Food Sci. Biotechnol. Vol. 15, No. 6, pp. 884 ~ 888 (2006)

Food Science and Biotechnology



# Extension of Shelf Life of *Kimchi* by Addition of Encapsulated Mustard Oil

**Mi Jeong Kim, Jee Yun Ha, Ye Rang Yun, Jeong Sook Noh, Yeong Bok Song[1], and Yeong Ok Song***

*Department of Food Science and Nutrition/Kimchi Research Institute, Pusan National University, Busan 609-735, Korea*

*[1]Sejeon Research Institute of Food Science and Technology, Jincheon, Chungbuk 365-820, Korea*

**Abstract** In this study, we have attempted to characterize the effects of encapsulated mustard oil with regard to the extension of the shelf life of *kimchi*. The quantity of mustard oil or encapsulated mustard oil added to the brined cabbage in this study was 0.05%(w/w). Overall, the fermentation processes in the encapsulated mustard oil-added *kimchi* (EMO) and mustard oil-added *kimchi* (MO) occurred at a slower rate than in the controls. The periods during which the MO and EMO *kimchi* samples were edible were prolonged for more than two weeks, according to measurements of pH, total acidity, and microbial changes. The overall acceptability of EMO was superior to MO throughout the entirety of the fermentation period. Sensory evaluation verified that EMO yielded a more favorable product than the MO and control varieties. Encapsulated mustard oil can be employed as a natural food additive to prolong the shelf life of *kimchi*, via an induced delay of the fermentation process.

**Keywords:** encapsulated mustard oil, shelf life of *kimchi*, sensory evaluation

## Introduction

The *kimchi* market has been enjoying a significant expansion of late, primarily because of a global recognition of the health-promoting effects of *kimchi* (1, 2). Improvements in intestinal health (3), an anticancer effect (4, 5), and a hypolipidemic effect (6) have been established as some of the beneficial functional properties of *kimchi*. Although *kimchi* clearly exhibits various positive health aspects, the over-ripening of *kimchi* during storage has constituted a major concern in the *kimchi* industry. Thus, it is essential that methods be developed for the control of the *kimchi* fermentation process. Various techniques and ideas have been applied to extend the shelf life of *kimchi*, including the addition of salts (7), the use of natural preservatives (8-11), and gamma-irradiation (12). Several researchers have focused on the antimicrobial effects exerted by mustard oil, and attempted to utilize these effects to extend the shelf lives of a variety of foods (13-15). Hong and Yoon (16) showed that the addition of mustard oil to *kimchi* exerted an antimicrobial effect on major lactic acid bacteria, including *Lactobacillus plantarum, Lactobacillus brevis, and Leuconostoc mesenteroides*, and also delayed the fermentation process. However, the addition of mustard oil in an attempt to extend the shelf life of *kimchi* proved somewhat counterproductive, as it resulted in a strong undesirable taste and odor. Therefore, the need has been recognized for a novel method of using natural mustard oil in *kimchi* to extend the shelf life without degrading the sensory qualities of *kimchi*.

Microencapsulation is a technique used for the protection and stabilization of specific ingredients. It is designed to release ingredients in a slow, controlled manner. This technique also facilitates the incorporation of ingredients which, in their original form, are undesirable for some reason. The most commonly-used wall materials for the encapsulation of ingredients are starch, starch derivatives, proteins, gums, lipids, or any combination thereof. Techniques including spray-drying, freeze-drying, and fluidized bed-coating are often utilized in microencapsulation schemes (17, 18).

In the present study, we have examined the effects of encapsulated mustard oil-added *kimchi* (EMO) with regard to the extension of *kimchi* shelf life, by measuring the chemical, microbial, and sensory characteristics during the fermentation process. In order to better determine the effects of encapsulated mustard oil, the chemical, microbial, and sensory properties of EMO were compared with those of mustard oil-added *kimchi* (MO).

## Materials and Methods

**Preparation of encapsulated mustard oil** The encapsulated mustard oil used in this study was provided by the Sejeon Co., Ltd., Korea. The process of encapsulation is provided in detail elsewhere (19). In brief, we constructed microcapsules (mustard slurry) that contained mustard oil, arabic gum, corn starch, and maltodextrin (10% mustard oil/total wt), followed by spray-drying. The final product was characterized as a white powder that retained the original qualities of the mustard oil.

**Preparation of *kimchi*** Chinese cabbage (baechu) was trimmed and cut into 3×4 cm pieces, then brined for 2 hr in 10% salt water. The cabbage was then washed three times in tap water, and drained for 2 hr. The recipe used for *kimchi* preparation was as follows: red pepper powder 2.9 g, garlic 2.9 g, ginger 1.0 g, fermented shrimp sauce 3.3 g, fermented anchovy sauce 1.7 g, glutinous rice paste 4.2 g, sugar 0.7 g, radish 3.5 g, green onion 3.2 g, and shrimp stock 3.2 g per 100 g of brined baechu. For the

*Corresponding author: Tel: 82-51-510-2847; Fax: 82-51-583-3648
E-mail: yosong@pusan.ac.kr
Received July 26, 2006; accepted September 13, 2006

MO sample, 0.05% mustard oil per brined baechu (wt) was added to the seasoning mixture before the *kimchi* was made. As each of the microcapsules contained 10% mustard oil, 0.5% encapsulated mustard oil was added for the preparation of the EMO sample. The control *kimchi* contained no mustard oil. The final salinity of the *kimchi* was 2.1±0.1%. About 250 g of *kimchi* were stored in a glass jar. A total of 21 glass jars were prepared for each of the *kimchi* samples. The *kimchi* samples were stored for 5 hr at room temperature, and then stored for 60 days at 5±1°C.

**Chemical analyses** *Kimchi* juice was obtained using a vegetable juice blender. pH was measured with a pH meter (Hanna instruments, Singapore), and the total acidity was determined via the titration of 10 mL of filtrate with 0.1 N NaOH, and expressed as the quantity of lactic acid in the *kimchi*. pH and acidity were determined every three days. Organic acids in *kimchi* were analyzed via HPLC with Supelcogel C-610H (7.8 mm i.d. × 30 cm) column. The HPLC conditions were as follows: mobile phase, 0.1% sulfuric acid; flow rate, 0.5 mL/min; detector, UV/VIS 214 nm; chart speed, 1.0 cm/min; temperature, 30°C (20). The organic acids measured in this study were lactic, succinic, tartaric, and malic acid.

**Microbial analyses** The lactic acid bacteria count was determined via the plate counting technique. *Kimchi* juice was diluted with distilled water, then mixed with slightly-modified MRS medium and incubated: Phenyl ethyl alcohol sucrose agar medium (PES) at 20°C, 5 days, and modified lactobacillus selection medium (LBS) at 30°C, 3 days for *Leuconostoc* sp. and *Lactobacillus* sp., respectively (21, 22).

**Sensory evaluation** The replicated randomized complete block design was applied (23). The sensory characteristics of *kimchi* were evaluated via a quantitative descriptive analysis (QDA) profile conducted by 8 trained sensory test panels in a specialized sensory test facility. Five subjective items (appearance, taste, flavor, texture, and overall acceptability) and 6 objective items (acidic taste, acidic odor, spicy taste, spicy odor, mustard oil taste, and mustard oil odor) were evaluated on a 9-point Likert scale. The higher the score is, the stronger the intensity of the corresponding attribute.

**Statistical analysis** One-way analysis of variance (ANOVA) was followed by Duncan's multiple range test, in order to determine the statistical significance of measurements between groups, using the SAS software ($p<0.05$) (24).

## Results and Discussion

**pH and total acidity** Patterns of pH and acidity changes differed between the mustard oil-added *kimchi* (EMO and MO) and the control (Fig. 1). In the control *kimchi*, which contained no mustard oil, pH decreased markedly to 4.14 by the 9th day of fermentation, and then gradually decreased further. However, a minimal drop in pH in the EMO and MO samples was detected during the first 9 days, followed by a rapid decrease over the following

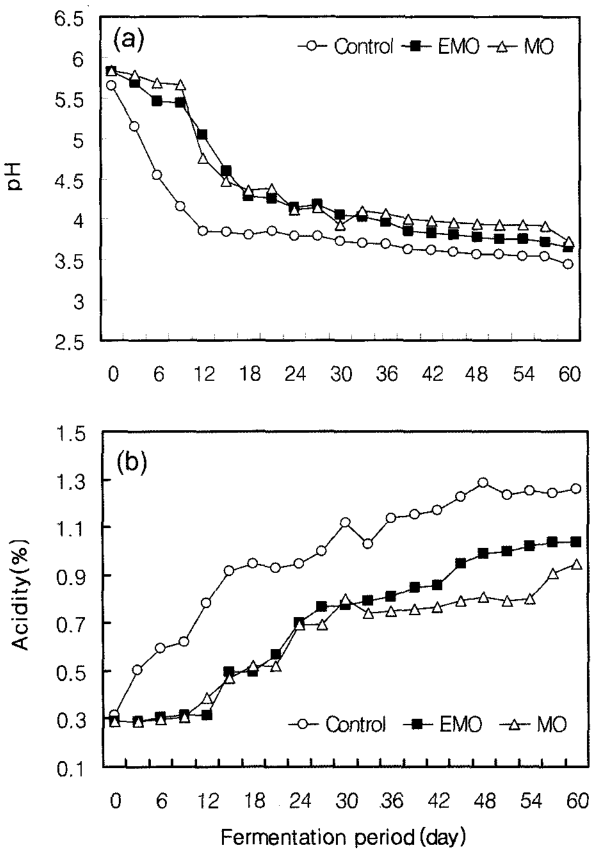


**Fig. 1. Changes in pH and total acidity of *kimchi* during *kimchi* fermentation at 5°C for 60 days.** (a) Changes of pH, (b) Changes of acidity. EMO: Encapsulated mustard oil-added *kimchi*, MO: Mustard oil-added *kimchi*.

several days, finally reaching pH values of 4.14 and 4.12 at the 24th day in the EMO and MO *kimchi*, respectively. On the basis of a previous report that the achievement of optimal ripening time in terms of the favorable edible quality of *kimchi* was associated with a pH value of approximately 4.1 (25), the control, EMO, and MO *kimchi* samples assessed in this study achieved optimal ripening time at the 9th, 12th, and 24th days of the fermentation process, respectively. The initial fermentation stage in the EMO and MO *kimchi* was prolonged for approximately one week, thus extending the time required to achieve optimum *kimchi* ripening by more than two weeks in both groups.

As had been expected, changes in acidity corroborated the pH results. The acidity of the control increased rapidly, achieving a value of 0.62% on the 9th day, and then increased continuously over the entirety of the fermentation period. The acidity of the EMO and MO *kimchi* samples remained at approximately the same levels until the 12th day, and then achieved a level of 0.7% on the 24th day (Fig. 1). According to the report of Lee *et al.* (26), the optimal period for the edibility of *kimchi* occurs in an acidity range of 0.4-0.75%. In this study, we determined that the optimal periods for eating *kimchi* were extended via the addition of mustard oil by up to 24 and 30 days in the EMO and MO *kimchi*, respectively. It is worthy of note that the acidity values for the EMO and

MO samples were lower than those of the control during the whole 2-month experimental period, thereby suggesting that microbial growth had been suppressed significantly via the addition of mustard oil to *kimchi*. These results are supported further by numerous citations in which the antimicrobial effects of mustard oil were discussed (13-16).

**Lactic acid bacteria** On day 12, *Leuconostoc* sp. in control increased up to 9.35 Log CFU/mL, whereas the EMO and MO evidenced only 30 and 11% of the amounts in the control *kimchi*, respectively. *Leuconostoc* sp. reached a plateau at the 12th, 24th, and 36th day of fermentation for the control, MO, and EMO samples, respectively (Table 1). These results indicate that the addition of mustard oil to *kimchi* may be desirable in terms of the retardation of the growth of *Leuconostoc* sp. EMO appears superior to the MO or control *kimchi* in this regard.

*Lactobacillus* sp. in the control and MO samples increased markedly up to day 12, followed by a gradual decrease thereafter, whereas *Lactobacillus* sp. in EMO reached a plateau on the 18th day of fermentation, and then decreased gradually (Table 1). These results are consistent with the study of Moon and Jang (27), in which gradual decrease in the number of *Lactobacillus* sp. after reaching the maximum was reported. However, our results were not consistent with Lee and Jo's (28) finding that the proportion of *Lactobacillus* sp. increased continuously throughout the fermentation process. The overall count of *Lactobacillus* sp. persisted at lower levels in the MO samples throughout the entirety of the fermentation period, as compared with the EMO and control specimens.

**Non-volatile organic acids** Among the organic acids examined in this study, lactic acid evidenced a notable difference between the mustard oil-containing *kimchi* and the control. Whereas the quantity of lactic acid in the control increased greatly over time, this tendency toward increase was less pronounced in the EMO and MO *kimchi*, particularly during the last stage of the 2-month fermentation. The concentration of lactic acid on the 60th day was 420.64, 278.01, and 279.45 mg% for the control, EMO, and MO samples, respectively. The quantities of succinic acid and tartaric acid in control *kimchi* decreased rapidly over the fermentation period, whereas those in the EMO or MO *kimchi* remained relatively high (Fig. 2). Malic acid was barely detectable in all samples (data not shown). These findings are consistent with those of Kim and Rhee (29), who previously reported that the levels of lactic acid

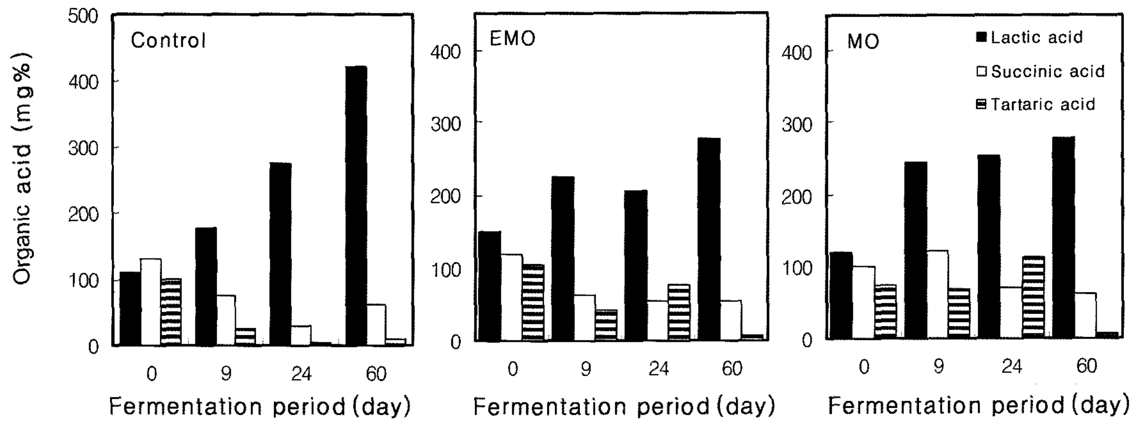


**Fig 2. Changes in non-volatile organic acids during *kimchi* fermentation at 5°C for 60 days.** EMO: Encapsulated mustard oil-added *kimchi*, MO: Mustard oil-added *kimchi*.

**Table 1. Microbial changes of *Leuconostoc* sp. and *Lactobacillus* sp. of *kimchi* during fermentation at 5°C for 60 days.**

| Fermentation period (day) | 0 | 12 | 18 | 24 | 36 | 48 | 60 |
|---|---|---|---|---|---|---|---|
| | | | *Leuconostoc* sp. (Log CFU/mL) | | | | |
| Control | 5.71 | 9.35 | 9.30 | 8.87 | 8.12 | 7.82 | 7.62 |
| EMO[1)] | 5.89 | 8.83 | 8.81 | 8.83 | 8.94 | 8.45 | 8.17 |
| MO[2)] | 5.73 | 8.40 | 8.93 | 9.08 | 8.61 | 8.55 | 8.54 |
| | | | *Lactobacillus* sp. (Log CFU/mL) | | | | |
| Control | 5.71 | 8.82 | 8.55 | 8.45 | 8.32 | 8.25 | 8.38 |
| EMO | 5.25 | 8.33 | 8.46 | 8.30 | 8.18 | 7.94 | 7.69 |
| MO | 5.29 | 7.80 | 7.53 | 7.48 | 7.14 | 7.23 | 7.11 |

[1)]Encapsulated mustard oil-added *kimchi*.
[2)]Mustard oil-added *kimchi*.

and succinic acid were higher than the levels of tartaric and malic acids, in cases in which the *kimchi* was fermented at 6-7°C (29). It appears that the lactic acid concentration increases markedly during fermentation, as compared with the changes observed in the other organic acids (30). Our results support the previously advanced notion that mustard oil was associated with a delay in the growth of lactic acid bacteria at each fermentation phase.

**Sensory properties** Significant differences in sensory evaluation were determined to exist among the control, EMO, and MO *kimchi* samples. Figure 3 shows the results for 6 sensory evaluation items (i.e., acidic taste, acidic odor, spicy taste, spicy odor, mustard oil taste, and mustard oil odor) acquired at 0, 12th, 36th, and 42nd days of fermentation. The scores for spicy taste and spicy odor differed less between the samples as fermentation proceeded. The mustard oil odor of the MO samples was detected strongly on the first day of the sensory test, and then became less profound. However, the unfavorable odor continued to be perceived over the fermentation period. The overall acceptability of MO, however, became much better than the control after 24 days of fermentation (Table 2). This result is consistent with Hong and Yoon's (16) finding that the score for the 'taste' of mustard oil-added *kimchi* was considerably higher than that of the control samples. The acidic taste and acidic odor in the control sample increased significantly as fermentation proceeded. This result appears to be associated with a series of microbial-chemical changes, including the rapid growth of lactic acid bacteria and an increase in the total acidity and level of lactic acid, as compared with the EMO or MO samples. In EMO, acidic taste and acidic odor were less profound than in the controls, and the mustard oil odor and mustard oil taste were only weakly detected. All of these factors may have contributed to the higher overall acceptability scores for the EMO samples than were received by the MO or control samples throughout the fermentation period. For instance, the overall acceptability scores for the EMO *kimchi* were significantly higher than those of the MO or control during the entirety of the fermentation periods, except for the 0 day. Furthermore, the overall acceptability of EMO between the 24th and 42nd days of fermentation was significantly better than the MO and control samples (on the 42nd day, overall acceptability scores were 6.5±1.5, 4.9±0.9, and 2.8±0.7 for EMO, MO, and control, respectively) (Table 2).

In summation, findings from sensory evaluation strongly indicate that the addition of encapsulated mustard oil to *kimchi* improved the overall sensory qualities of *kimchi* during the fermentation course, probably via a reduction in the original taste and odor of mustard oil, through a slow release of such sensory attributes. In addition, the fermentation pattern of the EMO sample appeared similar to that of MO, and was superior to control, based on the results of chemical and microbial analyses. It appears that

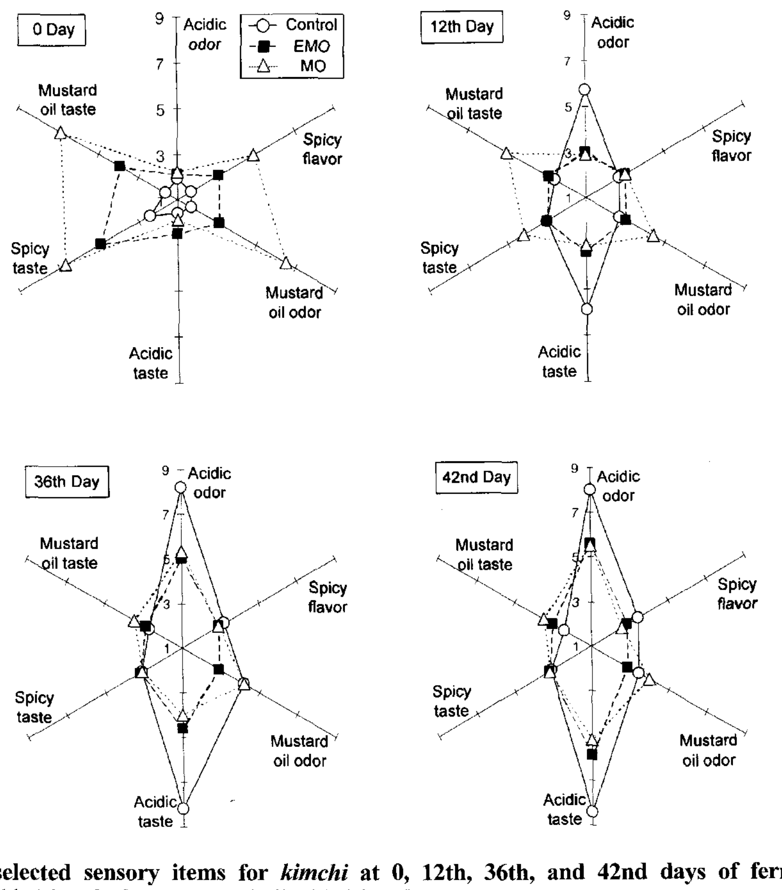


**Fig. 3. QDA profile of selected sensory items for *kimchi* at 0, 12th, 36th, and 42nd days of fermentation at 5°C.** EMO: Encapsulated mustard oil-added *kimchi*, MO: Mustard oil-added *kimchi*.

**Table 2. Overall acceptability scores for sensory evaluation of *kimchi* during fermentation at 5°C for 60 days**

| Attribute | Day | Sample[1)] | | |
|---|---|---|---|---|
| | | Control | EMO[2)] | MO[3)] |
| Overall acceptability | 0 | 7.5±1.4[a] | 5.9±0.9[b] | 3.0±1.1[c] |
| | 6 | 7.0±0.9[a] | 6.5±1.5[a] | 4.1±1.1[b] |
| | 12 | 6.3±1.6[a] | 6.3±1.6[a] | 4.6±1.0[b] |
| | 18 | 5.4±1.4[b] | 6.9±0.8[a] | 4.3±1.3[b] |
| | 24 | 3.5±0.9[c] | 6.9±0.8[a] | 5.6±1.1[b] |
| | 30 | 3.6±1.1[c] | 7.0±0.8[a] | 5.0±0.5[b] |
| | 36 | 3.1±1.7[c] | 6.9±1.2[a] | 5.3±1.2[b] |
| | 42 | 2.8±0.7[c] | 6.5±1.5[a] | 4.9±0.9[b] |
| | 48 | 2.8±1.0[b] | 6.0±0.8[a] | 5.4±0.9[a] |
| | 54 | 2.1±0.8[b] | 5.4±1.4[a] | 5.6±1.1[a] |
| | 60 | 1.9±1.0[b] | 4.8±1.5[a] | 5.0±1.4[a] |

[1)a,b,c]Means with different letters in row are significantly different by Duncan's multiple range test ($p$<0.05).
[2)]Encapsulated mustard oil-added *kimchi.*
[3)]Mustard oil-added *kimchi.*

the addition of natural mustard oil to *kimchi* in encapsulated form may effect a prolongation of the shelf life of *kimchi.*

## Acknowledgments

This work was supported for two years by a Pusan National University Research Grant.

## References


1. Kim DM, Lee JH. Current status of Korean *kimchi* industry and R&D trends. Food Ind. Nutr. 8: 52-59 (2001)
2. Kwang KS. Functionality and industrialization of Korean *kimchi* (2). Food Pres. Process. Ind. 4: 46-56 (2005)
3. Lee KE, Choi UH, Ji GE. Effect of *kimchi* intake on the composition of human large intestinal bacteria. Korean J. Food Sci. Technol. 28: 981-986 (1996)
4. Park KY, Cho EJ, Rhee SH, Jung KO, Yi SJ, Jhun BH. *Kimchi* and an active component, β-sitosterol, reduce oncogenic H-Ras$^{v12}$-induced DNA synthesis. J. Med. Food 6: 151-156 (2003)
5. Kong CS, Kim DK, Rhee SH, Rho CW, Hwang HJ, Choi KL, Park KY. Fermentation properties and *in vitro* anticancer effect of young radish *kimchi* and young radish watery *kimchi.* J. Korean Soc. Food Sci. Nutr. 34: 311-316 (2005)
6. Kwon MJ, Chun JH, Song YS, Song YO. Daily *kimchi* consumption and its hypolipidemic effect in middle aged men. J. Korean Soc. Food. Sci. Nutr. 28: 1144-1150 (1999)
7. Kim WJ, Kang KO, Kyung KH, Shin JI. Addition of salts and their mixtures for improvement of storage stability of *kimchi.* Korean J. Food Sci. Techonol. 23: 188-192 (1991)
8. Cho SH, Lee SC, Park WS. Effect of botanical antimicrobial agent-citrus products on the quality characteristics during *kimchi* fermentation. Korean J. Food Pres. 12: 8-16 (2005)
9. Choi MH, Park YH. Selective control of *lactobacilli* in *kimchi* with nisin. Lett. Appl. Microbiol. 30: 173-177 (2000)
10. Kim JM, Song KY, Kim SY, Shin WC, Yoon SS. Effect of eggshell powder on extending the shelf-life of *mul-kimchi.* Food Sci. Biotechnol. 13: 136-140 (2004)
11. Moon KD, Byun JA, Kim SJ, Han DS. Screening of natural preservatives to inhibit *kimchi* fermentation. Korean J. Food Sci. Techonol. 27: 257-264 (1995)
12. Lee SC. Effect of irradiated red pepper powder on *kimchi* quality during fermentation. J. Food Sci. Nutr. 9: 218-221 (2004)
13. Yoo MJ, Kim YS, Shin DH. Antibacterial effects of natural essential oils from ginger and mustard against *Vibrio* species inoculated on sliced raw flatfish. Food Sci. Biotechnol. 15: 462-465 (2006)
14. Suhr KI. Nielsen PV. Antifungal activity of essential oils evaluated by two different application techniques against rye bread spoilage fungi. J. Appl. Microbiol. 94: 665-674 (2003)
15. Nielsen PV, Rios R. Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. Int. J. Food Microbiol. 60: 219-229 (2000)
16. Hong WS, Yoon S. The effects of low temperature heating and mustard oil on the *kimchi* fermentation. Korean J. Food Sci. Technol. 21: 331-337 (1989)
17. Gibbs BF, Kermasha S, Alli I, Mulligan CN. Encapsulation in the food industry: a review. Int. J. Food Sci. Nutr. 50: 213-224 (1999)
18. Ko S, Kim HS, Jo SC, Cho SH, Park WS, Lee SC. Evaluation of pH-sensitive Eudragit E100 microcapsules containing nisin for controlling the ripening of *kimchi.* Food Sci. Biotechnol. 14: 358-362 (2005)
19. Ha JU. The effect of encapsulated mustard oil on extending the storage period of Korean cabbage *kimchi.* pp. 5-7. MS thesis. Pusan National University, Busan, Korea (2003)
20. Supelco Catalog. Chromatography Products. St. Louis, MO, USA. p.147 (2000)
21. Kim YC, Jung EY, Kim EH, Jung DH, Yi OS, Kwon TJ, Kang SM. Strain improvement of *Leuconostoc paramesenteroides* as a acid-resistant mutant and effect on *kimchi* fermentation as a starter. Korean J. Appl. Micobiol. Biotechnol. 26: 151-160 (1998)
22. Lee MK, Park WS, Kang KH. Selective media for isolation and enumeration of lactic acid bacteria from *kimchi.* J. Korean Soc. Food Sci. Nutr. 25: 754-760 (1996)
23. Kim KO, Lee YC. Sensory Evaluation of Food. Hakyeon Publishing Com., Seoul, Korea. pp. 192-268 (1995)
24. SAS institute. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC, USA (2000)
25. Mheen TI, Kwon TW. Effect of temperature and salt concentration on *kimchi* fermentation. Korean J. Food Sci. Techonol. 16: 443-450 (1984)
26. Lee KH, Cho HY, Pyun YR. Kinetic modeling for the prediction of shelf life of *kimchi* based on total acidity as a quality index. Korean J. Food Sci. Technol. 23: 306-310 (1991)
27. Moon SW, Jang MS. Effects of *omija* (*Schizandra chinensis Baillon*) on the sensory and microbiological properties of *nabakkimchi* during fermentation. J. Korean Soc. Food Sci. Nutr. 29: 822-831 (2000)
28. Lee SH, Jo OK. Effect of *Lithospermum crythrorhizon. Glycyrrhiza uralensis* and dipping of chitosan on shelf-life of *kimchi.* Korea J Food Sci Technol 30: 1367-1372 (1998)
29. Kim HO, Rhee HS. Studies on the nonvolatile organic acids in *kimchis* fermented at different temperatures. Korean J. Food Sci. Technol. 7: 74-87 (1975)
30. Ryu JY, Lee HS, Rhee HS. Changes of organic acids and volatile flavor compounds in *kimchis* fermented with different ingredients. Korean J. Food Sci. Technol. 16: 169-174 (1984)