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Note

Prediction of the Shelf-life of Chilled Foods at Various Temperatures

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This study was designed to estimate the shelf-life of the popular chilled foods *kimbab* (rice rolled in dried laver), *samgak kimbab* (triangular rice rolled in dried laver), *eomook (*fish surimi, boiled fish paste) *mook* (acorn-starch jelly), and tofu (soybean curd) in large discount markets and convenience stores. Different types of chilled foods were stored at 5, 7, and 10 for 7 and 28 days, and changes in the total numbers of the aerobic bacteria were monitored. Values of 6 and 7 log cfu/g were used as the standard. Ready-to-eat foods stored at 5 showed a much longer shelf-life compared to storage at 10. The respective percentage increases in the shelf-life observed at both 7 and 5 were *kimbab* (70%, 171%), *samgak kimbab* (87%, 143%), soybean curd (46%, 95%), fish surimi (46%, 99%), and *mook* (45%, 87%). To reduce the microbiological contamination, storages at 7 and 5 are recommended for the increases of 45-88 and 87-171% in the shelf-life of these chilled foods.

Key words: *chilled food, large discount market, refrigerator, shelf-life, storage temperature*

Ease and convenience in the way of modern life is important for many people due to the development of processed foods and an increase in the social participation of the women. The market share of ready-to-eat-foods in the convenience stores and the wholesale marts has been rapidly increasing [Lee *et al*., 2001]. Statistics on the food-borne disease outbreaks in Korea show that the scale of outbreaks is increasing due to the growth in the market of the group food services. Ready-to-eat-foods, such as complex processed products and *kimbab*, are thought to be the principal causes of food-borne diseases in Korea. Critical information on the food products includes product name, raw materials, shelf-life, and storage method [Marks, 1984]. Of these, the storage method, such as storage temperature, is known to be the most important factor in maintaining the microbiological quality of the food products. The Korean law requires that chilled and frozen foods be maintained at temperatures below 10°C and minus 18°C, respectively [KFDA, 2008]. However, due to the current inappropriate management of the chilled and the frozen foods in the Korean food markets, quality loss, shortened shelf-life, and increased outbreaks of food-borne disease are still common occurrences. The temperatures of the refrigerators and the freezers in the food markets need to be strictly monitored. Studies of *Staphylococcus aureus* at various temperatures revealed that the growth of the bacteria in food stored at 10°C for 3 days was below the level of 4 cfu/mL, whereas storage at 20°C for 3 days resulted in a much more rapid growth, reaching 95,000,000 cfu/mL. Accordingly, a comparison study showed that management of the temperature is important for maintaining the microbiological quality of the stored food [KFDA, 2007]. The storage temperature and the shelf-life are also known to be crucial factors that affect the quality of the frozen and the chilled

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Abbreviations: cfu, colony-forming unit

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foods, along with processing, packaging conditions, and storage period [MHW, 1999]. The shelf-life of food product in Korea is determined by the "sell by" date based on condition of a constant storage. The shelf-life for each food is determined depending on the use of the food, the typical storage behaviors of the consumers, and the chemical, microbiological, and sensory quality characteristics of each food. Because each food quality factor is affected by temperature, humidity, and the presence of oxygen, differences in the shelf-life among the same products may be due to the freshness of the raw materials, the manufacturing process, and the hygiene of the manufacturing environment [Labuza, 1982; Kim *et al*., 1994; KFRI, 1998]. Accurate prediction of the shelf-life is important for both safety and efficient use of the resources. However, studies on the food product shelf life are still insufficient. The shelf-life should be estimated on the basis of the changes in the selected quality indicators grounded in a sound scientific theory [Koo *et al*., 2007]. The present study was designed to estimate the shelf-life of the popular chilled foods *kimbab, samgakkimbab,* fish surimi, *mook,* and soybean curd sold in large discount markets and convenience stores.

Material and Methods

Samples and storage conditions. The popular ready-to-eat foods *kimbab* (rice rolled in dried laver)*, samgak kimbab* (triangular rice rolled in dried laver)*, eomook* (fish surimi, boiled fish paste), *mook* (acorn-starch jelly), and tofu (soybean curd).

Kimbab (Lotte Freshdelica Co, Yong-in, Korea), *samgak kimbab* (Lotte Freshdelica), *eomook* (Sam Ho F&G Co, Seongnam, Korea), *mook* (Achim Deulnyuk, Seoul, Korea), and tofu (CJ Co, Seoul, Korea) were purchased from a convenience food mart in Anseong, Korea in November 2007. The samples were stored in an ice box and immediately transported to our lab. Upon arrival, *kimbab* and s*amgak kimbab* were stored at 5, 7, and 10°C for 7 days, and fish surimi, *mook*, and soybean curd were stored at the same temperatures for 28 days. Samples were regularly taken during storage for microbiological analysis.

Enumeration of total aerobic bacteria. Ten grams of each sample was diluted to a total volume of 90 mL with 0.1% peptone water in stomacher bags using a stomacher (Elmex SH-II M, Tokyo, Japan). Additional dilutions were prepared in sterile 0.1% peptone water. Appropriate dilutions were pour-plated on tryptic soy agar (Difco Laboratories, Detroit, MI), and incubated at 37°C for 24±1 h. All experiments were replicated three times. The colonies were counted. The results were expressed as cfu/g and converted to $\log_{10}$ cfu/g values.

Estimation of shelf-life. Changes in the microbiological quality during storage were analyzed to predict the shelf-life. Quality indicators for the prediction of the shelf-life for each product were determined by comparing the microbiological quality during the storage periods. Value of 6 or 7 log cfu/g was used as the standard for the microbiological safety [Egan *et al*., 1981; Brown *et al*., 1982]. The shelf-life was predicted based on a regression-equation using Y-values for total aerobic bacteria and X-values for the storage period.

Result and Discussion

Effect of storage conditions on total aerobic bacteria. Table 1 shows the results of the total aerobic bacteria found in the popular chilled foods, *kimbab*, *samgak kimbab*, fish surimi, *mook*, and soybean curd, at various storage temperatures and storage periods. As the storage temperature increased, the total number of microbes in all samples increased, and even products with a low initial number of microbes at the early stage increased to a high level following an extended storage period.

Total aerobic bacteria in *kimbab* were initially lower than 5 log cfu/g. However, this number increased rapidly after 12 h of storage, reaching 6 log cfu/g after just 1 day of storage at 10°C. In contrast, the same level was not reached until 3 and 4 days at 5 and 7°C, respectively. Koo *et al*. [2007] determined that the initial level of 2.9-4.43 log cfu/g of total aerobic bacteria in *kimbab* increased to 4.51-6.98 log cfu/g after 48 h storage at 10°C. These results showed that the quality of *kimbab* is dependent on the storage temperature.

Although the initial level of 3.25 log cfu/g of the total aerobic bacterial count in *samgak kimbab* increased to 7.92 log cfu/g after 6 days of storage at 10°C, the levels were 5.69 and 6.71 log cfu/g after 7 days of storage at 5 and 7°C, respectively. Park *et al*. [1996] reported that the levels of total aerobic bacteria in *samgak kimbab* in the food market refrigerators were in the range of 3.50-5.54 log cfu/g, and this level increased to 3.0×10^5cfu/g after 34 h storage at 10°C. They verified that the level of total aerobic bacteria in foods increases rapidly at the general retail refrigerator temperatures. Kim and Song [1996] reported that the level of total aerobic bacteria increased up to 100-fold after 48 h at room temperature.

Although the level of 1.70 log cfu/g for the initial total aerobic bacterial count in the fish surimi increased to 6.65 log cfu/g after 28 days of storage at 10°C, levels of 4.28 and 5.06 log cfu/g were attained after 28 days of storage at 5 and 7°C, respectively. Shin *et al*. [2007] reported that

Table 1. Effects of storage temperature on levels of total aerobic bacteria in *kimbab, samgak kimbab,* tofu, *eomook*, and *mook* (Unit: log cfu/g)

Items	Storage temp. (°C)	Storage period (day)												Regression equation	r^2
		0	0.5	1	2	3	4	5	6	7	14	21	28		
kimbab	5	4.50±0.05	4.51±0.06	4.95±0.04	5.34±0.20	5.76±0.20	6.29±0.14	6.47±0.09	6.69±0.12	6.95±0.05	-	-	-	Y=0.1850x+4.3592	0.9742
	7	4.58±0.03	4.64±0.13	5.68±0.03	5.94±0.14	6.12±0.13	6.73±0.06	7.45±0.23	7.77±0.14	-	-	-	-	Y=0.2632x+4.4345	0.9572
	10	4.59±0.10	4.91±0.10	5.71±0.12	6.63±0.17	7.56±0.03	8.22±0.18	-	-	-	-	-	-	Y=0.4705x+4.1530	0.9893
samgak kimbab	5	3.20±0.40	3.40±0.05	3.51±0.23	3.61±0.16	3.98±0.02	4.45±0.04	5.15±0.23	5.55±0.10	5.69±0.12	-	-	-	Y=0.1901x+2.8865	0.9682
	7	3.21±0.09	3.75±0.06	4.33±0.30	4.40±0.03	4.46±0.06	4.97±0.31	5.41±0.42	6.04±0.10	6.71±0.08	-	-	-	Y=0.2148x+3.2345	0.9489
	10	3.25±0.10	4.29±0.09	4.56±0.15	4.96±0.02	6.13±0.07	7.38±0.05	7.45±0.16	7.92±0.13	-	-	-	-	Y=0.3859x+3.2815	0.9582
eomook	5	1.70±0.00	-	-	-	1.70±0.00	-	-	-	2.09±0.13	2.65±0.07	3.45±0.16	4.28±0.14	Y=0.0948x+1.3963	0.9814
	7	1.70±0.00	-	-	-	1.85±0.21	-	-	-	2.54±0.19	3.65±0.17	4.25±0.20	5.06±0.16	Y=0.1244x+1.5361	0.9866
	10	1.70±0.00	-	-	-	2.00±0.00	-	-	-	2.78±0.05	4.17±0.30	5.69±0.21	6.65±0.15	Y=0.1859x+1.3844	0.9949
mook	5	1.70±0.00	-	-	-	1.92±0.17	-	-	-	2.29±0.16	3.22±0.18	4.12±0.14	4.79±0.09	Y=0.1148x+1.4984	0.9956
	7	1.70±0.00	-	-	-	2.24±0.19	-	-	-	3.14±0.14	4.42±0.02	4.87±0.18	5.44±0.16	Y=0.1351x+1.8563	0.9512
	10	1.70±0.00	-	-	-	2.76±0.13	-	-	-	3.55±0.01	5.45±0.12	6.14±0.04	7.06±0.11	Y=0.1859x+2.0201	0.9685
tofu	5	1.70±0.00	-	-	-	1.70±0.00	-	-	-	3.07±0.17	4.13±0.16	5.27±0.19	6.03±0.21	Y=0.1650x+1.4779	0.9769
	7	1.70±0.00	-	-	-	2.35±0.17	-	-	-	4.18±0.14	5.26±0.04	6.08±0.10	7.37±0.23	Y=0.1967x+1.9000	0.9575
	10	1.70±0.00	-	-	-	3.40±0.30	-	-	-	5.22±0.05	6.25±0.14	7.54±0.12	-	Y=0.2606x+2.2161	0.9226

Table 2. Estimated shelf-life of *kimbab, samgak kimbab,* tofu, *eomook*, and *mook* during refrigerated storage

(Unit: log cfu/g)

Food samples	Critical limit of shelf-life (log cfu/g)	Estimated shelf-life (days, % increased)		
		10°C	7°C	5°C
kimbab	6	1.45	2.47 (70%)	3.93 (171%)
	7	2.52	4.37 (73%)	6.63 (163%)
samgak kimbab	6	3.16	5.93 (87%)	7.68 (143%)
	7	4.59	8.26 (79%)	10.31 (124%)
tofu	6	13.52	19.84 (46%)	26.39 (95%)
	7	17.35	24.92 (43%)	32.45 (87%)
eomook	6	23.82	34.88 (46%)	47.56 (99%)
	7	29.20	42.92 (46%)	58.11 (99%)
mook	6	20.40	29.67 (45%)	38.21 (87%)
	7	25.78	37.07 (43%)	46.92 (82%)

the initial level of 3.80 log cfu/g of total aerobic bacteria in the fish surimi at 5°C increased to 6 log cfu/g after 9 days of storage. Furthermore, according to the study of Cho *et al.* [1998], the initial level of 2.02 log cfu/g of total aerobic bacteria in the fish surimi at 15°C increased to 6 log cfu/g after 8 days of storage. All of these results support the report of Chung *et al.* [1996] that storage at low temperature is important to the maintenance of the quality of chilled foods.

Although the initial level of 1.70 log cfu/g of the total aerobic bacterial count in the *mook* increased to 7.06 log cfu/g after 28 days of storage at 10°C, the levels increased to only 4.79 and 5.44 log cfu/g after 28 days of storage at 5 and 7°C, respectively. In the study of Kim and Ko [2005], the growth of total aerobic bacteria in the *mook* stored at 3, 10, and 25°C for 6 h showed higher increases at higher temperatures.

Despite the lower initial levels of total aerobic bacteria observed in the soybean curd than those in *kimbab* and *samgak kimbab*, the levels increased faster in soybean curd. Although the level of 1.70 log cfu/g of total aerobic bacteria in the *mook* increased to 7.54 log cfu/g after 21 days of storage at 10, the level increased to only 6.03 log cfu/g after 28 days of storage at 5°C. Lee *et al.* [1995] reported that the initial level of 10^3 cfu/g of total aerobic bacteria in the soybean curd increased to 1.2×10^7 cfu/g at 10°C after 4 days of storage. Youn [2003] also reported that the initial level of 1.20 log cfu/g of total aerobic bacteria in the soybean curd increased to 6 log cfu/g after 16 days of storage at 10°C. However, Kwon *et al.* [1999] reported that the number of coliforms in the soybean curd declined at a low temperature for a certain period of storage and proposed that the chilling helps to extend the storage life of the soybean curd.

Consequently, the levels of total aerobic bacteria in the popular chilled foods can increase rapidly at 10°C and reach 6 log cfu/g within a short time [Brown *et al*., 1982; Egan *et al*., 1981]. However, the growth of the aerobic bacteria can be significantly decreased at 5°C.

Estimation of shelf-life. In order to predict the shelf-life using a straight regression equation with the increase in the storage time as an effective quality indicator, a critical limit for an appropriate quality standard should first be established. The present study used the standard values of 6 and 7 log cfu/g that have been adopted as the international microbiological safety standards [Egan *et al*., 1981; Brown *et al*., 1982]. Shelf-life was predicted by using a regression-equation based on the Y-values for total aerobic bacteria and X-values for the storage period. Table 2 shows the predicted shelf-life when the number of microorganisms reached 6 and 7 log cfu/g [Brown *et al*., 1982; Egan *et al*., 1981] at 5, 7, and 10°C. Storage at either 5 or 7°C greatly extended the shelf-life of the chilled foods.

For *kimbab*, although the initial level of 4.5 log cfu/g of total aerobic bacteria increased to 6 log cfu/g at 10 after 2 days, storage at 7 and 5°C extended the time required to reach this level to 3 and 5 days, respectively. The shelf-life of the chilled foods stored at 7 and 5°C was extended by 70 and 171%, respectively, compared to the storage at 10°C.

For *samgak kimbab*, although the initial level of 3.23 log cfu/g of total aerobic bacteria increased to 6 log cfu/g at 10°C after 4 days, storage at 7 and 5°C extended the time required to reach this level to 6 and 8 days, respectively. For fish surimi, the initial level of 1.71 log cfu/g of total aerobic bacteria increased to 6 log cfu/g at 10°C after 24 days of storage. Storage at 7°C and 5 extended the time required to reach this level to 35°C and 48 days, respectively. For *mook*, the initial level of 1.71 log cfu/g of total aerobic bacteria increased to 6 log cfu/g at 10°C after 21 days. Storage at 7 and 5°C extended the time required to reach this level to 30 and 39 days, respectively. For soybean curd, the initial level of 1.71 log cfu/g of total aerobic bacteria increased to 6 log cfu/g at 10°C after 14 days storage. Storage at 7 and 5°C extended the time required to reach this level to 20 and 27 days, respectively. The percentage increases in the shelf-life observed at 7 and 5°C were as follows: *kimbab* (70%, 171%), *samgak kimbab* (87%, 143%), tofu (46%, 95%), eomook (46%, 99%), and *mook* (45%, 87%).

Consequently, to reduce the microbiological contamination in the chilled foods, storages at 7 and 5°C are recommended to attain the increases of 45-87 and 87-171% in the shelf-life.

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