Establishment of F_0-value Criterion for Canned Tuna in Cottonseed Oil

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F_0-values of the canned tuna in cottonseed oil (CTCO) were investigated under different sterilizing conditions to optimize the energy consumption and microbiological safety. The F_0-values were measured using a microcomputer based technique. The exact cold point was not the volumetric center of the cans, and it was located in the center of meat mass in can which had *ca.* 6% of head space. Location of the test cans in retort showed no remarkable influence on the F_0-values when the cans were jumble loaded. The process time before sterilization should be shortened as much as possible to prevent the contamination of microorganisms. Thermophilic spore forming bacteria found from raw and precooked tuna were *Bacillus subtilis, Bacillus cereus* and *Bacillus pasteurii*, and the most heat resistant was *Bacillus subtilis*. The rational F_0-value for the CTCO obtained from the preservation test was regarded as 6*min*.

Introduction

It is well known that the main purpose of thermal sterilization in the food industry is to inactivate the microorganisms and enzymes contained in food. But the thermal sterilization is one of the most energy consuming process in food industry (Singh, 1977; Barreiro *et al.*, 1984; Lappo and Povey, 1986). Moreover some chemical reactions can take place during the thermal process and they can lead to quite different qualities of foods (Teixeria *et al.*, 1969; Saguy and Karel, 1979; Heiss and Eichenr, 1984).

The criterion of microbiological safety of thermally sterilized foods is F_0-value (Stumbo, 1973; Leniger and Beverloo, 1975). It is the equivalent, in minutes at 121.1℃, of all lethal heat in a process with respect to the destruction of a microorganisms characterized by a z-value of 10℃. Thus, the sterilizing process should be optimized in the consideration of the relation among the F_0-value, degree of energy consumption, nutritive value and sensory qualities.

To reach some parts of this goal, we deviced a microcomputer based automatic sterilizing and F_0-value measuring system. The accuracy of the system was also verified (An *et al.*, 1992; Cho *et al.*, 1992). On the other hand, CTCO is one of the most frequently consumed canned seafood in Korea. But very few studies dealing with the sterilizing condition for the CTCO to optimize the relation among the energy consumption, microbiological safety and other quality factors of the final product have been published. Thus, the price and quality of the CTCO are not yet optimized.

The purpose of this paper is to suggest an appropriate F_0-value for commercial sterilization of the CTCO. The F_0-values of the CTCO obtained under different sterilizing conditions, *i.e.* under different time-temperature profiles, were measured, and the microbiological safety of the CTCO was evaluated.

Materials and methods

Test product: The CTCO was prepared in Gosung Mulsan Co., a canning factory in Gosung, Kyeong-Nam, Korea. The frozen skipjack (*Katsuwonus pelamis*, 2~3*kg*) was thawed in a tank of running water for 4 hours, head and viscera were removed and then precooked at 90℃ for 65 *min*. The white muscle was then cleaned by removal of skin, bones and dark muscle.

After precooking, the meats were held at 2℃ overnight so that the meat would cool and firm up enough to handle. The precooked tuna chunks (133 ± 2*g*) were vacuum sealed in a cylindrical can(211 *mm* x 109 *mm*) by the same method as in the canning industry with cottonseed oil (36 ± 2*g*) and vegetable sauce (23 ± 2*g*), and then stored at -40℃ until investigating.

The refrigerated cans were thawed in a temperature controlled water tank for approximately 4 hours to guarantee the homogeneity of meat temperature and then thermally sterilized under different conditions of time and temperature. Processed cans were cooled in a tank of cold water for later experiments.

F_0-value measurement: The F_0-values were measured in a vertical still-retort equipped with automatic F_0-value measuring system (An *et al.*, 1992; Cho *et al.*, 1992) under different sterilizing conditions. The lethal rates were measured using following equation in every 0.2*sec*, and the integrated lethal rates during the whole process was regarded as F_0-value (Cho *et al.*, 1992),

$$F_0 = m\, D_{121.1} = \sum_{0}^{t} L\, \Delta t$$

where m, $D_{121.1}$, L and Δt are sterilizing value, D-value at 121.1℃, lethal rate and thermal treatment time, respectively.

Analytical procedures: The contents of moisture, crude protein (N x 6.25), crude lipid and crude ash were determined by the standard procedures of A.O.A.C.(1982). The other component was regarded as carbohydrate. Contents of volatile basic nitrogen (VBN) and amino-nitrogen (NH_2-N) were determined by the methods of Miwa and Iida (1973) and Spies and Chamber (1951), respectively.

Microbiological experiments: Counting, isolation and identification of viable cell were carried out by the method of A.P.H.A.(1970), Gibbs and Skinner (1966), Harrigan and MaCnee (1976), Collins and Lyne (1976) and Bergey's Manual of Systematic Bacteriology (Kreig and Holt, 1984). The heat resistance of bacterial spores was measured by TDT-tube method (Stumbo, 1973; Cho, 1993).

Results and discussion

Cold point and location of test cans in a retort: In general, all of the canned products have 4~6% of head space to the total volume. The CTCO had also *ca.* 6% of head space and contained tuna meat, vegetable sauce and cottonseed oil. In this case, the temperature at the cold point of the CTCO could rise by the conductive and convective heat transfer (Hallstroem and Skjeoldbrand, 1988), and as the consequence the cold point could also be altered. Thus, it is necessary to fix the correct cold point for the exact measurement of the F_0-value in commercial sterilization, since the value should be obtained under the worst conditons for the microbiological safety.

Table 1 showed the influence of temperature sensing point in the test can on the F_0-value. The exact cold point was not the geometric center of the test can *i.e.* volumetric center, but the geometric center of the filled tuna meat *i.e.* the mass average center.

Since the location in the retort and loading method of the test can might also affect on the F_0-value, the top and bottom-side of the test can was bundled with another 2 cans and then loaded at

Table 1. Temperature sensing point and the F_0-values of the CTCO sterilized at 110℃ (Unit: *min*)

Total processing time	Come up time	Sterilizing time	F_0-value
108	19.6	73.4	VC: 12.56 MC: 10.99
115	20.4	79.6	VC: 13.19 MC: 12.87

V C: At the geometric center of the test can
MC: At the mass average center of the filled tuna meat

Table 2. F_0-values of the CTCO located in various point in the retort (Unit: *min*)

Total processing time	Come up time	Sterilizing time	F_0-value
103	18.5	69.5	UR: 10.58 MR: 10.94 LR: 11.01
103	14.4	73.6	UR: 11.32 MR: 11.67 LR: 11.58

*: Sterilized at 110℃,
UR: Upper part in the retort, MR: Middle part in the retort, LR: Lower part in the retort.

3 different locations in the retort. In this case, the effect of the conductive heat transfer through the both sides of the test can could be neglected. But as could be seen in Table 2, there was no remarkable difference in F_0-value between locations of jumble loaded cans in retort.

Those results could be explained as follows; After complete air exhaust, the saturated steam contacting on the test can surface might be condensed and then the condensed water flew down on the can surface. In this case, the thermal conductivity of the saturated water is greater than that of the saturated steam at same temperature and pressure (VDI-Waermeatlas, 1974). For this reason, the location of the cans in the retort showed no remarkable influence on the F_0-value.

Changes in proximate composition: Table 3 data show that the VBN contents and the viable cell counts of the CTCO were increased slightly during the pretreatment before the thermal sterilization. It means that the process time before the sterilization should be shortened as much as possible to prevent the contamination of microorganisms.

F_0-value: Changes in viable cell concentration in the CTCO during storage were shown in Table 4. No viable cell was found in the CTCO immediately after sterilization. But in the CTCO of F_0-value 1.44 *min*, the concentration of the viable cell increased with elapsing storage time. The concentration in the CTCO stored at 50℃ marked $10^5 \sim 10^6$ *counts/ml* after 30 days and more than 10 *counts/ml* after 60 days.

However specially northworthy is that the viable cell concentration 2 (*counts/ml*) in the CTCO with the F_0-value 5.18*min* stored 120 days at 50 ± 1℃, since thermophilic bacteria can grow well at this temperature. But in fact, little clear-cut evidence has been obtained to confirm that the number 2 might be from an experimental error. To prove this confusing result more clearly, the CTCO sterilized at 110℃ with more detailed F_0-values were stored at 50 ± 1℃. As could be seen in Table 5, through this repeating experiment the number of 2(*counts/ml*) in Table 4 was recognized as an experimental error.

The spore-forming bacteria isolated from the raw and precooked tuna meat were *Bacillus subtilis*

Table 3. Proximate composition, pH, contents of Volatile basic nitrogen (VBN), Amino nitrogen (NH_2-N) and number of viable cell of the raw and precooked tuna meat and canned CTCO before sterilization

components	Raw	Precooked*	CTCO
Moisture (%)	69.2	68.3	57.1
Crude protein (%)	24.5	25.5	23.1
Crude lipid (%)	3.0	2.9	16.3
Crude ash (%)	2.8	2.7	3.1
Carbohydrate (%)	0.5	0.6	0.4
pH	5.98	6.07	6.11
NH_2-N (*mg*/100*g*)	134	156	142
VBN (*mg*/100*g*)	13.56	15.46	16.28
Viable cell (*counts/ml*)	1.1×10^1	3.1×10^2	4.2×10^2

*: Precooked at 90℃ for 65*min*

(*B. subtilis*), *Bacillus cereus*(*B. cereus*) and *Bacillus paeteurii*(*B. pasteurii*). The most heat resistant spore among the 3 species was that of *B. subtilis*. The D-value of the spores of *B. subtilis* at 121.1℃ was 0.18*min* in phosphate buffer(0.1M,pH 7.0). But the CTCO contains *ca.* 57% of lipid, and it is well known that the lipid and oils show a protective effect on the heat resistance of bacterial spores (Karel *et al.*, 1975). Even though the high oil concentration, no microorganisms was detected in the products with F_0-values more over 5.18 *min*(Table 4 and 5).

Table 4. Changes in viable cell concentration during storage of the CTCO sterilized at 110℃ (Unit: *counts/ml*)

F_0-vale (*min*)	Storage temperature (℃)	Storage days				
		0	30	60	90	120
1.44	5	ND*	80	2.1×10^2	$>10^4$	$>10^6$
	25	ND	3.1×10^2	5.4×10^3	$>10^4$	$>10^6$
	50	ND	$>10^4$	$>10^6$	$>10^6$	$>10^6$
5.18	5	ND	ND	ND	ND	ND
	25	ND	ND	ND	ND	ND
	50	ND	ND	ND	ND	2
10.01	5	ND	ND	ND	ND	ND
	25	ND	ND	ND	ND	ND
	50	ND	ND	ND	ND	ND
15.43	5	ND	ND	ND	ND	ND
	25	ND	ND	ND	ND	ND
	50	ND	ND	ND	ND	ND
21.54	5	ND	ND	ND	ND	ND
	25	ND	ND	ND	ND	ND
	50	ND	ND	ND	ND	ND

* ND: Not detected

Table 5. Viable cell concentration in the CTCO stored at 50 ± 1℃ for 21 days after sterilization at 110℃ with various F_0-values

F_0-value (*min*)	Viable cell (*counts/ml*)	F_0-value (*min*)	Viable cell (*counts/ml*)
0	4.2×10^2	3.82	ND
0.09	3.1×10^2	4.52	ND
0.53	3.7×10^2	6.57	ND
1.11	44	8.54	ND
1.58	10	9.87	ND
1.80	ND*	10.25	ND
2.44	ND	15.43	ND
3.18	ND	20.27	ND

* ND: Not detected

In spite of the great importance of the F_0-value as a sterilizing criterion for the canned foods, the conventional sterilization process for the canned seafoods in Korea has been followed the cannery sterilizing criterion employed in Japan or in European countries. Thus, the practical F_0-values for the CTCO varies in the range of 10 to 12 *min*. But Heiss and Eichner(1984) pointed out that the reasonable F_0-value for canned tuna meat is in the range of 2.7~7.8 *min* in commercial sterilization.

Judging from this and the both results in Table 4 and 5, it was considered that the acceptable F_0-value for the CTCO in commercial sterilization was 6 *min*, and the nutritive and sensory quality of the products should be optimized on the basis of the sterilizing conditions equivalent to the F_0-value of *ca.* 6*min*.

Conclusion

To optimze the energy consumption and microbiological safety, F_0-values of the CTCO were investigated under differernt sterilizing conditions. The exact cold point was not the volumetric center of the test can which had ca. 6% of head space, but the mass average center of the filled tuna meat. Location of the test cans in the retort showed no remarkable influence on the F_0-values when the cans were jumble loaded. The processing time before sterilization should be shortened as much as possible to prevent the contamination of microorganisms. Spore forming bacteria found from the raw and precooked tuna were *B. subtilis, B. cereus* and *B,pasteurii,* and the most heat resistant among them was *B. subtilis.* Judging from the results of preservation test at elevated temperatures such as 5 ± 1, 25 ± 1 and 50 ± 1℃, it was considered that the acceptable optimal F_0-value for the CTCO is *ca.* 6*min*.

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Establishment of F_0-value Criterion for Canned Tuna in Cottonseed Oil

참치 기름담금 통조림의 F_0-값 설정에 관한 연구

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통조림 식품의 가열살균 공정은 에너지 소비와 제품의 미생물학적 안전성, 영양적 및 기호적 품질을 감안하여 최적화되어야 한다. 본 연구에서는 일차적으로 가열살균에 따른 에너지 소비와 제품의 미생물학적 안전성과의 관계를 최적화하고자 하였다. 참치 기름담금 통조림을 서로 다른 살균조건 즉, F_0-값을 달리하여 열처리하고, 마이크로 컴퓨터를 이용하여 자체 개발한 F_0-값 측정 씨스템을 사용하여 측정한 F_0-값과 미생물학적 안전성과의 관계를 조사하여 적정 F_0-값을 제시하였다.

참치 기름담금 통조림의 냉점은 시험대상 통조림의 기하학적 중심이 아니라 내용물의 무게 중심이었으며, 시험대상 통조림들을 레토르트에 무작위하게 넣는 경우에 레토르트 내의 통조림의 위치는 F0-값에 영향을 미치지 않았다. 또한 미생물에 의한 원료의 오염 방지를 위하여서는 가열살균 이전의 공정을 가능한 한 단축시켜야 함을 확인하였다.

원료 및 자숙한 참치에서 분리된 내열성 박테리아는 *B. subtilis, B. cereus* 및 *B. pasteurii*였고 이 중 내열성이 가장 큰 것은 *B. subtilis*였으나, F^0-값 6분 이상의 제품에서는 저장 중에도 미생물이 전혀 검출되지 않았으며, 상업적 살균에 의해 생산되는 참치 기름담금 통조림의 가열살균 기준으로는 F_0-값 6분이 적당한 것으로 판단되었다.