The Korean Journal of Culinary Research
Vol. 20, No. 6, pp. 254～261 (2014)

Determination of Optimum Sterilization Condition for the Production of Retorted *Kimchi* Soup

Hee Soon Cheon[1] · Eun-Ji Park[2] · Won-Il Cho[3] · Keum Taek Hwang[1] · Myong-Soo Chung[2] · Jun-Bong Choi[¶]

Dept. of Food and Nutrition, Seoul National University[1)]
Dept. of Food Science and Engineering, Ewha Womans University[2)]
CJ Foods R&D, CJCheiljedang Corporation[3)]
Graduate School of Hotel and Tourism, The University of Suwon[¶]

레토르트 처리한 김치찌개 제품의 최적 살균조건 결정

천희순[1)] · 박은지[2)] · 조원일[3)] · 황금택[1)] · 정명수[2)] · 최준봉[¶]
서울대학교 식품영양학과[1)], 이화여자대학교 식품공학과[2)],
CJ제일제당(주) 식품연구소[3)], 수원대학교 호텔관광대학원[¶]

Abstract

In order to optimize process conditions for manufacturing retorted *Kimchi* soup by using stationary and rotary types systems were applied for sterilization process. For investigating the differences in heat penetration characteristics during sterilization, *Kimchi* soup was packed into retort pouches, and sterility (F_0 value) at various positions in the product was measured through a wireless F_0 sensor. Heat penetration characteristics were significantly affected by sterilization method. From data analysis, optimum ranges of sterilization temperature and time was determined to be 120.7℃, 13 min for rotary type and 120.7℃, 20 min for stationary type. At those conditions, they had similar sterility (F_0 value). The results showed that rotation provides faster heat penetration and more uniform sterility than various positions of the product. These results derived a lot of advantages from related industry. For instance, many of the more viscous semi-liquid products and heat sensitive natural products could be sterilized in the lager pouch sizes without overcooking or scorching. Hence, current study suggests that rotary type retort would make it possible not only to reduce processing times as 35～45%, but also to improve the quality of product as overall taste, flavor, color, and texture with significant difference (p< 0.05).

Key words: retorted *Kimchi* soup, stationary type, rotary type, sterilization, F_0 value

Ⅰ. Instruction

In commercial thermal sterilization of foods in cans or retort pouches, the container is heated in a pressurized steam or hot water retort at certain conditions of temperature and time. The aim of sterilization is to produce a product that is safe to consume. Although this process will make micro-

¶ : Jun-Bong Choi, +82-10-2521-3404, junbongchoi@hanmail.net, Graduate School of Hotel and Tourism, The University of Suwon, Hwaseong 445-743, South Korea

organisms and spores inactivate, it may also cause the destruction of essential nutrients, which lead to the deterioration of product quality (Cho YB 2008; Rha YA et al 2004; Teixeira AA & Tucker GS 1997).

Consumers demand products with high sensory and nutritional quality, therefore optimization of processing conditions is needed. Excessive heat treatment should be avoided because it is detrimental to food quality, waste energy and under utilizes plant capacity (Terajima Y 1975). Reduction in process time will have an advantageous effect on the sensory and nutritional qualities of thermally processed products. Rotary thermal processing was found to be more advantageous than stationary thermal processing, mainly for a high viscosity medium as it reduced sterilization time by approximately 50%. In stationary processes, semi-liquid products are usually heated by both convection and conduction and processes are necessarily long due to the slow rate of transfer of heat to the cold point of the contents. Movement of the contents along the walls of the containers is slow and overcooking or scorching of the product often occurs. In the larger container sizes this problem increases to the extent that many somewhat viscous semi-liquid products and some of the more heat sensitive vegetable products cannot be satisfactorily sterilized due to serious overcooking and occurring with undesirable color and flavor changes (Yim SK & Sohn KH 2004; Loey AV et al 1994). Rotation of the crate of the retort has a positive effect on the heat penetration in retort pouches during thermal processing (Ali AA et al 2006; Smout C et al 2001; Smout C et al 1998).

To develop a processed foods using *Kimchi* with merchantable quality, the investigation of optimum conditions on manufacturing process was important (Cho YB 2005; Sihn EH & Jung SJ 2003; Park WP et al 2000). In order to optimize process conditions for manufacturing retorted *Kimchi* soup with high sensory quality and storage stability, the objectives of this investigation were to compare the sterilization values obtained from heat penetration tests in a stationary and rotary retort with a retort pouched *Kimchi* soup.

Ⅱ. Materials and Methods

1. Sample Preparation

Experiments to compare heat penetration characteristics were carried out with retort pouched *Kimchi* soup (Kang HW 2013; Jung HO et al 2002). The cutting *Kimchi* and tofu, pork purchased from local supermarkets in Seoul, Korea. Tofu was sliced (2.5×2.5×1.0 cm) and pork was blanched in water at 100℃ for 1min and sliced (3.0×3.0×0.5 cm). *Kimchi* soup sauce was composed of anchovy paste, anchovy powder, chopped garlic and green onion, pork extract, pepper powder, rice powder, water and etc (Kim JH & Park GS 2014; Kim MJ & Kim GR 2006).

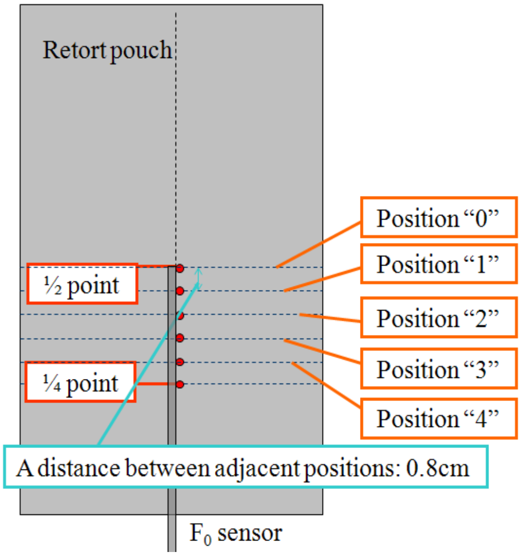
Retort pouches (16.0×24.8×2.0 cm) with a three-layer configuration, manufactured by Sam-A Aluminum, Korea, were used for this experiment. As the quality of the retort pouch was expected to have an important bearing on the shelf-life, its full properties were analyzed by bond strength and heat seal strength, bursting strength, tensile strength.

Wireless F_0 Sensor (Ellab TrackSense® Pro sensor, Denmark) was injected into the pouch through a hole in the bottom of the pouch. A specially designed rubber bar had a hole in the center through which the F_0 sensor could be injected into a slice of pork and used to fix the F_0 sensor in retort pouch. *Kimchi*, tofu, pork and sauce were filled into each pouch and were immediately sealed with a heating bar (impulse sealer, Korea) to minimize the level of entrapped gases. After filling and sealing, the pouches were placed in a water bath for 1 hour (at 65℃) to equilibrate the initial temperature.

2. Sterilization Process

Filled pouches were processed by a pilot 1-basket water cascading retort (HTST Retort: WS-PILOT-30s, Woosung Machinery, Korea) in static or rotary mode to study the effect of rotation on heat penetration. The rotation speed was set at 8 rpm and temperature was set at 121℃ with a steam pressure of 2.0 bar during each process. The retort had a programmable logic controller-assisted manual control, i.e. retort operation executed manually but with the help of separated electronic programmable input detector controllers for temperature and pressure (Garrote RL et al 2007; Denys S et al 1996).

During sterilization process, temperature and F_0 value were recorded by a wireless F_0 sensor at different position in the retort pouch and compared. The sterility is expressed as the F_0 value calculated as $F_0 = F_t \times 10^{(T-121.1)/z}$(Fig. 1). illustrated the general view of the each position. The recorded data were analyzed using a computer.



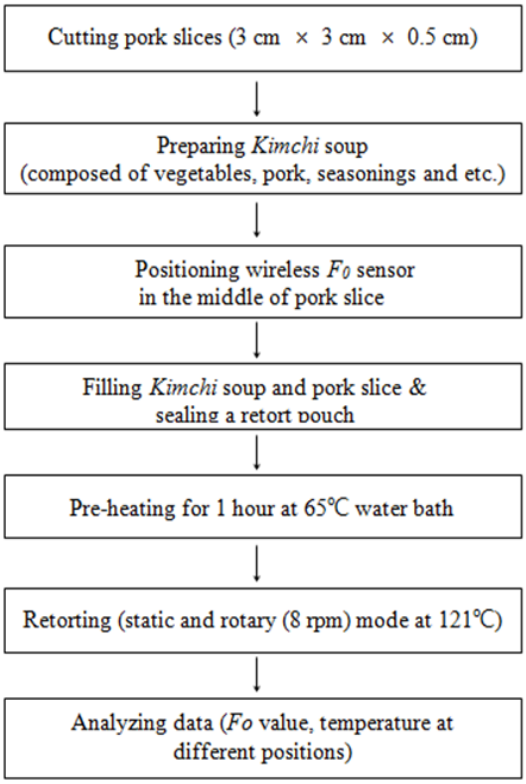
〈Fig. 1〉 **Schematic diagram of the experimental set-up indicating position of F_0 sensor in the pouch.**

3. Sensory Evaluation

Sensory evaluations were performed by a trained panel consisting of ten housewife-monitoring from the R&D center, food company. After completing three training sessions, the sensory attributes of preference for overall taste, flavor, color, appearance and texture were evaluated. All samples were the same weight and each was served on a randomly coded plate after being heated in a microwave oven for 3 min. Water was provided to the panelists to cleanse the palate after tasting each sample. The panelists rated the preference of sensory attributes from 1 (extremely bad) to 5 (extremely good) for each sample on a 5-point hedonic scale.

4. Statistical Analysis

The experiments were repeated at least five times for each position. All the data were expressed as averages of five replicate measurements and the standard deviation. The statistical analysis was conducted using Minitab (Minitab Inc., Pennsylvania, USA). In order to verify to significant differences between the samples, analysis of variance and Duncan's multiple range test were carried out (p<0.05). The experimental procedure is shown 〈Fig. 2〉.



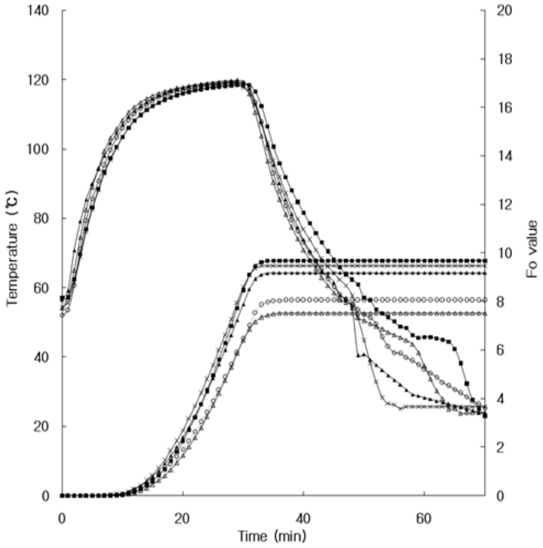
〈Fig. 2〉 **Schematic flow sheet of the experimental procedure.**

Ⅲ. Results and Discussion

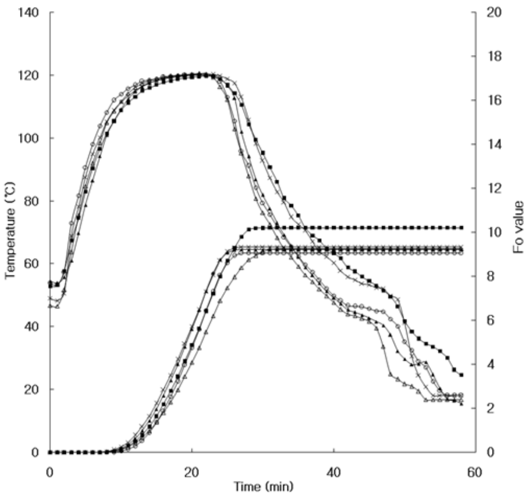
1. Heat Penetration Characteristics

The goal of this study was to compare heat penetration characteristics in two occasions, when stationary and rotary retorts conducted. The heat penetration data of both methods were compared in order to determine the effect of the rotation (Terajimi Y & Nonaka Y 1996). Each experiment about heat penetration characteristics was carried out at five different positions; position 0 was located in the center of the retort pouch, position 1 was located 0.8 cm below from the center of the retort pouch, position 2 was located 1.6 cm below from the center of the retort pouch and both position 3 and 4 were located in same way. In other word, the distance between adjacent positions was 0.8 cm. And pouches were processed to the same F_0 value of 9±1.5 in both retort.

The two process of heat penetration were carried out to demonstrate the performance of this strategy. 〈Fig. 3~4〉 showed the effect of rotation with different positions of the pouches. As seen 〈Fig. 3〉, the deviation of F_0 value was 7.522 to 9.679, 〈Fig. 4〉 shows that the deviation of F_0 value was 9.057 to 10.207. It is due to rotation of the retort during sterilization. Rotation results more even heat transfer characteristics by agitating the contents in retort pouches. As result from rotation during retort, there was no significant difference among each F_0 value in rotary retort by analysis of variance and Duncan's multiple range test (p<0.05).



〈Fig. 3〉 **Heat penetration curves at different position in *Kimchi* soup with stationary retort.** (○=Temperature and F_0 value at position 0; △=position 1; ▲=position 2; X=position 3; ■=position 4).



〈Fig. 4〉 **Heat penetration curves at different position in *Kimchi* soup with rotary retort.** (▲=Temperature and F_0 value at position 0; △=position 1; ○=position 2; X=position 3; ■=position 4).

whereas the results of stationary retort indicated a little deviation. This deviation was generated since the stationary retort operated in static mode, thus there was no movement of contents in retort pouches. These results were summarized in 〈Table 1〉.

〈Fig. 5〉 showed the temperature history and F_0 value profile of a cold point in the *Kimchi* soup as a function of sterilization time in stationary and rotary type retort.

From the results, standard deviation of stationary retort greater than rotary retort. In comparison with A and B graphic in 〈Fig. 5〉, the positive influence of induced rotation on the heating of the product was visible. Firstly, the gross processing time was reduced by rotation. In stationary retort overall processing time took 58 min, while rotary retort took 49 min based on termination of cooling stage. As a result entire processing time could be decreased by 9 min. It was obvious that a method of agitation of pouches which would give a very rapid come-up of the pouch's contents to retort temperature would offer many advantages. This effect of gross processing time could expect that economize the spending energy for retorting and the cost for operating. Secondly, there was considerable reduction in sterilization time with rotation. Thermal sterilization was done at 120.7℃ to the same F_0 value. In stationary retort, sterilization time required 20 min to obtain target F_0 value and then again, in rotary sterilization required only 13 min based on measurement data of wireless F_0 Sensor. Consequently sterilization time was reduced by 7 min. The rotation increase the heat transfer rate, in consequence sterilization time could be reduced.

2. Improvement of Sensory Quality

From result of this study, it is most interesting to note the dramatic improvement in sensory quality between stationary and rotary retort. The *Kimch* soup sterilized in rotary retort obtained high

〈Table 1〉 **Mean F_0 value at different positions**

Method	Position[1)]				
	0	1	2	3	4
Stationary retort	8.046±0.860	7.522±0.894	9.178±0.758	9.479±0.836	9.679±0.821
Rotary retort	9.257±0.422	9.057**±0.374	9.223±0.403	9.340±0.408	10.207±0.387

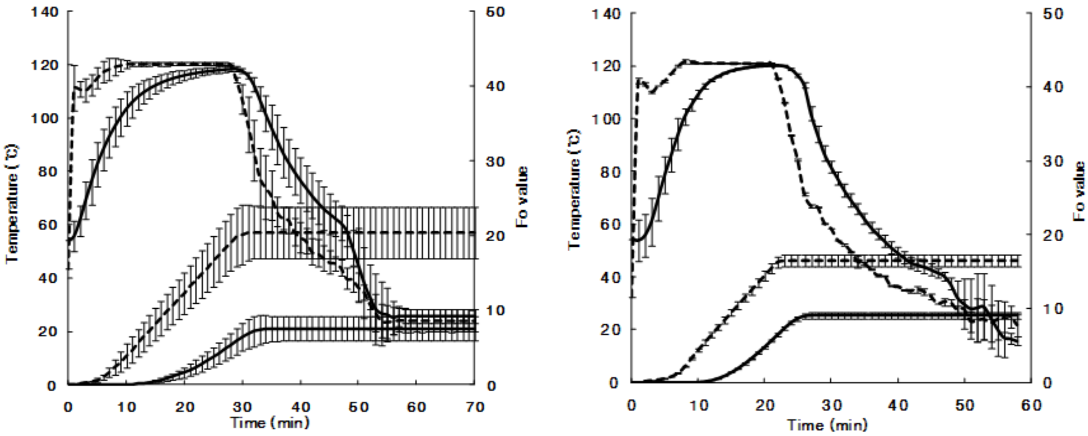
1) Values are expressed as mean±standard deviation (n=5).

** Significant difference between stationary retort and rotary retort by two sample *t*-test ($p<0.05$).

<Table 2> **Comparisons of sensory evaluation of retorted *Kimchi* soup with stationary retort and rotary retort**

	Preference score (5 - point hedonic scale)[1)]				
	Overall taste	Flavor	Color	Appearance	Texture
Stationary retort	3.5±0.5	3.6±0.5	3.5±0.5	3.6±0.7	3.4±0.5
Rotary retort	4.0[**]±0.4	4.1[**]±0.3	4.0[**]±0.4	3.9±0.8	3.9[**]±0.3

[1)] Values are expressed as mean±standard deviation (n=10).
[**] Significant difference between stationary retort and rotary retort by two sample *t*-test (p<0.05).



(A) (B)

<Fig. 5> **Temperature history and F_0 value profile of a cold point in the *kimchi* soup as a function of sterilization time (stationary retort(A), rotary retort(B)).**
----- Profiles of hot water in retort
── Profiles of a cold point in *Kimchi* soup

grade by sensory evaluation with house wife-monitoring. The preference of overall taste, flavor and color were improved with significant difference (p<0.05) on rotary retort (Table 2). Moreover the texture of *Kimchi* and pork was better than static mode. This is because of the uniform heat transfer due to rotation of basket during retort. Furthermore, burn-on at the surface of *Kimchi* soup can be substantially eliminated by induced agitation.

3. Advantages of Rotary Type Retort

Based on the working principle of both retorts, the slowest heating zone of a container which is conducted by convection heating was expected to be situated near the container bottom along the vertical axis, since that position is most shielded from the water flow. Nevertheless, for pouch of both retort, position 1 (0.8 cm below from the center of the pouch) was heating slower. That is to say, position 1 for both methods was a cold point because retort pouches were laid down during sterilization.

The results of the heat penetration curves showed that the rotary type retort reached object temperature 1.46 times faster than stationary type retort. “Position 1” (0.8 cm below from the center of the pouch) for both methods was a cold point. However rotary type retort indicated less F_0 value difference among various positions. Consequently reaching to the similar F_0 value, processing time could be reduced by 35～45% in rotary type retort than stationary type retort. Moreover sensory improvement could be expected by rotary type retort.

The rotation of retort has many advantages on the heat penetration in retort pouch, tray and can during thermal processing (Ali AA et al 2006; Smout C et al 2001). Such result on this study also could offer a positive effect. For instance, many of the more viscous semi-liquid products and heat sensitive natural products could be sterilized in the lager pouch sizes without overcooking or scorching (Nha YA & Park JN 2003). In addition this method for sterilizing products in the pouch would improve color, flavor and nutritive value of many pouched foods. Moreover, heat resistant organisms could be destroyed in many products without heat injury to the product.

Ⅳ. Conclusion

The results of heat penetration characteristics in stationary and rotary retorts were compared in order to determine the effect of the rotation. Firstly, the F_0 value deviation was compared. For this experiment, F_0 values were evaluated at five different positions (position 0, 1, 2, 3, 4). In consequence rotation results less difference F_0 value among each position. Secondary, heat transfer characteristics were compared. For this experiment, heat transfer rate in both methods were compared. As a result, rotation during retort reduces gross process and sterilization time. Also, rotary type retort would make it possible to improve the quality of *Kimchi* soup as overall taste, flavor, color, texture with significant difference (p<0.05) by uniform heat transfer due to induced agitation.

한글초록

레토르트 김치찌개의 최적 가열 살균 조건 설정을 위해 정치식 및 회전식 레토르트 방식을 이용하여 최적화 연구를 수행하였다. 연구 고찰 결과 가열 특성은 레토르트 살균 방식에 의해 영향을 많이 받아 회전식에서는 120.7℃, 13분, 정치식에서는 120.7℃, 20분의 가열 살균이 최적 공정 조건으로 나타났다. 두 가지 레토르트 방식에서 김치찌개 파우치 내 냉점의 F_0 값은 동일한 결과를 보여 회전식이 정치식 보다 승온이 더 빠르며, 또한 빠른 온도 상승으로 시료 위치별 온도 편차도 적게 발생하였다. 이러한 전열 특성으로 냉점에서 동일 F_0 값 도달에 있어 회전식 레토르트 방식이 정치식에 비해 가열 살균시간이 35～45%의 단축되는 큰 장점이 있어 전반맛, 향, 색상과 조직감이 유의차 (p<0.05) 있게 향상되었다. 이러한 장점으로 육, 해물, 야채 등의 고형물이 포함되어 있는 다양한 메뉴의 레토르트 파우치 식품의 관능품질이 크게 향상될 것으로 기대된다.

References

Ali AA, Sudhir B, Krishnaswamy T, Gopal S (2006). Effect of rotation on the heat penetration characteristics of thermally processed tuna in oil in retort pouches. *Int J Food Sci Technol* 41 (2):215-219.

Cho YB (2005). Developing processed foods by adding *Kimchi* for international product strategy. *Culinary Society of Korean Academy October* 8-9: 63-86.

Cho YB (2008). The effects of *Kimchi* product selection attribute on customers satisfaction and repurchase intent. *The Korean Journal of Culinary Res* 14(4):203-216.

Denys S, Nornha J, Stoforos NG, Hendrickx M, Tobback P (1996). Evaluation of process deviations, consisting of drops in rotational speed, during thermal processing of foods in rotary water cascading retorts. *Journal of Engineering* 30(3):327-338.

Garrote RL, Silva ER, Roa RD, Bertone RA (2007). Kinetic parameters of surface color degradation of canned fresh green peas sterilized in a rotary retort. *LWT-Food Science and Technology* 41 (3):408-413.

Jung HO, Chung DO, Park ID (2002). A study in sensory characteristics of herb onion *Kimchi* differing in herb content. *The Korean Journal of Culinary Res* 8(3):259-265.

Kang HW (2013). Characteristics of *Kimchi* added with anchovy sauce from heat and non-heat treatments. *The Korean Journal of Culinary Res* 19(5):49-58.

Kim JH, Park GS (2014). Quality characteristics of *Kimchi* added with blue crab. *The Korean Journal of Culinary Res* 20(2):246-259.

Kim MJ, Kim GR (2006). *In vitro* evaluation of cholesterol reduction by lactic acid bacteria extracted from *Kimchi*. *The Korean Journal of Culinary Res* 12(4):259-268.

Loey AV, Fransis A, Hendrickx M, Maesmans G, Noronha JD, Tobback P (1994) Optimizing thermal process for canned white beans in water cascading retorts. *J Food Sci* 59(4):828-832.

Nha YA, Park JN (2003). Effect of dried powders of pine needle, pine pollen, green tea and horse radish on preservation of *Kimchi-yangnyum*. *The Korean Journal of Culinary Res* 9(40): 179-190.

Park WP, Park KD, Kim JH, Cho YB, Lee MJ (2000). Effect of washing condition in salted Chinese cabbage on the quality of *Kimchi*. *J. Korea Soc. Food Sci Nutr* 29(1):30-34.

Rha YA, Park JN, Na YS (2004). The effects of pine pollen and horse radish on fermentation of *Kimchi*. *The Korean Journal of Culinary Res* 10(4):178-189.

Sihn EH, Jung SJ (2003). Optimization of bread fermentation with lactic acid bacteria & yeast isolated from *Kimchi. The Korean Journal of Culinary Res* 9(3):130-140.

Smout C, Loey AV, Hendrickx M (1998). Heat distribution in industrial-scale water cascading (rotary) retort. *J Food Sci* 63(5):882-886.

Smout C, Loey AV, Hendrickx M (2001). Role of temperature distribution studies in the evaluation and identification of processing conditions for static and rotary water cascading retorts. *J Food Eng* 48(1):61-68.

Teixeira AA, Tucker GS (1997). On-line retort control in thermal sterilization of canned foods. *Food Control* 8(1):13-20.

Terajima Y (1975). Overall heat transmission from the heating medium (steam and water) to the contents of the retortable pouch. *Canners Journal* 54(1):73.

Terajimi Y, Nonaka Y (1996). Retort temperature profile for optimum quality during conduction heating of foods in retortable pouches. *J Food Sci* 61(4):673-678.

Yim SK, Sohn KH (2004). Effects of sterilization temperature on the quality of carrot purees. *Food Science Biotechnol* 13(2):141-146.

2014년 09월 15일 접수
2014년 10월 30일 1차 논문수정
2014년 11월 15일 2차 논문수정
2014년 11월 30일 3차 논문수정
2014년 12월 05일 논문게재확정