages from each sample were necessary to give one slice to each panelist. All samples were stored at 0.0 or 5.0 °C until sensory analysis was performed. The day of sensory analysis, the packages of smoked salmon were opened and kept open for 15 minutes at ambient temperature, after that every 6 slices was individually repacked in aluminum foil. Panelists rated the sensory attributes on a continuous unstructured line scale from low intensity (0) to high intensity (10). Products were assigned 3-digit numbers, randomised and served simultaneously. Botteled water and balady bread were presented between samples. A sensory description test was performed on each product by a panel consisting of 5 people with a large experience in tasting smoked salmon. The following criteria were used: odour, appearance, flavour, and texture. Each panelist described the main characteristics of the products as well as the intensity of perception. All samples were evaluated and assessed. After an individual evaluation of each product, a discussion allowed panelist's descriptions to be compared, and samples were gathered in class according to their common characteristics. Finally, this screening allowed products to be sorted out, and 100 products were selected. The remaining flesh in the 3 packages opened for microbiological analysis was homogenized in a Warring Blender. The flesh was diluted five times with distilled water and measured using a pH meter, Mettler 320 (Mettler-Toledo, England).

RESULTS AND DISCUSSION

Microbiological Results of Market Samples of Smoked Salmon

This study was performed to examine the microbiological quality and safety of cold smoked salmon sold in Egypt from different markets on either plate counts or selective agar. The results of total bacterial counts (TBC), total psychrotrophic count (TPC), total lactic acid bacteria (LAB), lactobacilli count (LC), *Enterobacteriaceae* count (ENT), total staphylococci count (SC), *Staphylococcus aureus* and *Listeria* spp. are shown in Tables 1 and 2. A total of 50 samples of cold smoked salmon (n=50) were purchased from various markets to examine the safety and quality of different brands sold from different factories. The TBC and TPC were very different from one sample to another, which ranged from 2.67 to 6.70 Log CFU/g and 2.17 to 7.30 Log CFU/g, respectively except the F and H samples. The TBC and TPC in F and H samples were ranged between 6.70 to 6.24 and 7.30 to 7.10 Log CFU/g, respectively. Among samples that had not exceeded 6 Log CFU/g which means these samples do not pass the existing regulation (for the Egyptian and French market where the limit is 6 Log CFU/g). However, it is important to point out that the TBC and TPC were enumerated by spread plates onto PCA and LH media, respectively instead of the pour plate media onto PCA that recommended in the European standard, and it has been clearly shown that counts on LH are generally one logarithm higher than PCA counts **(Joffraud and Leroi, 2000)**. Final report of European contract FAIR-PL- 95-1207- Spoilage and safety of cold-smoked fish).

Table 1. Total bacterial count (TBC), Total psychrotrophilic count (TPC), lactic acid bacteria (LAB), lactobacilli and *Pseudomonas* spp., in cold smoked salmon from different supermarkets (log CFU/g)

Smoked salmon brand sample (n=50) [*]	TBC	TPC	LAB	Lactobacilli	*Pseudomonas* spp.
A	2.67±0.22	2.17±0.12	2.25±0.25	2.15±0.22	1.22±0.12
B	3.70±0.23	3.10±0.13	2.72±0.34	1.92±0.28	1.74±0.34
C	3.85±0.32	3.35±0.30	2.83±0.12	1.87±0.29	1.82±0.19
D	2.88±0.11	2.28±0.21	2.11±0.54	2.09±0.19	1.14±0.17
E	3.78±0.24	3.18±0.29	2.73±0.24	2.89±0.24	1.71±0.11
F	6.70±0.32	7.30±0.12	2.76±0.11	2.55±0.23	5.72±0.29
G	3.90±0.13	3.40±0.11	2.92±0.24	2.62±0.09	1.61±0.18
H	6.24±0.19	7.10±0.15	3.10±0.45	3.18±0.11	2.40±0.19
I	3.78±0.18	3.18±0.12	2.38±0.23	2.18±0.19	1.48±0.17
J	4.38±0.13	4.18±0.17	3.48±0.24	3.28±0.21	2.06±0.11

All values reflect the mean values of 3 replicates and standard errors. *The name of the brands: A-J. each brand 5 samples were analyzed.

Table 2. Total *Enterobacteriaceae* group (ENT), staphylococci count (SC) *Staph. aureus* and *Listeria* spp. in cold smoked salmon from different supermarkets (log CFU/g)

Smoked salmon brand sample (n=50) [*]	ENT	SC	*Staph. aureus*	*Listeria* spp.
A	1.22±0.22	2.15±0.25	2.15±0.13	1.12±0.11
B	2.75±0.23	3.12±0.15	2.91±0.16	1.71±0.13
C	1.95±0.32	3.13±0.08	2.81±0.15	1.32±0.14
D	1.58±0.11	1.71±0.23	1.18±0.11	1.14±0.15
E	2.38±0.24	3.03±0.21	2.81±0.09	1.41±0.23
F	1.73±0.32	2.56±0.13	2.15±0.07	1.62±0.34
G	2.50±0.13	2.42±0.26	2.12±0.16	1.51±0.16
H	2.06±0.19	3.00±0.19	2.28±0.15	2.49±0.10
I	1.88±0.18	2.68±0.11	2.38±0.14	1.38±0.16
J	1.08±	2.14±0.13	2.36±0.15	2.30±0.23

All values reflect the mean values of 3 replicates and standard errors. *The name of the companies: A-J. each brand 5 samples were analyzed.

Based on the different microbiological counts, the 50 samples could be divided into 2 groups. Group 1 consisted of samples with generally high contamination level (TBC > 6 Log CFU/g). Group 2 consisted of samples with generally low contamination level (TBC < 6 Log CFU/g). However, most samples were composed of a mixture of LAB (mostly *Lactobacillus*), *Enterobacteriaceae,* staphylococci*, Pseudomonas* and in a lesser extend *Staph. aureus* and *Listeria* spp. As TPC of F and H samples were on average one log higher than the other TBC, and based on results from **Leroi et al. (1998, 2001),** their results also presume that marine Gram-negative bacteria such as *Vibrio* spp, *Photobacterium* sp, *Aeromonas, Shewanella* spp. are also dominant. LAB and lactobacilli were the dominating flora in the examined samples while staphylococci were dominated and higher than *Enterobacteriaceae* and *Listeria* spp. in all the tested samples. Groups A and D consisted of samples with better hygienic profile. Groups A, B, C, D, E, G, I and J consisted of samples with a relatively low TBC, TPC, LAB and ENT but with different qualitative microflora composition. Microflora of group H (5 samples) was dominated by Pseudomonads, probably belonging to *Pseudomonas* genus, while lactobacilli selective count on Rogosa agar was very low (3.18 Log CFU/g). In Group F (5 samples), all counts enumerated on selective media were very high and TPC was probably constituted of *Pseudomonas*. Group A (5 samples) was a particular group, consisting of samples for which all the counts were below than all the tested groups. The presence of staphylococci may have been due to the fact that these foods were often prepared handly in final packaging and this direct contact may lead to an increase of contamination with *Staphylococcus* **(Colombari et al., 2007; Dalgaard and Mejlholm, 2019).** The results of this study indicated that there were some poor handling practices during the preparation of smoked salmon which require more attention. In spite that, Pathogenic microorganisms (*Staphylococcus aureus*, and *Listeria monocytogenes*) were examined in all samples and were not detected in all the fifty samples tested (the data not shown).

Microbiological Changes in Smoked Salmon during Storage

The results of total bacterial counts (TBC) and total lactic acid bacteria (LAB) made on cold smoked salmon are presented in Fig. 1. There was a positive increase in both TBC and LAB with storage temperatures and time. The LAB and TBC at the beginning of storage ranged from 2.62 to 3.95 Log CFU/g, respectively. At the end of shelf life, after 28 and 14 days, at 0 and 5°C, respectively, levels of 6 and 6.28 Log CFU/g were reached. However, **Sernapesca (1996)**, established limits for total viable count of bacteria between 10^5 and 5×10^5 CFU/g. **Truelstrup et al. (1995)** also found that cold-smoked salmon with a high number of microorganisms (10^8 CFU/g) was not always spoiled. The results of *Pseudomonas* group and *Enterobacteriaceae* count are shown in Fig. 1. The ENT and *Pseudomonas* ranged from 1.30 to 2.0 Log CFU/g at the beginning of storage and after 28 and 14 days at 0 and 5°C, levels of 2.77 and 3.40 Log CFU/g and 2.58 and 3.97 Log CFU/g were found, respectively. No correlation was found between ENT storage time and temperature. *Staphylococcus aureus* and *Listeria monocytogenes* were not detected in cold-smoked salmon throughout storage time at 0 or 5°C. **Truelstrup et al. (1996)** have reported that yeasts and molds were not considered to be of any importance for spoilage of cold smoked salmon. However, lactic acid bacteria dominated the microflora throughout the storage period of cold smoked salmon (Fig. 1). This was also reported by **Leroi et al. (1996 and 1998)**. The lactic acid bacteria group (LAB) is known to produce organic acids and ethanol as typical fermentation end products **(Gottschalk, 1986)**.

In the case of smoked-salmon, the roles of the microflora are not as clear as many authors have shown, in that there is no correlation between shelf life and LAB count, or any other bacterial number **(Dodds et al., 1992; Chan et al., 2020)**. They may be found in high numbers before the product is spoiled **(Truelstrup et al., 1996)**. *Lactobacillus* spp., showed significant correlation with storage time and sensory quality at all storage temperatures. Differences among the microflora isolated from three different smokehouses and production batches, indicate
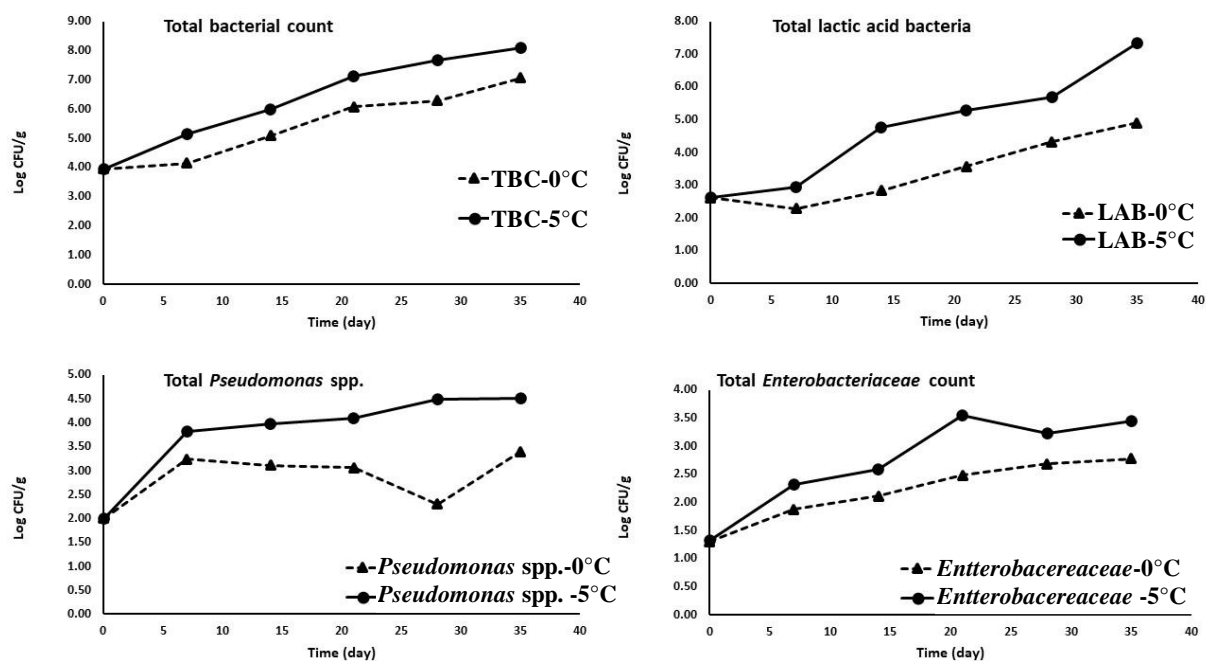
Fig. 1. Changes in total bacterial count (TBC), lactic acid bacteria (LAB), *Pseudomonas* spp. and *Enterobacteriaceae* count (Log CFU/g) in vacuum-packed cold-smoked salmon during storage

that the existence of one typical microflora including one specific spoilage organism for cold smoked-salmon is unlikely. The microflora at the time of spoilage is highly variable with lactic acid bacteria, *Enterobacteriaceae* and marine bacteria among the dominating microorganisms (**Truelstrup *et al.,* 1998**). The bacteria mainly responsible for spoilage in sterile cold-smoked salmon stored in vacuum packs at 5°C were *Lactobacillus. sakei*, *Lactobacillus. farciminis* and *Brochthrix thermosphacta*, which produced sulphurous, acidic and rancid off-odours, respectively. Some strains of *Streptococcus. liquefaciens* produced rubbery, cheesy or acidic off-flavours. Some *Photobacterium. phosphoreum* isolates were characterized by an acidic effect (**Stohr, *et al.,* 2001**). In cold-smoked fish, aerobic conditions lead to faster spoilage than under vacuum or modified atmosphere packaging. Under aerobic conditions, *Pseudomonas* and some lactic acid bacteria developed, whereas anoxic packaging conditions resulted in development of lactic acid bacteria with a minor component of Gram-negative bacteria. Typically, shelf life is reduced by aerobic storage as compared to vacuum-

packed storage (**Dufresne *et al.,* 2000; Gram, 2001**).

Sensory Evaluation and pH

Results of the sensory analyses and pH values of cold-smoked salmon at 0 and 5°C are shown in Fig. 2. The results showed reduction in mean sensory scores and pH levels during storage at 0 and 5°C. With increasing storage temperatures, decreased shelf life was obtained. The spoilage patterns described by the panelists were: softening of texture before off-odours developed and presence of bitter, sour, rancid and ammonia off-flavours. Appearance score decreased as colour discolouration increased. Autolytic enzymes can have a major impact on the loss of textural quality of cold-smoked salmon during the early stages of deterioration, but they did not produce the characteristic off-flavours and off-odours, which are typical of microbiological activity (**Truelstrup *et al.,* 1996**). Shelf-life values were 28 and 7 days for samples stored at 0 and 5°C, respectively. **Truelstrup *et al.* (1998)**, found that the estimated shelf life at 5 and 0°C of vacuum-packed slices of cold-smoked salmon
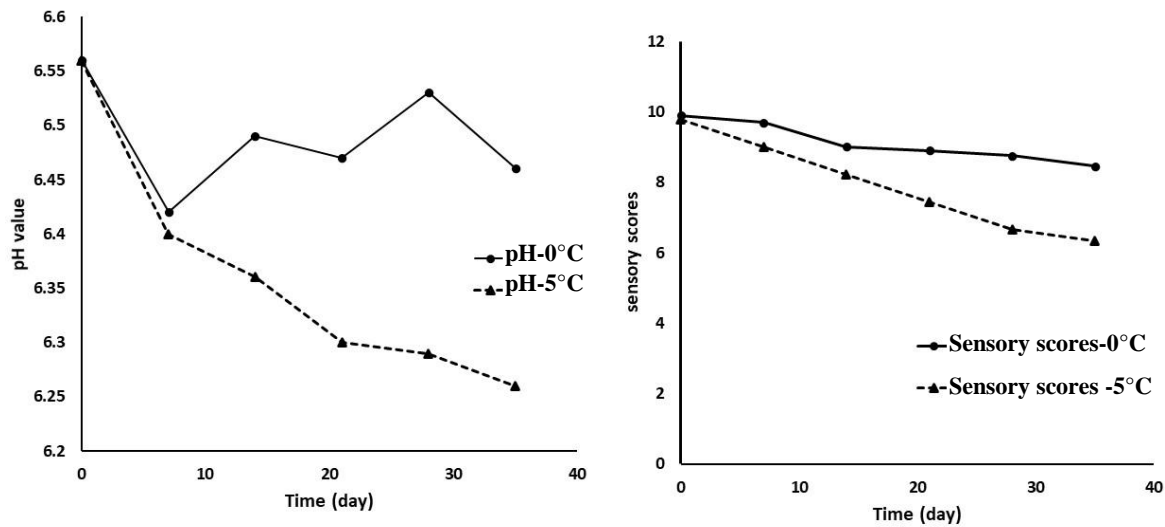
Fig. 2. Changes in pH value and sensory scores in vacuum-packed cold-smoked salmon during storage

ranged between 21 and 36 days, respectively. Shelf lives of whole fillets were always longer than shelf lives of the corresponding sliced products. It may, however, be difficult to compare salmon produced by different smokehouses because a number of important factors, such as packaging material, production method, size and composition of initial microflora, numbers of freezing and thawing cycles and quality of raw material, varied and this may explain why salmon with 4.1% and 6.1% salt in the water phase, had comparable longer shelf lives. For French vacuum-packed cold-smoked salmon stored at 5 ^{0}C, the shelf life was very variable (1–6 weeks) and was related to the initial *Enterobacteriaceae* load, depending on hygienic conditions in the smokehouse rather than on the material quality or the processing parameters (**Leroi** *et al.,* **2001**).

Based on our results, for Egyptian vacuum-packed cold-smoked salmon stored at 0 or 5°C, the shelf life was very variable (4 or 2 weeks, respectively). Estimation of cold-smoked salmon quality is possible by measuring three parameters: TBC, LAB and lactobacilli concentration. Positive correlations were found between storage time, sensory quality and TBC, LAB, *Lactobacillus* spp., and pH values at different storage temperatures. These indicators were found to be superior as an indicator of quality because a

clear relation to sensory evaluation could be established.

Conclusions

According to microbiological quality and sensory analysis of vacuum-packed cold smoked salmon presented a shelf life of 28 days at 0°C and 14 days at 5°C. TBC, TPC, LAB and *Lactobacillus* spp., were the most suitable indicators to determine cold smoked salmon freshness. There was a significant correlation of these variables with storage time and sensory analysis at different storage temperatures. *Pseudomonas* and ENT were not useful deterioration indicators of cold smoked salmon at temperatures in the range of 0–5°C. Pathogenic microorganisms such as *L. monocytogenes* and *Staph. aureus* were not detected in cold-smoked salmon.

REFERENCES

Anonymous (2001). Fish Farmer. November/ December, 5 – 18.

Anonymous (2002). Le saumon fumé n'est pas à la fête. 60 millions de consommateurs, Institut national de la consommation, 367: 48-54.

Beltran A. and A. Moral (1991). The effects of fat contents and storage temperature on the

storage life of smoked sardine fillets (*Sardina pilchardus* W.) prepared from frozen sardine. Food Chem., 42 (3): 347-356.

Cardinal, M., C. Knockaert, O. Torrissen, S. Sigurgisladottir, T. Morkore, M. Thomasen and J.L. Vallet (2001). Relation of smoking parameters to the yield, colour and sensory quality of smoked Atlantic salmon (*Salmo salar*). Food Res. Int., 34: 537-550.

Colombari, V., M.D. Mayer, Z.M. Laicini, E. Mamizuka, B.D. Franco and M.T. Destro (2007). Foodborne outbreak caused by *Staphylococcus aureus*: phenotypic and genotypic characterization of strains of food and human sources. J. Food Prot., 70: 489-493.

Chan, S.S., B. Roth, F. Jessen, T. Løvdal, A.N. Jakobsen and J. Lerfall (2020). A comparative study of Atlantic salmon chilled in refrigerated seawater versus on ice: from whole fish to cold-smoked fillets. Scientific Reports, 10 (1): 1-12.

Dodds, K., M. Brodsky and D. Warburton (1992). A retail survey of smoked ready-to-eat fish to determine their microbiological quality. J. Food Prot., 55(3): 208–210.

Davidson, C. and F. Cronin (1973). Medium for the selective enumeration of lactic acid bacteria from foods. Appl. Microbiol., 26 (3): 439–440.

Dalgaard, P. and O. Mejlholm (2019). Modelling growth of Listeria and lactic acid bacteria in food environments. In: Bridier, A. (Ed.), Foodborne Bacterial Pathogens. Springer, New York, NY, 247–264.

Eklund, M.W., F.T. Poysky, R.N. Paranjpye, L.C. Lashbrook, M.E. Peterson and G.A. Pelroy (1995). Incidence and sources of *Listeria monocytogenes* in cold smoked fishery products and processing plants. J. Food Prot., 58: 502-508.

FDA (1992). Bacteriological analytical manual (7th Ed.). Edited by Division of Microbiology, CFSAN, and Technical Editing Branch. 2200 Wilson Boulevard, Suite 400, Arlington: Published by the Ass. Official Agric. Chem.

Gram, L. (2001). Special supplement - chapter III, potential hazards in cold smoked fish: *Clostridium botulinum* type E. J. Food Sci., 66: 1082-1087.

Gram, L. and H.H. Huss (1996). Microbiological spoilage of fish and fish products. Int. J. Food Microbiol., 33 (1): 121-137.

Gottschalk, G. (1986). Bacterial Metabolism. New York: Springer.

Gudmundsdóttir, S., B. Gudbjörnsdóttir, H.L. Lauzon, H. Einarsson, K. Kristinsson and M. Kristjánsson (2005). Tracing Listeria monocytogenes isolates from cold smoked salmon and its processing environment in Iceland using pulsed-field gel electrophoresis. Int. J. Food Microbiol., 101: 41-51.

Hansen, L.T. and H.H. Huss (1998). Comparison of the microflora isolated from spoiled cold-smoked salmon from three smokehouses. Food Res. Int., 31(10): 703-711.

Hansen, L.T., S.D. Rontved and H.H. Huss (1998). Microbiological quality and shelf life of cold-smoked salmon from three different processing plants. Food Microbiol., 15: 137-150.

Indrasena, W.M., L.T. Hansen and T.A. Gill (2000). Effect of cold-smoking and drying on the textural properties of farmed Atlantic salmon (*Salmo salar*). J. Aquatic Food Prod. Technol., 9 (1): 47-64.

IRI (2015). Industrial Research Institute, Info. Scan™ Census. https://www. iriworldwide. com/es-ES.

Joffraud, J.J. and F. Leroi (2000). Spoilage and safety of cold-smoked fish. Final Report Europ. Contract FAIR-PL-95-1207.

Leroi, F., N. Arbey, J. Joffraud and F. Chevalier (1996). Effect of inoculation with lactic acid bacteria on extending the shelf life of vacuum-packed cold-smoked salmon. Int. J. Food Sci. and Technol., 31: 497–504.

Leroi, F., J.J. Joffraud, F. Chevalier and M. Cardinal (1998). Study of the microbial ecology of cold-smoked salmon during storage at 8°C. Int. J. Food Microbiol., 39: 111-121.

Leroi, F., J.J. Joffraud and F. Chevalier (2000). Effect of salt and smoke on the microbiological quality of cold-smoked salmon during storage at 5°C as estimated by the factorial design method. J. Food Prot., 63: (4): 502-508.

Leroi, F., J.J. Joffraud, F. Chevalier and M. Cardinal (2001). Research of quality indices for cold-smoked salmon using a stepwise multiple regression of microbiological counts and physico-chemical parameters. J. Appl. Microbiol., 90: 578-587.

Løvdal, T. (2015). The microbiology of cold smoked salmon. Food Control, 54: 360-373.

Maleysson, F. and E. Bonneff (2001). Tout va à vau l'eau. Que choisir, 388, 30-34. NF V-09-105 (1995). Directives générales pour l'implantation de locaux destinés à l'analyse sensorielle. In Contrôle de la qualité des produits alimentaires-Analyse sensorielle. AFNOR, Paris.

Meiselman, H. (2001). Criteria of food quality in different contexts. Food Service Technol., 1: 67-84.

Muñoz, I., M.D. Guàrdia, J. Arnau, P. Dalgaard, S. Bover, J.O. Fernandes and H. Oliveira (2020). Effect of the sodium reduction and smoking system on quality and safety of smoked salmon (*Salmo salar*). Food and Chem. Toxicol., 143: 111-554.

Pedro, S. and M.L. Nunes (2019). Reducing salt in seafood products. In: Beeren, C., Groves, K., Titoria, P.M. (Eds.), Reducing Salt in Foods. Woodhead Publishing Limited, Camb., 185–211.

Rizo, A., A. Fuentes, J.M. Barat and I. Fernandez-Segovia (2017). A development of a novel smoke-flavoured salmon product by sodium replacement using water vapour permeable bags. J. Sci. Food Agric., 98 (7): 2721–2728.

Rora, A.M.B., A. Kvale, T. Morkore, K.A. Rorvik, S.H. Steien and M.S. Thomassen (1998). Process yield, colour and sensory quality of smoked Atlantic Salmon in relation to raw material characteristics. Food Res. Int., 31(8): 601-609.

Rørvik, L.M. (2000). *Listeria monocytogenes* in the smoked salmon industry. Int. J. Food Microbiol., 62: 183-190.

Sernapesca (1996). Programa de certificaci_on de producto final, Norma t_ecnica CER/ NT/95.

Sperber, W.H. (1983). Influence of water activity on foodborne bacteria-a review. J. Food Prot., 46 (2): 142-150.

Stohr, V., J. Joffraud, M. Cardinal and F. Leroi (2001). Spoilage potential and sensory profile associated with bacteria isolated from cold-smoked salmon. Food Res. Int., 34: 797- 806.

Stone, H. and J.L. Sidel (1985). Sensory Evaluation Practices. Academic Press Inc., New York.

Truelstrup, L., T. Gill and H.H. Huss (1995). Effects of salt and storage temperature on chemical, microbiological and sensory changes in cold-smoked salmon. Food Res. Int., 28 (2): 123-130.

Truelstrup, L., T. Gill, S. Drewes and H. Huss (1996). Importance of autolysis and microbiological activity on quality of cold-smoked salmon. Food Res. Int., 29 (2): 181–188.

Truelstrup, L., S. Drewes and H. Huss (1998). Microbiological quality and shelf life of cold-smoked salmon from three different processing plants. Food Microbiol., 15: 137–150.

Van Spreekens, K.J.A. (1974). The suitability of a modification of Long and Hammer's medium for the enumeration of more fastidious bacteria from fresh fishery products. Antonie Leeuwenhoek, 25: 213-219.

Vergara, A., A. Di Pinto, P. Losito and G. Tantillo (2001). Microbiological and chemical quality of vacuum-packed smoked salmon up to the declared expiry date. Adv. Food Sci., 23 (1): 25-30.

التغيرات في الجودة الميكروبيولوجية وسلامة السلمون (*Salmo salar*) المدخن البارد المعبأ بالتفريغ الهوائي أثناء التخزين

أية أحمد البهنساوي- حسن ابراهيم عبدالفتاح- هويدا محمد لبيب عبدالباسط – سمير احمد مرغنى محجوب

قسم الميكروبيولوجيا الزراعية - كلية الزراعة - جامعة الزقازيق - مصر

الهدف الأول للدراسة هو تقييم الجودة الميكروبيولوجية والسلامة لعشرة أسماء تجارية مختلفة للسلمون المدخن البارد المعبأ بالتفريغ: CSS (ن =50) من مجموعة من السوبر ماركت لمدينتين في مصر، الهدف الثاني للدراسة هو دراسة التغيرات فى الجودة الميكروبيولوجية والسلامة للسلمون المدخن على البارد (*Salmo salar*) CSS حيث تم الحصول عليه من مصنع واحد بالعاشر من رمضان بعد الانتاج مباشرة وتم تخزين العينات في صفر و 5 درجة مئوية ثم فحصها بعد صفر، 7 ، 14، 21، 28 و35 يومًا من التخزين، لجميع العينات، تم إجراء المعلمات الميكروبيولوجية (تعداد البكتيريا الكلي: TBC، مجموع بكتيريا حمض اللاكتيك: LAB، عدد العصيات اللبنية، مجموعة *Pseudomonas*، مجموعة *Enterobacteriaceae*) في نفس الوقت، تم فحص الكائنات الدقيقة الممرضة (السالمونيلا، المكورات العنقودية الذهبية، والليستيريا المستوحدة) في جميع العينات، لم يتم اكتشاف هذه البكتيريا الممرضة في جميع العينات الخمسين المختبرة وخلال فترة التخزين، أظهرت مجموعات كل من TBC، LAB، lactobacilli، *Pseudomonas* و*Enterobacteriaceae* زيادة معنوية مع أنظمة وقت التخزين ودرجة الحرارة، كان العمر الافتراضي للسلمون المدخن المخزن عند صفر و5 درجات مئوية 26 و 8 أيام على التوالي وكانت بكتيريا الـ spp. *Lactobacillus*. و spp. *Pseudomonas* هي المهيمنة من حيث تدهور الجودة.

الكلمات الإسترشادية: سمك السلمون المدخن، معلمات الجودة، التقييم الميكروبيولوجي، الميكروبات الممرضة.