Modified Atmosphere Storage of Chum Salmon (*Oncorhynchus keta*) Fillets

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The effects of elevated CO₂ levels in modified atmospheres on the preservation quality of chum salmon fillets were investigated. The fillets of chum salmon (*Oncorhynchus keta*) were held in the modified atmospheres (30% CO₂ : 70% N₂, 50% CO₂ : 50% N₂, 70% CO₂ : 30% N₂) and 100% CO₂, and stored at 5°C and 10°C up to 6 days. Controls were stored similarly in air.

After 2 to 6 days of storage at both temperatures, the bacterial counts were lower in chum salmon stored in the CO₂-enriched atmospheres compared to samples stored in air. The CO₂ levels of more than 50% at 5°C and 70% at 10°C showed the effective inhibition of microbial growth, respectively. Moreover, a modified at-

mosphere containing 70% CO₂ was more effective than 100% CO₂ on the inhibition of microbial growth of chum salmon fillets in this study.

Chum salmon (*Oncorhynchus keta*) is a representative table fish in Japan. The fishery products of chum salmon have gradually increased. Recently, the consumption of chum salmon fillets have rapidly increased in retail stores, while that of the round or semi-dressed chum salmon has gradually decreased. Therefore, the extension of the shelf life of chum salmon fillets will become an important subject in the Japanese fishery industry.

There have been reviews¹⁾²⁾ and some reports^{3)~10)} describing the modified atmosphere (MA) storage of fishery products. These reports have shown that high levels of carbon dioxide (CO₂) would inhibit microbial growth and make possible prolonged storage time of fish held in such atmospheres.

The purpose of this study was to determine the optimal CO₂ levels in MA on the preservation quality of chum salmon fillets.

Table 1 Changes in the concentration of headspace gases in the bags

Composition of atmosphere		Storage time (days) at 5°C				
		0	1	2	3	6
Air	CO ₂ (%)	—	0.9±0.1	1.3±0.2	2.3±1.0	11.6±1.6
	O ₂ (%)	21.2±0.2	20.5±0.1	20.3±0.1	19.8±0.5	13.7±0.6
	N ₂ (%)	78.8±0.2	78.5±0.0	78.4±0.1	77.9±0.5	74.6±0.9
100%CO ₂	CO ₂ (%)	94.2±2.5	85.4±0.5	80.0±2.8	80.3±1.6	78.4±7.1
	O ₂ (%)	1.4±0.5	4.3±0.2	4.9±0.4	4.3±0.3	3.2±1.2
	N ₂ (%)	4.4±1.9	10.3±0.7	15.1±2.4	15.3±1.4	18.4±5.9
70%CO ₂ /30%N ₂	CO ₂ (%)	66.6±0.3	61.0±3.1	62.6±0.8	61.6±0.5	56.5±6.3
	O ₂ (%)	1.2±0.2	2.6±0.6	2.0±0.1	2.0±0.1	5.4±3.5
	N ₂ (%)	32.2±0.2	36.4±2.5	35.4±0.8	36.4±0.5	38.1±3.2
50%CO ₂ /50%N ₂	CO ₂ (%)	50.7±2.9	44.0±1.8	45.6±0.7	45.8±0.7	38.5±3.0
	O ₂ (%)	1.1±0.4	2.2±0.5	2.0±0.0	1.9±0.1	2.8±0.9
	N ₂ (%)	48.3±2.5	53.8±1.4	52.4±0.7	52.2±0.8	58.7±2.1
30%CO ₂ /70%N ₂	CO ₂ (%)	25.7±0.5	23.9±0.7	23.8±0.5	20.2±4.1	25.9±1.1
	O ₂ (%)	1.9±0.2	3.1±0.1	2.9±0.2	5.3±3.1	2.2±0.3
	N ₂ (%)	72.4±0.3	73.0±0.8	73.3±0.4	74.6±1.0	71.9±1.0

The data are presented as the mean±standard deviation of three sample bags.

Materials and Methods

Materials

The chum salmon (*Oncorhynchus keta*) which were caught in the east coast of Hokkaido in 1994 were transported on ice to our laboratory. They were processed as fillets with the skin on, and then the fresh fillets were used for experiments within 2 days after catching.

The three fillets, weighing ca. 100 g each, were placed in sterilized plastic trays, which were then packed in gas-impenetrable EVAL EF-XL film (COWPACK Co., Aichi, Japan). The O_2 permeability of this film was 1 ml/m^2 in 24 hr at 20°C at 1 atm and 65% relative humidity. A vacuum was activated on each tray individually and the MAs (air, CO_2 100%, CO_2 70%/N₂ 30%, CO_2 50%/N₂ 50%, CO_2 30%/N₂ 70%) were introduced using an auto vacuum packer FVC II-G (Furukawa Seisakusho, Tokyo). The bags were stored at 5°C and 10°C , and three sample bags from each of the five packaging treatments were taken after 0, 1, 2, 3 and 6 days of storage at both temperatures. All data for gas composition and bacterial

count represented the means of three bags in this study.

Gas analysis

Before microbiological sampling the gas composition in each bag was measured by Shimadzu GC-15A gas chromatography (GLC) with a thermoconductivity detector (TCD) under the following conditions: column, WG-100 stainless steel column ($0.25 \text{ in.} \times 1.8 \text{ m}$) (GL Science Inc., Japan); column temperature, 50°C ; detector temperature, 70°C ; injection temperature, 90°C ; carrier gas, helium, at a flow rate of 30 ml/min ; TCD current, 120 mA. Twenty microliters of headspace gas in each bag was subjected to GLC with a gas-tight syringe.

Bacterial count

A core sample of approximately 10 g was obtained from the flesh side of each of the fillets with sterilized scissors. After homogenization for 1 min in 90 ml of sterile 0.9% NaCl, the appropriate serial dilutions (all in sterile 0.9% NaCl) were pour-plated in duplicate in Standard Methods Agar (Nissui, Tokyo, Japan). The plates were incubated at 35°C for

of chum salmon fillets during storage at 5°C and 10°C

Storage time (days) at 10°C				
0	1	2	3	6
0.3 ± 0.2	1.2 ± 0.2	3.4 ± 1.1	8.5 ± 1.3	21.4 ± 1.0
20.9 ± 0.1	20.3 ± 0.1	19.0 ± 0.5	14.6 ± 0.9	1.9 ± 1.0
78.9 ± 0.2	78.5 ± 0.1	77.6 ± 0.6	76.9 ± 0.4	76.7 ± 0.5
93.4 ± 2.4	88.6 ± 1.2	81.2 ± 6.3	80.0 ± 4.1	84.6 ± 2.4
1.7 ± 0.6	3.3 ± 0.4	4.2 ± 1.2	3.4 ± 0.9	1.3 ± 0.9
4.8 ± 1.7	8.1 ± 0.8	14.6 ± 5.1	16.6 ± 3.4	14.0 ± 5.9
70.3 ± 2.8	61.1 ± 1.1	60.7 ± 2.4	61.8 ± 2.1	17.2 ± 4.4
1.2 ± 0.3	2.4 ± 0.1	2.5 ± 0.5	1.3 ± 0.1	16.3 ± 0.2
28.5 ± 2.5	36.5 ± 1.0	36.7 ± 1.9	37.0 ± 2.2	66.4 ± 4.2
54.3 ± 6.8	43.7 ± 2.2	45.9 ± 1.2	46.6 ± 0.9	34.3 ± 5.9
0.7 ± 0.2	2.4 ± 0.4	2.1 ± 0.4	1.9 ± 0.3	6.5 ± 2.8
45.0 ± 6.6	53.9 ± 1.8	52.0 ± 0.9	51.5 ± 0.6	59.1 ± 3.4
26.4 ± 0.2	25.2 ± 1.4	24.9 ± 0.8	25.8 ± 0.7	30.7 ± 0.5
2.0 ± 0.1	3.2 ± 0.3	2.7 ± 0.1	2.3 ± 0.2	0.4 ± 0.1
71.6 ± 0.4	71.6 ± 1.1	72.5 ± 0.8	71.9 ± 0.8	68.9 ± 0.5

Fig. 1 Changes in the bacterial counts of chum salmon fillets stored in different atmosphere at 5°C

Symbols : ■, Air ; □, 30% CO₂/70% N₂ ; ◆, 50% CO₂/50% N₂ ; ◇, 70% CO₂/30% N₂ ; ▲, 100% CO₂

Fig. 2 Changes in the bacterial counts of chum salmon fillets stored in different atmosphere at 10°C

Symbols are the same as Fig. 1.

48 hr, and the plate counts were calculated and expressed on the basis of colony formation unit per g samples.

Results and Discussion

Table 1 shows the gas compositions in the headspace of sample bags containing chum salmon fillets stored in MAs. The CO₂ concentrations in the controls(100% air) gradually increased from 0 to 11.6% at 5°C and from 0.3 to 21.4% at 10°C by 6 days of storage as a result of microbial and postmortem metabolic activity. Initially, the headspace of the bags filled with MAs and 100% CO₂ contained small quantities of O₂ (0.7–2.0%). After 1 day of storage at both temperatures, the O₂ concentrations of the headspace increased up to 2.2–4.3% as a result of O₂ leaching from the foam tray and fillets into the package headspace. Thereafter, the O₂ concentrations of all bags almost unchanged. After 1 day of storage at both temperatures, dissolution of CO₂ into the fillets led to a reduction in CO₂ headspace concentration. Higher CO₂ concentration in MAs resulted in more decreases in CO₂ concentrations. The CO₂ concentration in the headspace decreased during early storage and then increased as the microbial activity increased. This similar trend was reported by several researchers^{11,12}.

The changes in the bacterial counts of chum salmon fillets stored in MAs are shown in Fig. 1 at 5°C and Fig. 2 at 10°C. The initial bacterial load of the chum salmon fillets in this study was 2.6×10^2 organisms per gram. During storage at 5°C, the bacterial counts of samples stored in air gradually increased with storage time and reached about 10^6 after 6 days of storage. A marked increase in the lag phase was evident for all samples packed in CO₂-enriched atmospheres. On day 2, some reductions in bacterial counts were observed in the CO₂-enriched atmosphere. Although bacterial counts of the samples stored in the 30% CO₂ rapidly increased after 2 days of storage, those of samples stored in MAs except for 30% CO₂ hardly increased and were maintained below 10^4 during 6 days of storage. If a bacterial count of 10^4 per gram is used as an

index of marginal quality for chum salmon fillet, the shelf-life of a sample held in MAs containing a CO₂ concentration higher than 50% would be extended 6 days or more. During storage at 10°C, the bacterial counts of samples stored in air rapidly increased, and the fillets became totally spoiled during 6 days of storage. The bacterial counts of samples stored in 30% and 50% CO₂ exceeded 10⁴ after 2 days of storage and increased to over 10⁶ after 6 days of storage. On the other hand, the bacterial counts during storage in 100% and 70% CO₂ were maintained at 4.5×10^5 organisms per gram or below throughout the entire storage time. Inhibition of bacterial growth was evident for all samples packed in MA containing CO₂.

It was observed in this study that the bacterial counts of samples stored in 70% CO₂ were a little lower than that in 100% CO₂ during the storage time after 2 days at both temperatures. Thus, it was possible that the MA containing 70% CO₂ was more effective than 100% CO₂ in the inhibition of bacterial growth. At present, the cause of this phenomenon is not known. Apparently further studies should be done on this aspect. Whatever the mechanisms are involved in the above phenomenon, from a practical point of view, it is known that the fillets stored in MAs containing higher CO₂ concentration had a bitterer taste and harder textures produced by the dissolution of CO₂ into fillets^{13,14}. Therefore, it was proposed in this study that 70% CO₂ concentration in a MA was suitable for packaging for extension of the shelf life of chum salmon fillets.

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シロサケ (*Oncorhynchus keta*) 切り身の MA 包装

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シロサケ切り身の MA 包装による品質保持に対する炭酸ガス濃度の影響を検討した。シロサケ切り身を炭酸ガス濃度の異なる混合ガスで置換包装して 5°C と 10°C で 6 日間保蔵し、それぞれ経時的にガス組成および一般生菌数を調べた。

含気包装と比較すると 6 日間の保蔵では 2 日目以降試験したどの MA 包装でもシロサケ切り身の一般生菌数は少なく、5°C では 50%、10°C では 70% 以上の炭酸ガス濃度で効果的に菌の増殖を抑制した。さらに今回の試験では炭酸ガス濃度 100% よりも 70% の方がシロサケ切り身の菌の増殖抑制に効果的であった。