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The Effects of Electric Grill and Microwave Oven Reheating Methods on the Quality Characteristics of Precooked Ground Pork Patties with Different NaCl and Phosphate Levels

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전기그릴과 전자레인지 재가열이 소금농도와 인산염 첨가수준에 따른 분쇄 돈육 패티의 품질 특성에 미치는 영향

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Abstract

The objective of this study was to determine the effects of different reheating methods on the quality characteristics of precooked ground pork patties with different combinations of salt (1, 2%) and phosphate (0, 0.3%). The cooking and reheating methods used were the electric grill and the microwave oven. The cooking method and the addition of phosphate had detectable effects on the quality characteristics of ground pork patties. The reheating rate by microwave oven was faster than by electric grill, and decreased with increases in salt and the addition of phosphate. Cooking loss and reduction in patty diameter after reheating by microwave oven were higher than by electric grill, and these values decreased with increasing of salt/phosphate levels. The pH of patties with added phosphate was significantly higher than patties without phosphate, and no significant difference in pH was observed among patties reheated by each method. The patties reheated by electric grill had higher moisture contents than those reheated by electric grill, and the addition of phosphate resulted in higher moisture contents. The hardness of patties reheated by electric grill was lower than patties reheated by microwave oven, and the addition of phosphate increased the hardness with both reheating methods.

Key words : reheating method, cooking method, microwave oven, phosphate, ground patty

Introduction

Cooking methods are largely responsible for many aspects of the final quality of meat products, and the selection of an appropriate heating method for cooking can affect not only quality but also production cost. The cooking method and cooking temperature are also important factors (Cambell *et al.*, 1977; Campbell and Mandigo, 1978), presumably because of their influence on time-temperature regimes during cooking. Microwave cooking has several advantages including rapid heating, ease of control and lower energy usage. Although conventional cooking methods are popular for the preparation of meat products, with increasing health concerns about fat intake consumers prefer simple and convenient cooking methods such as microwave cooking. Recently, Kirchner *et al.* (2000) and Jeong *et al.* (2004) studied how to use a microwave oven not to simply reheat precooked products, but to directly cook raw meat products. However, this demonstrated several disadvantages such as non-uniformity of heating, edge overheating, soggy texture, lack of browning, and cost considerations (Datta *et al.*, 2005).

Korean people generally prefer eating warm food to cold, and precooked meat products in particular are eaten after

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reheating. Commercial precooked meat products may be frozen uncooked, frozen cooked, or cooked and stored at refrigerator temperature. Since pre-cooked meat products such as patties and sausages are stored chilled or frozen, consumers use many cooking methods for reheating and eating. Although several studies have addressed problems associated with reheating, most are studies pertain to off-flavor and lipid oxidation (Tim and Watts, 1958; Cipra and Bowers, 1971; Lyon and Ang, 1990). Little attention, however, has been given to basic studies on the reheating of meat products. In order to minimize changes in meat product qualities due to various reheating methods, it is necessary to conduct a basic study on adequate reheating temperatures and times for various cooking methods such as conventional and microwave cooking.

The objective of this study, therefore, was to determine the effect of reheating method on the quality characteristics of ground pork patties with different salt and phosphate levels.

Materials and Methods

Preparation of patties

M. biceps femoris, M. semitendinosus, and *M. semimembranosus* from fresh pork (castrated boars; Landrace×Yorkshire×Duroc; 5 months old) were purchased from a local processor at 48 hr postmortem. Pork back fat was also collected. All subcutaneous and intermuscular fat and visible connective tissue were removed from the fresh ham muscles. The fat content of the trimmed pork was 5.12±0.12%. Lean muscles were initially ground through a Ø-13 mm plate and the pork back fat was ground through a Ø-8 mm plate using a meat grinder (PM-70, Mainca, Barcelona, Spain). The ground meat and fat were packaged with Nylon/PE film, and stored at 4°C.

All patties were composed of 80% pork ham and 20% pork fat. Salt and phosphate levels for each formulation were as follows; S1 (1% salt), S1+P (1% salt and 0.3% phosphate), S2 (2% salt), and S2+P (2% salt and 0.3% phosphate). Each batch of meat and fat was mixed by hand for 3 min. After salt (Natural hanju salt, Hangu Corp., Ulsan, South Korea) and sodium tripolyphosphate (Dongbang Foodmastar, Eumseong, South Korea) were added, the batches were mixed for an additional 3 min and then mixed for 30 min at 4°C using a meat mixer (RM-90, Mainca, Barcelona, Spain). Before patties were formed, the batches were held at 4°C for 1 hr (Trout and Dale, 1990). The batches were formed into 120±1 g patties with a diameter of 100 mm and a thickness of 15 mm using a patty press (Small Round Press, Spikomat Ltd., Nottinghamshire, UK), and then stored at 4°C.

Cooking and reheating methods

For reheating by electric grill, patties were cooked on a preheated electric grill (CG20, Hobart, OH, USA) with a surface temperature of 150°C. Patties were cooked for 3 min on each side, and flipped over every 2 min thereafter until the target center temperature of 76.5°C was reached (Zimmermann, 1984). For reheating by microwave oven, patties were cooked in a household-type microwave oven (NN-S963/S763, Panasonic Inc., Ontario, Canada) at medium-high power (750 W) operating at 2450 MHz according to the "operation instruction" of the microwave oven, since full power (1250 W) caused deterioration of the patties. Each patty was placed in the center of the oven on a microwave-safe plastic container with a plastic rack (approximately 8-mm from the bottom of the container), which allowed drippings to escape from the underside, until the targeted center temperature of 76.5°C was reached. The container was also rotated in the oven during cooking.

After cooking, the patties were held for 2 min and temperature changes were measured. While patties were being cooked, time-temperature trials were conducted to determine the length of cooking time needed to reach the designated internal temperature. Cooking time was defined as the time necessary to reach the desired temperature. Cooking properties of each patty were measured immediately after cooking. The cooked patties were cooled down to 4°C and packaged in groups of five patties per polyethylene bag. The patties were stored at 4°C for 5 days.

Precooked patties were reheated as described above until the internal temperature of the patty reached 74°C (Cremer and Hartley, 1988).

Cooking rate and reheating rate

The initial internal temperature of patties was measured, and the patties were cooked and reheated until then the final internal temperature reached 76.5°C or 74°C. The average cooking times for each patty formulation was also measured. The cooking rates and reheating rates were determined as follows:

Cooking rate (°C/min)

$$= \frac{\left(\begin{array}{c}\text{Final internal temperature}\\ \text{−initial internal temperature of raw patties}\end{array}\right)}{\text{cooking time}} \times 100$$

Reheating rate(°C/min)

$$= \frac{\left(\begin{array}{c}\text{Final internal temperature}\\ \text{−initial internal temperature of precooked patties}\end{array}\right)}{\text{cooking time}} \times 100$$

Cooking loss, reheating loss, and reduction in diameter

Each patty was cooked or reheated until the temperature reached 76.5°C or 74°C, and then cooled down to room temperature. Cooking loss and reheating loss were calculated using the following formula.

$$\text{Cooking or reheating loss (\%)} = \frac{\begin{pmatrix}\text{Weight of raw patty} \\ -\text{weight of cooked or reheated patty}\end{pmatrix}}{\text{Weight of raw patty}} \times 100$$

To measure the diameter of each patty before and after cooking, two points per patty were marked. After each patty was cooked or reheated, it was cooled down to room temperature. The diameter of raw, cooked and reheated patties were recorded using vernier calipers (530-122, Mitutoyo, Kawasaki, Japan) and calculated using the following expression.

$$\text{Reduction in diameter (\%)} = \frac{\begin{pmatrix}\text{Diameter of raw patty} \\ -\text{diameter of cooked or reheated patty}\end{pmatrix}}{\text{Diameter of raw patty}} \times 100$$

pH measurements

The pH of each sample was determined with a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). The pH value was measured by blending a 5 g sample with 20 mL distilled water for 60 sec in a homogenizer (Ultra-Turrax T25, Janke & Kunkel, Staufen, Germany).

Hardness measurements

The hardness of cooked and reheated patties was measured by a 0.25 ϕ spherical probe attached to a texture analyzer (TA-XT2*i*, Stable Micro Systems Ltd., Surrey, UK). The test conditions were as follows: stroke, 20 g; test speed, 2 mm/sec; and distance, 10.0 mm. Data on hardness were collected and analyzed (kg).

Moisture and fat contents

The moisture content (%) was determined by weight loss after 12 hr of drying at 105°C in a drying oven (SW-90D, Sang Woo Scientific Co., Bucheon, South Korea) using AOAC methods (2000). Fat content (%) was determined by the Soxhlet method with a solvent extraction system (Soxtec®Avanti 2050 Auto System, Foss Tecator AB, Höganas, Sweden).

Thermogram measurements

The surface and internal thermograms of patties immediately after cooking were measured with an IRISYS Universal Thermal Imager (IRI 1011, Infrared Intergrated Systems Ltd., Northants, U.K.) and a pocket PC (IPAQ rx1950, Hewlett-Packard Company, CA, USA).

Statistical analysis

For all variables measured, ANOVA was performed using a General Linear Model (GLM) procedure of the SAS statistical package (1999). The Duncan's multiple range test ($p<0.05$) was used to determine the differences between treatment means.

Results and Discussion

Effects of cooking method on ground pork patties with different salt and phosphate levels

Properties after cooking

Table 1 shows the properties of ground pork patties cooked by two different methods (electric grill and microwave oven). The cooking time of patties cooked by electric

Table 1. Properties of ground pork patties with different salt and phosphate levels cooked by different methods

Property	Electric grill cooking				Microwave oven cooking			
	S1	S1+P	S2	S2+P	S1	S1+P	S2	S2+P
Cooking time (s)	680.5 ±22.1^{B}	689.5 ±22.4^{B}	700.5 ±30.0^{AB}	719.0 ±35.7^{A}	201.2 ±21.0^{D}	210.6 ±19.1^{D}	238.7 ±22.8^{C}	244.0 ±17.2^{C}
Cooking rate (°C/min)	6.39± 0.75^{C}	6.31± 0.65^{C}	6.21± 0.53^{C}	6.05± 0.38^{C}	21.62± 2.50^{A}	20.71± 1.77^{A}	18.22± 1.85^{B}	17.83± 1.15^{B}
Cooking loss (%)	27.30± 2.19^{CD}	25.99± 1.94^{D}	26.85± 2.23^{D}	23.78± 2.99^{E}	34.16± 2.45^{A}	31.46± 2.10^{B}	32.65± 1.43^{B}	28.65± 2.86^{C}
Reduction in diameter (%)	22.58± 2.86^{B}	21.89± 2.67^{B}	22.30± 2.70^{B}	20.23± 2.43^{C}	25.11± 2.99^{A}	23.90± 2.80^{A}	24.59± 2.93^{A}	22.15± 2.79^{B}
Hardness (kg)	0.76± 0.08^{D}	0.79± 0.08^{D}	0.83± 0.08^{C}	1.07± 0.10^{A}	0.71± 0.06^{E}	0.71± 0.07^{E}	0.72± 0.07^{E}	0.87± 0.08^{B}
pH	6.10± 0.06^{C}	6.25± 0.03^{A}	6.11± 0.05^{C}	6.26± 0.03^{A}	6.14± 0.07^{B}	6.26± 0.02^{A}	6.15± 0.03^{B}	6.27± 0.02^{A}
Moisture content (%)	57.47± 2.58^{AB}	58.70± 2.04^{A}	57.73± 1.46^{AB}	58.01± 1.81^{A}	55.05± 3.78^{B}	57.25± 1.83^{AB}	56.68± 0.48^{AB}	57.28± 1.21^{AB}

S1, patties containing 1% salt and no phosphate; S1+P, patties containing 1% salt and 0.3% phosphate,
S2, patties containing 2% salt and no phosphate; S2+P, patties containing 2% salt and 0.3% phosphate
All values are the mean±standard deviation.
$^{A-E}$ Mean values with different superscripts within the same row are significantly different ($p<0.05$).

grill was 3 to 4 times longer than those cooked by microwave oven. In addition, cooking times significantly increased with the increasing salt and phosphate levels regardless of the cooking method ($p<0.05$). Chung and Chung (1993) reported that the rate of temperature rise in beef cooked by conventional heating is 10 to 20 times slower than beef cooked by microwave. Jeong *et al.* (2007) reported that the addition of salt influences the cooking time of ground patties cooked by microwave. The cooking rate by microwave oven was 2.9-3.5 times faster than by electric grill ($p<0.05$). The cooking rate was not significantly different among the samples cooked by electric grill, however patties supplemented with 1% salt cooked faster in a microwave oven than those with 2% salt. Cooking loss and reduction in the diameter of patties cooked by electrical grill were lower than patties cooked by microwave oven ($p<0.05$). The addition of phosphate to ground pork patties resulted in a slightly lower cooking loss and reduction in diameter, regardless of cooking method. The hardness of patties cooked by microwave oven was lower than that of patties cooked by electric grill ($p<0.05$). Patties with 2% salt and 0.3% phosphate had the highest level of hardness among samples cooked by the same method. Also, the pH values of patties treated with phosphate were highest among all formulations regardless of cooking method. The moisture content of S1+P and S2+P patties cooked by electric grill was higher than S1 patties cooked by microwave oven. These results support the reports of Moore *et al.* (1980) and Powell *et al.* (2000) showing that meat cooked in a microwave oven has greater cooking loss and lower hardness than meat cooked in a conventional oven. On the contrary, Jakobsson and Bengtson (1974) reported that ground beef patties cooked by microwave energy have less cooking loss than patties pan-fried or deep-fat fried.

Infrared thermogram

Fig. 1 shows the surface and internal thermograms of ground pork patties cooked by two cooking methods (electric grill and microwave oven). Immediately after cooking, infrared thermogram was used to determine the surface and internal temperature of the patties. Using this method, we determined whether or not the surface and internal temperature patterns of cooked patties were uniform. The result of this study shows that patties cooked by electric grill generally have uniform surface and internal thermograms. However, based on infrared thermograms (because center temperature differs from edge temperature), patties cooked by microwave oven are cooked non-uniformly. This supports the findings of Datta *et al.* (2005) who reported that non-uniformity is characteristic of microwave cooking, and combination with other cooking methods is recommended to solve this problem. This non-uniformity of microwave cooking also agrees with the results of Aktas and Ozilgen (1992) and Jeong *et al.* (2004).

Effects of reheating method on the properties of precooked pork patties with different salt and phosphate levels

Reheating rate, reheating loss, and reduction in diameter

The reheating rate, reheating loss and reduction in diameter of pork patties for each reheating method and NaCl/phosphate level are presented in Table 2. The reheating rate of patties reheated by electric grill (reheated by electric grill after cooking by electric grill (EGEG) or microwave oven cooked and electric grill reheated (MWEG)) ranged from 5 to 6 °C/min, and patties reheated by microwave oven (electric grill cooking and microwave oven reheating (EGMW), microwave oven cooking and microwave oven reheating (MWMW)) had a reheating rate of 23-30 °C/min. There was no difference in reheating rates among patties reheated by electric grill regardless of the reheating method, salt or phosphate level ($p>0.05$), however the S1 and S2 patties without phosphate had faster reheating rates than S1+P and S2+P patties with added phosphate among the samples reheated by microwave oven ($p<0.05$). When cooked and reheated by the same cooking method (EGEG, MWMW), the reheating rate by electric grill was slower than the cooking rate, however the reheating rate by microwave oven was faster than the cooking rate (Table 1). Moore *et al.* (1980) showed that cooking in a microwave oven reduces cooking time relative to cooking by electric grill. Lee *et al.* (2007) reported that the rate of temperature increase was faster in samples with higher moisture contents when cooked by microwave oven. Also, Jeong *et al.* (2007) found that the salt level had great influence on the cooking rate of patties.

There was higher reheating loss with patties reheated by microwave oven regardless of salt level or the addition of phosphate (Table 2). The MWMW method resulted in the highest reheating loss, and the lowest reheating loss was seen with the EGEG method. This agrees with the findings of Dawson and Sison (1973) that cooking loss of chicken pieces during microwave reheating were affected more by the cooking method than by the phosphate content, and after microwave reheating the phosphate-treated chicken had

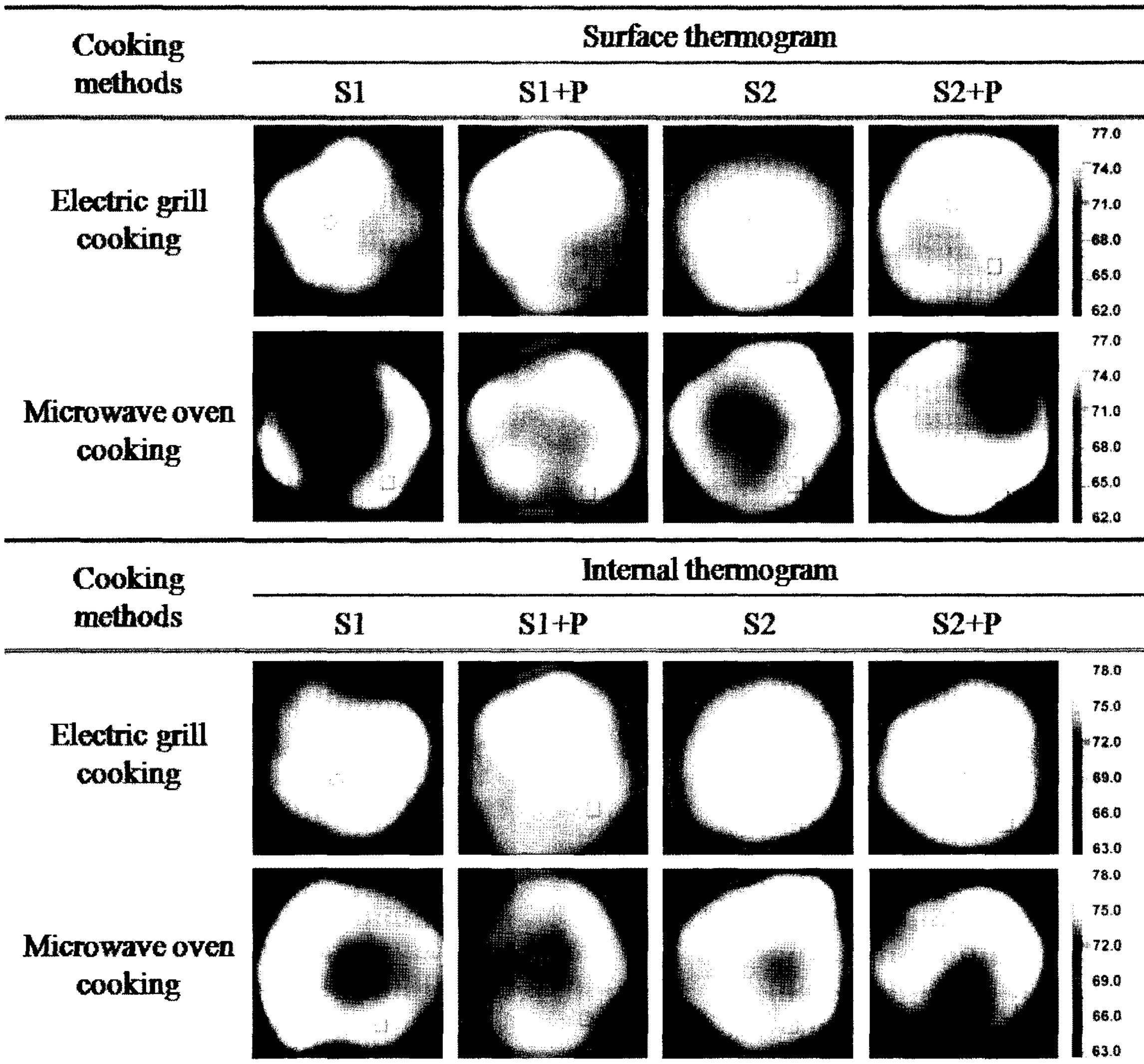

Fig. 1. Thermogram of ground pork patties with different salt and phosphate levels cooked by different methods (electric grill and microwave oven). S1, patties containing 1% salt and no phosphate; S1+P, patties containing 1% salt and 0.3% phosphate; S2, patties containing 2% salt and no phosphate, S2+P; patties containing 2% salt and 0.3% phosphate.

greater cooking yields than untreated pieces. Boles and Parrish (1990) reported that the addition of phosphate to meat products increases cooking yield and water holding capacity. Also, many researchers have found that cooking and/or reheating with microwave energy results in greater cooking loss than other cooking and reheating methods (Campbell and Mandigo, 1978; El-Shimi, 1992; Kirchner, 2000). As shown in this study, the reheating method has an effect on reheating loss and reduction in diameter. Similar to the results of reheating loss, reduction in diameter after reheating was higher after cooking regardless of salt level and whether to contain phosphate. However, reduction in diameter increased less than reheating loss (Table 2).

pH, moisture content, and hardness

The pH and moisture content of pork patties in relation to reheating method and NaCl/phosphate level are shown in Table 3. The pH of the S1+P and S2+P patties with added phosphate was higher than the pH of S1 and S2 patties, regardless of reheating method ($p<0.05$). The S1+P and S2+P patties reheated by the EGEG method had lower pH values than those reheated by other methods, but no significant differences in pH were observed among the patties reheated by different methods ($p>0.05$). Goutefongea (1992) reported that salt and phosphate added to meat products are used for relatively high pH (6.0) meat products, but El-Shimi (1992) and Keeton *et al.* (1983) found that cooking method does not significantly affect the pH value of reheat-

Table 2. Comparison of reheating rate, reheating loss, and reduction in diameter of ground pork patties according to reheating method and NaCl/phosphate level

Property	Reheating method 2)	Formulations 1)				
		S1	S1+P	S2	S2+P	SEM 3)
Reheating rate (°C/min)	EGEG	5.69^{Y}	5.60^{Y}	5.78^{Y}	5.68^{Y}	0.173
	EGMW	29.70^{AX}	25.09^{ABX}	26.88^{ABX}	23.46^{BX}	0.723
	MWEG	5.62^{Y}	5.57^{Y}	5.67^{Y}	5.62^{Y}	0.169
	MWMW	28.71^{AX}	25.05^{ABX}	25.75^{ABX}	23.70^{BX}	0.764
	SEM 3)	0.454	0.636	0.567	0.482	
Reheating loss (%)	EGEG	40.00^{AY}	37.69^{ABY}	38.06^{ABY}	35.77^{BY}	1.020
	EGMW	48.35^{X}	46.32^{X}	47.17^{X}	45.41^{X}	1.004
	MWEG	43.26^{AY}	41.03^{ABY}	41.33^{ABY}	38.13^{BY}	0.849
	MWMW	50.44^{X}	48.92^{X}	48.16^{X}	46.00^{X}	1.121
	SEM 3)	1.002	0.893	0.976	1.128	
Reduction in diameter (%)	EGEG	24.15^{Y}	23.39^{Y}	23.99^{Y}	22.94^{Y}	0.576
	EGMW	29.85^{XY}	29.14^{XY}	29.18^{XY}	28.99^{XY}	0.703
	MWEG	27.53^{XY}	27.02^{XY}	27.42^{XY}	27.06^{XY}	0.634
	MWMW	32.01^{X}	31.46^{X}	32.28^{X}	31.05^{X}	0.715
	SEM 3)	0.675	0.643	0.674	0.646	

1) The abbreviations are the same as in Table 1.
2) EGEG, electric grill cooking and electric grill reheating; EGMW, electric grill cooking and microwave oven reheating; MWEG, microwave oven cooking and electric grill reheating; MWMW, microwave oven cooking and microwave oven reheating.
3) Pooled standard error of the mean
A, B Mean values with different superscripts within the same row are significantly different (p<0.05).
X, Y Mean values with different superscripts within the same column are significantly different (p<0.05).

Table 3. Comparison of pH, moisture content, and hardness of ground pork patties according to reheating method and NaCl/phosphate level

Property	Reheating method 2)	Formulation 1)				
		S1	S1+P	S2	S2+P	SEM 3)
pH	EGEG	6.10^{BY}	6.22^{AY}	6.09^{BY}	6.22^{AY}	0.009
	EGMW	6.12^{BXY}	6.25^{AX}	6.15^{BXY}	6.25^{AX}	0.008
	MWEG	6.11^{BXY}	6.26^{AX}	6.13^{BXY}	6.27^{AX}	0.010
	MWMW	6.15^{BX}	6.24^{AXY}	6.16^{BX}	6.25^{AX}	0.009
	SEM 3)	0.011	0.008	0.009	0.009	
Moisture content (%)	EGEG	53.66^{X}	54.94^{X}	53.90^{X}	54.82^{X}	0.675
	EGMW	49.63^{Y}	52.20^{XY}	50.67^{XY}	51.90^{Y}	1.059
	MWEG	52.44^{X}	52.94^{XY}	52.37^{XY}	53.15^{XY}	0.491
	MWMW	49.79^{Y}	50.85^{Y}	49.28^{Y}	50.73^{Y}	0.737
	SEM 3)	0.634	0.642	1.080	0.619	
Hardness (kg)	EGEG	1.01^{BY}	1.05^{ABY}	1.07^{ABY}	1.15^{AY}	0.166
	EGMW	1.06^{BXY}	1.18^{ABX}	1.14^{ABXY}	1.31^{AX}	0.196
	MWEG	1.09^{BXY}	1.13^{AXY}	1.19^{AX}	1.19^{AXY}	0.174
	MWMW	1.13^{BX}	1.17^{ABX}	1.20^{ABX}	1.23^{AXY}	0.192
	SEM 3)	0.172	0.175	0.182	0.194	

1) The abbreviations are the same as in Table 1.
2) The abbreviations are the same as in Table 2.
3) Pooled standard error of the mean
A, B Mean values with different superscripts within the same row are significantly different (p<0.05).
X, Y Mean values with different superscripts within the same column are significantly different (p<0.05).

ed patties. Therefore, it can be said that phosphate in patties helps maintain a high pH even after reheating, though the reheating method does not have an influence on the pH of patties.

Patties reheated by electric grill (EGEG, MWEG) had greater moisture contents than those reheated by microwave oven (EGMW, MWMW), regardless of the salt level and the addition of phosphate (Table 3). Patties reheated by EGEG had the highest moisture content ($p<0.05$), and patties reheated by MWMW had the least moisture content ($p<0.05$). Patties with phosphate had higher moisture contents than those without phosphate ($p<0.05$). This agrees with the results of Campbell and Mandigo (1978) in which patties reheated by microwave had a lower moisture content than seen with conventional reheating. Also, Kirchner *et al.* (2000) reported that the moisture content of reheated patties was less than that of cooked patties. However, some studies have reported that a slower heating rate increases moisture loss (Obuz *et al.*, 2003; Foegeding *et al.*, 1986). Thus, the moisture content of patties is affected not only by cooking method but also by reheating method, and the addition of phosphate plays an important role in maintaining the moisture content of ground pork patties after reheating.

The hardness of pork patties according to reheating method and NaCl/phosphate level is presented in Table 3. Patties reheated by the MWMW method had the highest hardness values. The S1 patties with 1% salt showed significantly lower hardness than S2+P patties regardless of reheating method ($p<0.05$). The basis of this result is that the ionic strength of salt and phosphate added to the meat was very high and therefore the products were firmer (Knight, 1992). This result is consistent with the findings of Berry and Leddy (1984) in which lower hardness of beef patties was associated with conventional cooking compared to microwave oven cooking, and conventionally cooked meat was more tender than meat cooked by microwave (Korschgen and Baldwin, 1978). Also, there was a negative relationship between moisture content and hardness, that is, patties cooked and reheated by electric grill had high moisture contents and lower hardness, whereas patties cooked and reheated by microwave oven had lower moisture contents and higher hardness. The results of this study support the findings of Miller and Hoseney (1997), which showed that hardness may be reduced with an increase in moisture content. Contrary to this result, several studies reported lower tenderness after meat products were heated in a microwave oven compared with conventional heating (Moore *et al.*, 1980; Serrano *et al.*, 2007), while others found no significant difference in these properties (Voris and Van-Duyne, 1979).

According to the results of this study, it is an important consideration to select appropriate cooking and reheating methods for meat products. The quality properties of ground type meat products were influenced very highly by the method of cooking and reheating, and the addition of phosphate also affected the reheating properties of meat products. In addition, if use of a microwave oven is necessary, it may be more desirable to cook using a combination of procedures involving dry and moist-heat methods. Further research on the properties of precooked meat products is needed.

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