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Korkeala, H.

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Microbiological Changes in Smoked and Charred Baltic Herrings during Storage

HANNU J. KORKEALA[1]* and PEKKA K. PAKKALA[2]

College of Veterinary Medicine, Department of Food and Environmental Hygiene, P.O. Box 26, SF-00551 Helsinki, Finland and National Board of Health, Siltasaarenkatu 18, SF-00530 Helsinki, Finland

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ABSTRACT

The microbiological quality of smoked and charred Baltic herrings from two different processing plants was studied after preparation and after storage for 24, 48 and 96 h at 4 and 20°C. One of the processing plants used traditional processing methods and the other a modern processing technology. No significant increase in aerobic plate counts (APCs) was observed during storage of smoked herrings at 4°C; after 96 h the mean APC was 1.7×10^2 CFU/g. The mean APC of charred herrings increased markedly at 4°C within 48 h, and after 96 h was 2.4×10^4 CFU/g. At 20°C the mean APCs of smoked and charred herrings increased markedly within 24 h, and after 96 h were 1.0×10^8 and 1.7×10^9 CFU/g, respectively. At 20°C, high coliforms and fecal streptococci counts were found in some samples and high *Staphylococcus aureus* counts in 2 samples. The microbiological quality of smoked herrings was better than that of charred herrings both after processing and during storage. Bacterial numbers of smoked herrings prepared in a modern steel oven were lower than those of herrings prepared in a traditional tiled oven. The mean APC of charred herrings was, however, higher when the modern continuous-operating line was used compared to the traditional method. On the continuous-operating line, heavy bacterial contamination occurred during the salting stage. The salting procedure was therefore changed by cooling the brine. When chilled brine was used, the mean APC of charred herrings was lower than the corresponding mean for the traditional method.

Smoked and charred Baltic herrings are common items in the Finnish diet. They are frequently eaten with no further heating. The herring are often sold in such places as open-air markets, where temperature abuses are possible. In an earlier report *(3)*, herrings sold at retail markets showed high numbers of bacteria. Smoked and charred herrings have also been reported to be a common cause of staphylococcal food poisoning outbreaks *(2)*.

The pH of smoked and charred herrings is 6.5-6.6 and their water activity 0.95-0.97 *(3)*. According to Finnish public health legislation, foods with a pH over 4.5 and a water activity over 0.88 are classified as highly perishable *(8)*. These foods have to be stored under refrigeration or frozen if they are sold in a food establishment, and if they are ready-packed for retail sale they must also carry a label indicating the sell-by date and giving storage instructions. Most smoked and charred Baltic herrings, however, are sold outdoors, in market-places, where the refrigeration rules do not apply.

The investigation and control of the microbiological quality of smoked and charred herrings has received considerable attention in Finland. The purpose of this study was to assess the microbiological quality of smoked and charred Baltic herrings after processing and after storage for 24, 48 and 96 h at 4 and 20°C. The effect of traditional and modern processing methods on the microbiological quality of the fish was also evaluated.

MATERIALS AND METHODS

Samples

Seventy smoked and 70 charred Baltic herring samples were collected from two different processing plants on 5 different days. Seven smoked or charred fish samples were taken from each plant on each day and studied microbiologically immediately and after storage for 24, 48 and 96 h at 4 and at 20°C.

A traditional tiled oven was used for smoking the fish in plant A and a modern steel oven, with temperature control, in plant B. For the charring, a traditional method with dry salting was used in plant A and a conveyor belt system in which the fishes were immersed in saturated brine in plant B.

The bacterial numbers of charred fish samples from plant B, with the modern, continuous-operating line, were investigated at different stages of processing: the raw material (raw fish before processing), charring, salting and packing. Nine samples were taken at each stage and the same procedure was repeated after changing the continuous-operating line. The change was the cooling of the brine, from 35-40 to 0°C. In addition, bacterial numbers of the brine were examined at each analysis time. In this part of the study a total of 90 samples was analyzed.

Microbial methods

Each of the herring samples consisted of three fish. The samples were transported to the laboratory rapidly (within 1 h) and under refrigeration. The heads, dorsal bones and tail fins of the fish of each sample were removed, after which the fishes were ground together. Ten g of crushed fish was homogenized with 90 ml of 0.1% (w/v) peptone water. The homogenates and serial 10-

[1]*College of Veterinary Medicine*
[2]*National Board of Health*

fold dilutions in 0.1% peptone water were used for microbial analyses.

The aerobic plate count (APC) and coliforms were determined by the methods of the International Commission on Microbiological Specifications for Foods *(4)* using Plate Count agar (Difco) and Violet Red Bile agar (Difco), respectively. Fecal streptococci were enumerated by the method of the Nordic Committee on Food Analysis *(9)* using Slanetz-Bartley agar (Orion Diagnostica, Espoo, Finland) and *Staphylococcus aureus* by the method of Baird-Parker *(1)* on Baird-Parker agar (Difco).

Statistical analysis

Student's t-test was computed by the Survo 76 statistical system *(7)*.

RESULTS

Microbiological findings for smoked Baltic herrings stored at 4 and 20°C are presented in Table 1. During storage at 4°C no statistically significant increase in APCs was observed ($P>0.05$). At 20°C the mean APC was higher after 24 h than after processing ($P<0.01$), and increased markedly for later analysis times. At 48 h the APC values exceeded 10^7 colony forming units (CFU)/g in 2 samples of 10 and at 96 h in 9 samples of 10. Coliforms and especially fecal streptococci were detected in high counts in some samples at 20°C but not at 4°C. *S. aureus* cells were found in 2 samples at 20°C. The values were 1.0×10^2 and 6.0×10^6.

The microbiological changes taking place in charred Baltic herrings at 4 and 20°C are shown in Table 2. At 4°C the mean APC increased markedly ($P<0.05$) after a storage period of 48 h, and after 96 h was at the 10^4 CFU/g level. At 20°C, bacterial numbers increased sharply. After 24 h the increase was statistically significant ($P<0.001$), and after 96 h the mean APC exceeded 10^9 CFU/g. APCs exceeded 10^7 CFU/g in 8 of 10 samples at 48 h and in all samples at 96 h. High coliform and fecal streptococci counts were found after storage at 20°C. *S. aureus* cells were observed in 2 samples, with values of 1.0×10^2 and 3.6×10^5. The mean APC after processing was lower in smoked than in charred herrings ($P<0.001$). During the storage period studied, all means of APCs for charred herrings were significantly greater than for smoked ones ($P<0.01$ or $P<0.001$). The numbers of coliforms and fecal streptococci after storage at 20°C were also higher in charred herrings compared to smoked ones.

Table 3 shows the APC values for smoked and charred Baltic herrings after processing in two different plants. The bacterial numbers of smoked herrings prepared in a modern steel oven (processing plant B) were lower than for those prepared in a traditional tiled oven (plant A). The difference was statistically significant ($P<0.001$). The mean APC of charred herrings was, however, higher in plant B, with a conveyor belt, than in plant A, using the traditional method ($P<0.01$).

The bacterial numbers of herrings at different processing stages of the continuous-operating charring line are presented in Table 4. After charring an average decrease of 10,000-fold was observed in APC values. During the salting stage contamination occurred, and the bacterial numbers were higher after the salting stage than before ($P<0.01$). After packing there was a further increase in bacterial numbers. Due to the harmful microbiological consequences of the salting stage, the salting procedure was changed by cooling the brine. No differences were observed between APC values after charring, salting and packing when chilled brine was used ($P>0.05$). The mean APC of the herrings after salting and packing was greater when the brine was not cooled than with chilled brine ($P<0.001$). The mean bacterial count

TABLE 1. *Mean bacterial counts (log_{10} CFU/g) and range in smoked Baltic herring after processing and after storage at 4 and 20°C.*

Storage temperature	Storage period (h)	Number of analyses	Aerobic plate count	Coliforms	Fecal streptococci	*Staphylococcus aureus*
After processing	1	10	1.41 (ND[a]-2.65)	ND (ND)	ND (ND)	ND (ND)
4°C	24	10	1.76 (ND-2.69)	ND (ND)	ND (ND)	ND (ND)
	48	10	1.87 (ND-2.78)	ND (ND)	ND (ND)	ND (ND)
	96	10	2.23 (ND-3.97)	0.92 (ND-2.87)	ND (ND)	ND (ND)
20°C	24	10	2.94 (ND-5.80)	0.93 (ND-2.99)	2.05 (ND-5.19)	ND (ND-2.00)
	48	10	5.65 (2.00-7.94)	0.87 (ND-2.40)	3.07 (ND-6.45)	ND (ND)
	96	10	8.01 (5.34-9.30)	1.75 (ND-5.23)	3.33 (ND-7.09)	2.21 (ND-6.78)

[a]ND=Not detected; assigned 0.5 x detection limit for calculation of mean.

TABLE 2. *Mean bacterial counts (log_{10} CFU/g) and range in charred Baltic herring after processing and after storage at 4 and 20°C.*

Storage temperature	Storage period (h)	Number of analyses	Aerobic plate count	Coliforms	Fecal streptococci	*Staphylococcus aureus*
After processing	1	10	2.75 (1.85-3.35)	ND[a] (ND)	ND (ND)	ND (ND)
4°C	24	10	2.97 (1.78-4.53)	0.83 (ND-2.04)	ND (ND)	ND (ND)
	48	10	3.53 (2.63-4.90)	0.85 (ND-2.20)	ND (ND-2.30)	ND (ND)
	96	10	4.93 (ND-6.03)	2.11 (ND-4.48)	ND (ND-2.30)	ND (ND-2.00)
20°C	24	10	5.66 (4.35-6.85)	2.27 (ND-5.05)	3.43 (ND-4.66)	ND (ND)
	48	10	7.94 (5.70-8.90)	4.11 (ND-7.45)	5.97 (4.34-6.72)	2.09 (ND-5.56)
	96	10	9.23 (8.70-9.78)	6.15 (ND-9.15)	5.33 (2.95-7.16)	ND (ND)

[a]ND=Not detected; assigned 0.5 x detection limit for calculation of mean.

TABLE 3. *Mean aerobic plate counts (log_{10} CFU/g) and standard deviation in smoked and charred Baltic herrings of processing plants A and B within 1 h of processing.*

Processing method	Processing plant	Number of analyses	Aerobic plate count
Smoking	A	5	2.13±0.46
	B	5	0.70±0.00***
Charring	A	5	2.38±0.39
	B	5	3.12±0.15**

***P<0.001 for means between smoked fish of plant A and B.
**P<0.01 for means between charred fish of plant A and B.

(log_{10} CFU/ml) and standard deviation of the brine was 3.28 ± 0.34 before and 2.38 ± 0.75 after cooling. The difference was statistically significant (P<0.01).

When chilled brine was used in the continuous-operating charring line (plant B), the mean APC of the charred herrings was 59 CFU/g. The mean was now lower than the corresponding mean in plant A (240 CFU/g), but the difference was not statistically significant (P>0.05).

DISCUSSION

The microbiological quality of smoked Baltic herrings was better than that of charred herrings. The difference in bacteriological quality was already seen after processing, and during storage the charred herrings deteriorated more quickly than the smoked ones.

During the whole storage period at 4°C no charred or smoked herring sample exceeded the APC level of 10^7 CFU/g. The International Commission on Microbiological Specifications for Foods has issued microbiological criteria for cold smoked fish *(5)*; the APC limit for unacceptable (M) was 10^7 CFU/g. If we apply this limit to smoked and charred herrings, the microbiological quality of both types of product was satisfactory during a storage period of 96 h at 4°C. At 20°C, spoilage was quick. The mean log APC of smoked herrings was 5.65 at 48 h and counts over 10^7 CFU/g were found in 2 of 10 samples. At 96 h the mean log APC was 8.01 and the counts of 9 of 10 samples exceeded 10^7 CFU/g. Microbiological spoilage was quicker in charred herrings than in smoked ones; at 48 h the mean log APC was already 7.94 and the counts of 8 samples out of 10 exceeded 10^7 CFU/g.

A previous study *(3)* described the poorer microbiological quality of charred herrings compared to smoked ones at the retail market. The reason for this poorer quality is the processing method. During charring the skin of the fish is burnt and broken, which apparently increases the possibilities of bacterial contamination. Careful handling of the fish especially after charring is therefore needed.

The microbiological quality of smoked and charred herrings was affected by the processing method. The quality of smoked herrings processed in a modern steel oven was better than that of herrings smoked in a traditional tiled oven. The traditional tiled oven lacks a constant thermometer; temperature control during the smoking process is thus difficult, and temperatures in this study varied between 55-90°C. The steel oven was equipped with a thermometer and a hygrometer; the control of smoking temperature was thus better and the

TABLE 4. *Mean aerobic plate counts (log_{10} CFU/g) and standard deviation of charred Baltic herring at different processing stages in plant B without and with cooling of brine.*

Processing stage	Number of analyses	Without cooling of brine	With cooling of brine
Raw herring	9	5.35±0.66	5.65±0.50
After charring	9	1.52±1.00	1.47±0.69
After salting	9	2.91±0.54	1.62±0.81***
After packing	9	3.48±0.69	1.77±0.69***

***P<0.001 for means in rows within temperatures of brine.

temperature was more evenly distributed due to air circulation. The temperature varied during drying between 30-60°C and during smoking between 70-80°C. The quality of charred herrings prepared by the modern continuous-operating charring system was poorer compared to herrings charred by the traditional method. This was unexpected, as the contamination level was expected to be lower on the modern line due to the lesser need for handling of the fish. However, the charred fish warmed up the unrefrigerated brine. The temperature of the brine during processing was 35-40°C. The bacterial numbers of the warm brine increased, and the warm brine also delayed cooling of the herring, increasing the possibilities of bacterial multiplication on the fish. Cooling of the brine reduced the microbial load in the brine markedly. This also reduced the level of contamination in the charred herrings; after this change, the number of bacteria in herrings processed on the modern line was less than in charred herrings prepared by the traditional method.

Two high *S. aureus* counts were observed at 20°C. In the event of temperature-abuse during storage and sale, staphylococci may multiply and produce an enterotoxin presenting a risk to human health.

Smoked and charred herring are reported to be important vehicles of staphylococcal food poisoning in Finland *(2)*. It is known that staphylococci are unable to compete with normal foodborne bacteria in foods *(10,11,12)*. Heating of fish during processing destroys competing microorganisms, and after heating fish are a good medium for staphylococcal growth. Therefore, the handling of processed fishes has to be carried out with extraordinary care. Staphylococci contaminate fish after primary processing, and in virtually all instances the cause of contamination is human handling *(6)*. Because the processing of fish occurs in small plants and sale of fish occurs under conditions without good chilling possibilities, faults during handling and storage are possible and a risk of staphylococcal food poisoning exists. The present study gives further indication to the health authorities of the need to strengthen the regulations and supervision of retail sale of smoked and charred fish at market-places.

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