KOREAN J. FOOD SCI. ANI. RESOUR. Vol. 26. No. 2, pp. 223~228(2006)

Effect of Ohmic Thawing on Physico-Chemical Properties of Frozen Hamburger Patties

Jee-Yeon Kim, Geun-Pyo Hong, Sung-Hee Park, Walter E. L. Spiess[1], and Sang-Gi Min*

Department of Food Science and Biotechnology of Animal Resources, Konkuk University

[1]Department of Food Engineering, Karlsruhe University, Germany

Abstract

This study was carried out to investigate the effects of ohmic power intensity on the physico-chemical properties of hamburger patties. Six different ohmic power intensities (0, 10, 20, 30, 40, and 50 V) were delivered by controlling the power with the sine wave at 50Hz. The ohmic power intensity influenced the thawing rate, and increasing ohmic power intensity increased the thawing rate. The faster thawing rate was obtained at higher ohmic power intensity (50 V) with 0.5% NaCl added meat patties in comparison to no NaCl added hamburger patties. The pH values of all patties were not significantly different with increasing ohmic power intensity (*$p<0.05$*). Increasing thawing rate did not tend to improve the water holding capacity (WHC) of all patties by ohmic thawing. Cooking losses were almost the same regardless of increasing ohmic power intensity. Increasing ohmic power intensity tended to increase the thiobarbituric acid reactive substance (TBARS) levels. TBARS levels of all hamburger patties without NaCl were significantly higher than that of 0.5% NaCl added hamburger patties (*$p<0.05$*) at higher ohmic intensity (50 V). In conclusion, these results indicated that a higher ohmic power intensity at 50 V induced the lipid oxidation of all patties.

Key words : ohmic power intensity, thawing rate, TBARS, NaCl added hamburger patty

INTRODUCTON

Consumption of meat patties has grown in the last decade and meat patties are a popular type of fast-food widely present in the world (Echarte *et al.*, 2003). However, the possible formation of potentially harmful substances, such as lipid peroxides, has become an important portion of food safety, for the maintenance of good health. The quality of frozen hamburger patties is related to freezing and thawing processes. Even freezing has some disadvantages such as the formation of ice crystals between muscle fiber, it is necessary in the meat industry for longer storage period. Generally, thawing occurs more slowly than freezing and is subject to damage by chemical and physical changes. Therefore, thawing process should be of concern to food technologists (Fennema *et al.*, 1973). In contrast to the amount of studies about the effects of freezing rates on changes in physical, chemical and sensory meat properties, there are few reports about the effects of thawing rates on meat characteristics. Conventional meat thawing methods require that meat be heated externally through conduction, convection or radiation. Thawing of meats is a common practice using radio frequency heating (McCormick, 1988) which occurs volumetrically over conventional methods. It can result in unacceptable surface temperatures. Microwave energy is widely used as a heat source in applications such as heating and thawing of foods. However partial thawing of meat products with microwave is already practiced in the meat industry (Taher and Farid, 2001). Ohmic heating has been studied since the early 1900s. Using this method, frozen foodstuffs can be thawed rapidly in the temperature range −3 to 3°C (Ohtsuki, 1993). Recently, one possible method for improved is ohmic thawing technology due to short thawing time, high energy conversion efficiency, volumetric heating, etc (Fellow, 2000). This method can also be used in thawing frozen foods by placing them between two electrodes and applying an alternating current. However, the application of ohmic thawing for the frozen foods are still

* **Corresponding author** : Sang-Gi Min, Department of Food Science and Biotechnology of Animal Resources, College of Animal Husbandry, Konkuk University, 1 Hwayang-dong, Kwangjin-gu, Seoul 143-701, Korea. Tel: 82-2-450-3680, Fax: 82-2-455-1044, E-mail: foodeng301@paran.com

limited because of the overheating and electric power overflowing can destroy the food quality during thawing process. There is also a lack of information on the effects of ohmic thawing on the characteristics of hamburger patties. Kim *et al.* (2006) found that lipid oxidation of pork meat was increased during ohmic thawing. In meat industry, sodium chloride is often added to meats to improve sensory, functional and preservation properties (Tan and Shelef, 2002). However, its prooxidant activity accelerates the lipid oxidation in refrigerated or frozen meats, resulting in increasing thiobarbituric acid reactive substances (TBARS) (Lee *et al.*, 1997). Therefore, this study was conducted to investigate the effects of ohmic thawing on the physicochemical properties of frozen hamburger patties with or without NaCl at 20 % fat level.

MATERIAL AND METHODS

Materials and Sample Preparation

Porcine *m. longissimus dorsi* stored for 24 h after slaughter was purchased from local meat market. Meat was trimmed visible fat and connective tissue, and then ground through 8 mm plate twice with pork backfat. Fat level of all patties was adjusted to 20 %. Half of batch was separated and re-mixed with 0.5 % salt. Approximately 160 g of mixture was put into cylindrical molder (90 mm diameter and 20 mm thickness) and two thermocouples were inserted into both centre and surface of patties. All treatment was frozen at −50°C for 24 h.

Thawing Treatment

Frozen patties were attached within two stainless steel electrodes (86.8mm diameter × 1mm thickness). The alternating current source, of 50 Hz (sine wave), with different electric power (0, 10, 20, 30, 40 and 50 V) was used by the ACP power supply (AC Power Korea Co., Ltd., Korea) (Fig. 1). During operation a constant electric power was applied and monitored (TES 2730 Multimeter, China) (Fig. 2). The distance between stainless steel electrodes was 22 mm which were connected to the AC power unit. All ohmic thawing were conducted in 5°C set refrigerator (LG refrigerator, R-A50CD) on ohmic power intensity. Time and temperature were recorded (MV 100 Mobile Corder, Yokogawa, Japan) during freezing and thawing process. In this study, thawing rates were defined as the ratio of radius length to the thawing time to traverse the temperature range from −50 to 5°C.

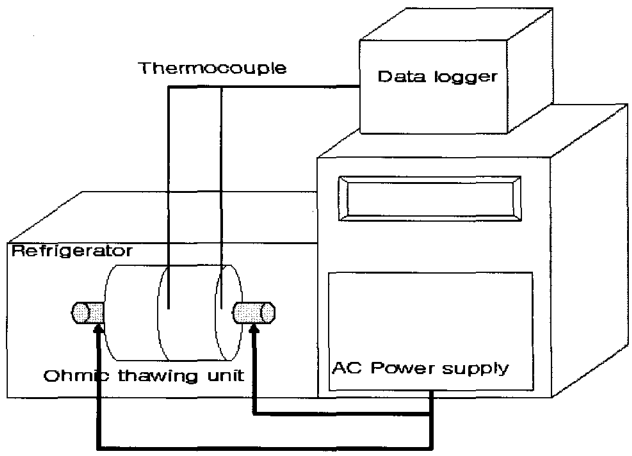

Fig. 1. Schematic diagram of ohmic thawing unit.

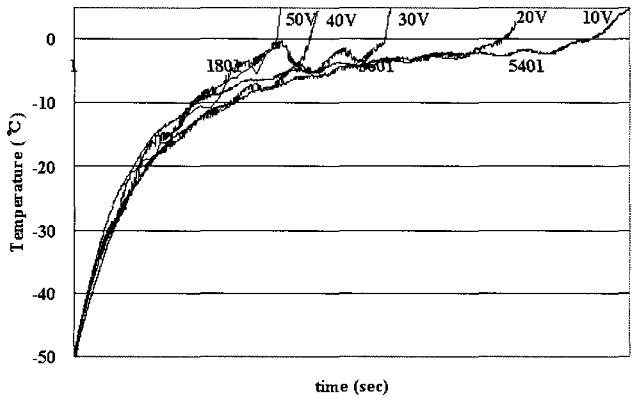

Fig. 2. Thawing curves of hamburger patties without NaCl due to different ohmic power intensity.

Each treatment was compared to the control without both freezing and thawing process. Triplicated experiments at different voltages with frozen pork samples were studied.

pH

pH measurements were carried out with a pH meter (Model 440, Corning, UK) on 5 g of sample mixed with 20 mL of water and homogenized at 13,000 rpm for 1 min in an SMT process homogenizer (SMT Co. Ltd., Japan).

Water Holding Capacity (WHC)

Water holding capacity was determined by the modified method of Pietrasik and Shand (2004). One gram of meat was weighed and placed in a centrifuge tube, along with gauze as absorbents. Samples were centrifuged for 10 min at 3,000 rpm in an automatic refrigerated centrifuge (RC-3, SORVALL Co., USA) at 4°C. After centrifuging, meat was removed and weighed centrifuge tube before and after drying. Water holding capacity was expressed as percentage of moisture content to meat.

Cooking Loss

Cooking loss was determined by assessing the value of exudation after thermal treatment. Three pork samples from each treatment were weighed before and after cooking in a water bath (DX9, Hanyoung Co., Korea) at 75°C for 30 min, and expressed as a percentage of the initial weight.

Lipid Oxidation

One gram of sample was mixed with 0.15 mL of butylated hydroxytoluene (BHT) and 9 mL of perchloric acid and was homogenized at 17,000 rpm for 2 min, after which 5 mL of distilled water was added and filtered using Whatman No. 2 filter paper. One milliliter of filtrate was added to 1 mL of 2-thiobarbituric acid (TBA), boiled at 100°C for 30 min, and cooled in ice water for 5 min. The readings were made on a UV/VIS spectrophotometer (Optizen III, Mecasys, Korea) at 531 nm. The conversion factor 6.2 was used for calculation of the thiobarbituric acid reactive substances (TBARS) expressed as mg malonaldehyde per kg meat.

Statistical Analysis

The data were analyzed by ANOVA using the SAS statistical program (SAS Institute, Inc., Cary, NC, USA), and differences among the means were analyzed using Duncan's Multiple Range test. The entire experiment was replicated twice, and all determinations were done in triplicate.

RESULT AND DISCUSSION

Thawing Rate by Ohmic Power Intensity

Effects of ohmic power intensity on thawing rate of hamburger patties are given in Fig. 3. On average for each hamburger patty at both no and 0.5 % NaCl added patties, samples thawed fastest at highest ohmic power intensity (50 V) and slowest at lowest ohmic power intensity (10 V). The total thawing time was run from a constant initial temperature of −50°C to a final temperature of 5°C (Table 1). In a previous experiment we have shown that the ohmic power intensity between 0 and 40 V could decrease total thawing time of frozen ground meat with ohmic power increment

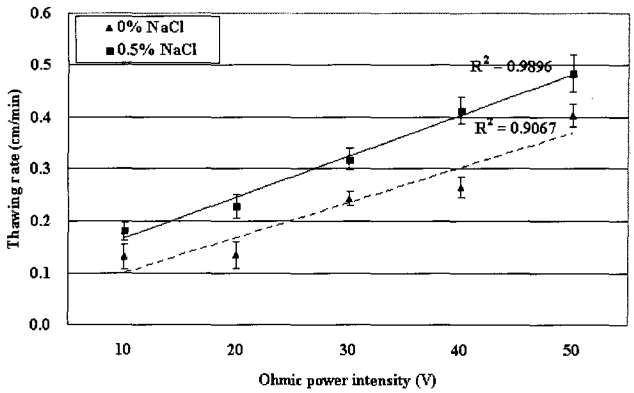

Fig. 3. Effects of ohmic power intensity on thawing rate of hamburger patties. The vertical bars represent the standard deviation.

(Kim *et al.*, 2006). In this study we carried out ohmic thawing for hamburger patties with higher intensity of the power (above 50 V), however, we found the over-heating at the surface connected to electrodes due to electric power overflowing. Therefore we just conducted ohmic thawing up to 50 V.

In ohmic thawing procedure, the fastest thawing time to traverse the temperature range from −50°C to 5°C was measured both 49 min without NaCl and 40 min with NaCl at 50 V of ohmic power intensity. In contrast, the slowest thawing time was measured 933 min at 0 V of forced air convection. 0.5 % NaCl added hamburger patties showed higher thawing rates than no NaCl added hamburger patties at any ohmic power intensity. However, regardless of NaCl content, the thawing rate changes linearly with ohmic power intensity between 10 V and 50 V. Most of meat thawing was found to occur within the temperature ranges of −5°C to −1 °C due to the ice-water phase transition, and only small

Table 1. Effects of ohmic power intensity on the total thawing time of hamburger patties

Ohmic thawing intensity (V)	Total thawing time (min)	
	0% NaCl	0.5% NaCl
0	937	-
10	152	110
20	98	87
30	82	62
40	75	48
50	49	40

fraction thaws within the temperature range of −24 to −5°C (Heldman, 1975). The effect of ohmic power intensity significantly reduced total thawing time of hamburger patties with decrease of the phase transition time. The amount of heat generated is directly related to the current induced by the power gradient and the electrical conductivity of the material being heated (Sastry and Li, 1996). The application of ohmic thawing is therefore dependent on the power intensity.

Changes in pH Value

Effects of ohmic power intensity on pH value of hamburger patties are given in Fig. 4. The pH value of hamburger patties made without NaCl was, pH 5.75 while that of ohmically thawed hamburger patties were between 5.65 and 5.73. The NaCl used in this study did not significantly increase the pH value of the hamburger patty. With the addition of NaCl the pH-value was originally 5.52 and that of ohmically thawed hamburger patties were not significantly changed at any ohmic power intensity. The NaCl used in the present study was quite low (0.5 % NaCl) and therefore the pH values of such hamburger patties were not affected. It was also found that electrical stimulation did not have an influence on the changes of the pH by ohmic thawing.

Changes in WHC and Cooking Loss

The WHC of meat products is one of the most important factors affecting economical value and meat quality due to the weight change during thawing (Lawrie, 1985). Fig. 5 showed the effect of ohmic thawing on WHC of hamburger patties. At the same ohmic power intensity, the WHC of the hamburger

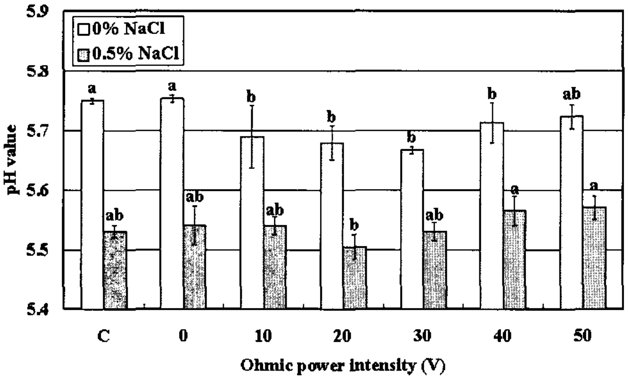

Fig. 4. Effects of ohmic power intensity on pH value of hamburger patties. The vertical bars represent the standard deviation. Different superscripts are significantly different (p<0.05). (C: control).

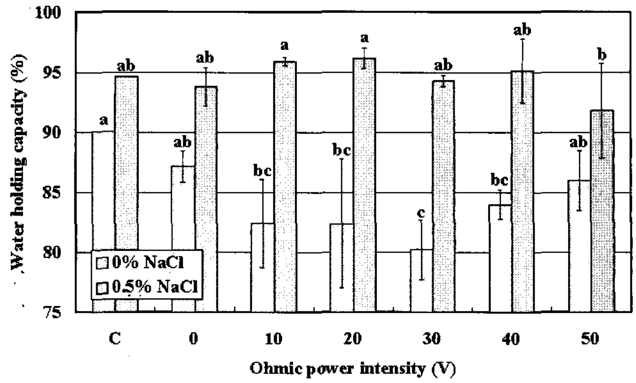

Fig. 5. Effects of ohmic power intensity on WHC of hamburger patties. The vertical bars represent the standard deviation. Different superscripts are significantly different (p<0.05). (C: control).

patties without NaCl were lower than that of NaCl added hamburger patties. In meat products, generally, salt contributes to water and fat binding by expanding the filament lattice of myofibrils and by partially solubilizing the myofibrillar proteins (Marita *et al.*, 2005). After ohmic thawing, no significant changes in the WHC of NaCl added hamburger patties as compared against the control. On the other hand, the WHC of no NaCl added hamburger patties slightly decreased after ohmic thawing as compared against the control. Yun *et al.* (1998) examined ohmic thawing of frozen chucks of meat and they showed the improved WHC when lower voltages (60 ~ 210 V) were applied. In this study, however, with much lower ohmic power intensity (10~50 V), the WHC of all patties was not improved and the WHC of no NaCl added patties showed significant decreased values. Cooking loss is a combination of liquid and soluble matters lost from the meat during cooking (Margit *et al*, 2003). Effects of ohmic power intensity on cooking loss of hamburger patties are given in Fig. 6. In this study, cooking losses of hamburger patties showed no differences between with and without the addition of NaCl. It also showed that ohmic power intensity did not affect the cooking loss. At the 0.5% NaCl content cooking loss was, however, always higher in ohmic thawed hamburger patties rather than the control. A different rate of protein denaturation could be an explanation for the differences seen in the cooking loss (Margit *et al.*, 2003). Therefore, there was no interaction between the ohmic power intensity and the hamburger patty on cooking loss at any salt contents.

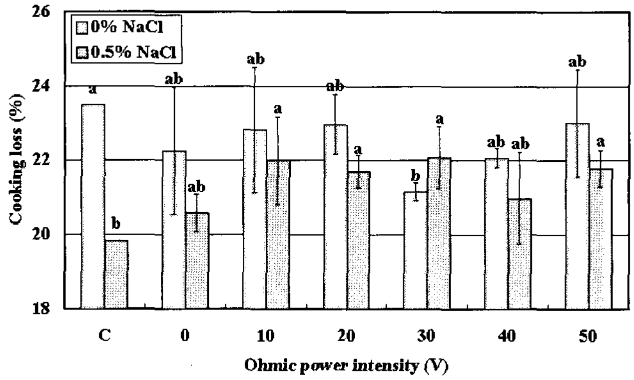

Fig. 6. Effects of ohmic power intensity on cooking loss of hamburger patties. The vertical bars represent the standard deviation. Different superscripts are significantly different (p<0.05). (C: control).

Changes in TBARS Value

Lipid oxidation is a major deterioration which results in a significant loss of the meat product quality. Fig. 7 showed the effects of ohmic power intensity on TBARS of hamburger patties. The TBARS of hamburger patties with or without NaCl increased with increasing ohmic power intensity. Thermal processes can promote lipid oxidation by disrupting cell membranes and releasing prooxidants (Sato and Hegarty, 1971). When the ohmic power intensity rises in frozen hamburger patties, the increase in lipid oxidation is more noticeable in no NaCl added hamburger patties than NaCl added ones. It indicates that the addition of NaCl does not affect the development of lipid oxidation by electrical stimulation during ohmic thawing. Generally, salts can interact with other components, modifying the hydrophobic/hydrophilic interactions among molecules (Walstra, 2003). The effect of salt ionic species drive conformational transition of other biomolecules, namely lipids and DNA (Cacace *et al., 1997*). Most studies deal with the effect of NaCl are very contradictory. In fact, while some authors have highlighted the pro-oxidant effect of NaCl (Kanner *et al.*, 1991; Osinchak *et al.*, 1992), others evidenced its anti-oxidant capability (Lonyuan et al., 1998). In this study, with faster thawing rates, the presence of NaCl could not interact with lipids undergoing oxidation during ohmic thawing. On the other hand, all freeze-thaw procedures promoted lipid oxidation and higher ohmic power intensity could significantly increase lipid oxidation. Generally, different heating methods could lead to modifications in the lipid fraction and microwave heating caused higher cholesterol oxidation in comparison to frying (Echarte *et al.*, 2003). Microwave heating is also known to cause greater alterations in edible fats than conventional heating (Rodriguez-Estrada *et al.*, 1997). Unlike other heat transfer modes, both microwave and ohmic heating heats foods directly through energy conversion, from electrical energy to heat (Piyasena and Dussault, 2003). In this study, the TBARS values of hamburger patties showed increase with higher ohmic power intensity (50V), indicating that electrical energy promoted lipid oxidation during ohmic thawing.

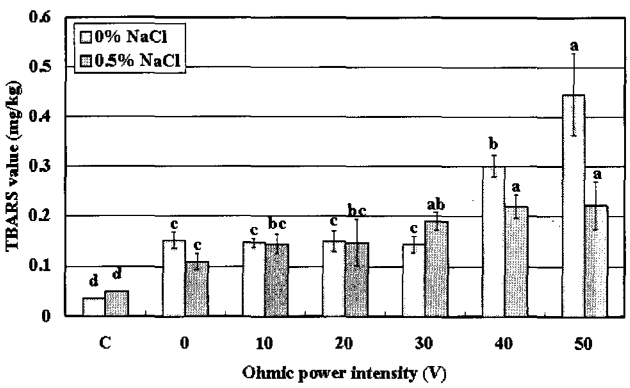

Fig. 7. Effects of ohmic power intensity on TBARS of hamburger patties. The vertical bars represent the standard deviation. Different superscripts are significantly different (p<0.05). (C: control).

REFERENCES

1. Cacace, M. G., Landau, E. M., and Ramsden, J. J. (1997). The hofmaister series: salt and solvent effects on interfacial phenomena. *Quarterly Rev. Biophys.* **30**(3), 241-277.
2. Echarte, M., Diana, A., and Iciar, A. (2003). Consequences of microwave heating and frying on the lipid fraction of chicken and beef patties. *J. Agri. Food Chem.* **51**, 5941-5945.
3. Fellow, P. (2000). Principles and practice. In: Food processing technology, 2nd ed., ed. Ellis Horwood, Chickester, UK, pp. 369-380.
4. Fennema, O. R., Powrie, W. D., and Marth, E. H. (1973). Low temperature preservation of foods and living matter. Marcel Dekker Inc. New York, USA, pp. 598.
5. Heldman, D. R. (1975). Food Process Engineering. 2nd ed., AVI Publishing Co. Inc., Westport, CT, USA.
6. Kanner, J., Harel, S., and Jaffe, R. (1991). Lipid oxidation

of muscle food as affected by NaCl. *J. Agri. Food Chem.* **39**, 1017-1021.

7. Kim, J. Y., Hong, G. P., Park, S. H., and Min, S. G. (2006). Effect of ohmic thawing process on physicochemical properties of frozen pork. *Food Sci. Biotechnol.* (In printing).
8. Lawrie, R. A. (1985). Meat Sci. 6th ed., Woodhead publishing limited, Cambridge, England. pp. 222.
9. Lee, S. K., Mei, L., and Decker, E. A. (1997). Influence of sodium chloride on antioxidant enzyme activity and lipid oxidation in frozen ground pork. *Meat Sci.* **46**(4), 349-355.
10. Lonyuan, M., McClements, D. J., and Decker, E. A. (1998). Ironcatalyzed lipid oxidation in emulsion as affected by surfactant, pH and NaCl. *Food Chem.* **61**(3), 307-312.
11. Margit, D. A., Camilla, B., Per, E., Hanne, C. B., and Henrik, J. A. (2003). Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. *Food Qual. Prefer.* **14**, 277-288.
12. Marita, R., Jukka, V., Marika, L., Liisa, L., Markku, N., Raija, A., and Eero, P. (2005). Reducing the sodium content in meat products: The effect of the formulation in low-sodium ground meat patties. *Meat Sci.* **69**, 53-60.
13. McCormick, R. (1988). Dielectric heat seeks low moisture applications. *Prepared Foods* **162**(9), 139-140.
14. Ohtsuki, T. (1993). Process for thawing foodstuffs. European Patent 0409430.
15. Osinchak, J. E., Hultin, H. O., Zaijcek, O. T., Kellerher, S. D., and Huang, C. H. (1992). Effect of NaCl on catalysis of lipid oxidation by the solute fraction of fish muscle. *Free Radic. Biol. Med.* **12**, 35-41.
19. Pietrasik, Z. and Shand, P. J. (2004). Effect of blade tenderization and tumbling time on the processing characteristics and tenderness of injected cooked roast beef. *Meat Sci.* **66**, 871-879.
20. Piyasena, P. and Dussault, C. (2003). Continuous heating a model viscous solution in a 1.5 kW radio-frequency heater: influence of active current, flow rate and salt content on temperature rise. *J. Agr. Bioresource Eng.* **45**(3), 27-34.
21. Rodriguez-Estrada, M. T., Penazzi, G., Caboni, M. F., Bertacco, G. and Lercker, G. (1997). Effect of different cooking methods on some lipid and protein components of hamburgers. *Meat Sci.* **45**(3), 365-375.
22. Sastry, S. K. and Li, Q. (1996). Modeling the ohmic heating of foods. *Food Technol.* **50**, 246-248.
23. Sato, K. and Hegarty, G. R. (1971). Warmed-over flavor in cooked meats. *J. Food Sci.* **36**, 1098-1100.
24. Taher, B. J. and Farid, M. M. (2001). Cyclic microwave thawing of frozen meat: experimental and theoretical investigation. *Chem. Eng. Process* **40**, 379-389.
25. Tan, W. and Shelef, L. A. (2002). Effects of sodium chloride and lactates on chemical and microbiological changes in refrigerated and frozen fresh ground pork. *Meat Sci.* **62**, 27-32.
26. Walstra, P. (2003). Bonds and interaction forces. In: P.W. ed., Physical chemistry of foods. New York, USA, Marcel Dekker Inc. pp. 46-58.
27. Yun, C. G., Lee, D. H., and Park, J. (1998). Ohmic thawing of a frozen meat chunk. *Korean J. Food Sci. Technol.* **30**, 842-847.

(2006. 3. 13. 접수 ; 2006. 4. 21. 채택)