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Quality Characteristics of Beef by Different Cooking Methods for Frozen Home Meal Replacements

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Abstract

Blanching beef for use in home meal replacements (HMR) is an important process that determines the final quality of the beef after the cooking process. Thermal pretreatment also minimizes the change in quality during the main cooking process or storage. In this study, beef samples were washed and sliced, then treated by immersion in boiling water (1-10 min), steaming (1-10 min), or pan-frying in oil (30-240 s). The color after each thermal treatment showed higher L* and b* values and lower a* values compared with the raw beef, except for the pan-frying thermal treatment. The total color difference (ΔE) and pH value were significantly increased by pan-frying ($p<0.05$). There was no significant difference in the shear force of the beef samples, except for the sample pan-fried for 210 s. The nutritional content of beef was measured as the moisture, protein, fat, and ash contents, which were 69.96, 16.64, 3.49, and 1.13%, respectively, in raw beef. After thermal treatment, the crude protein and fat contents were increased, whereas the moisture and ash contents decreased. The mineral content, including Na, Mg, Fe, and Ca was highest after pan-frying. The heat treatment decreased microorganisms in all the samples. The total bacteria count in raw beef was 4.5-4.7 Log CFU/g, whereas the bacteria count decreased to 2.2-2.8 Log CFU/g after blanching. Thermophilic bacteria, coliform, mold, and yeast not detected in any thermally treated sample.

Keywords: blanching method, beef, home meal replacement, quality characteristics

Introduction

The rapid growth of the home meal replacement (HMR) category in recent years have been attributed to the needs of the western life style of consumers and high technique for new products (Scollan *et al.*, 2006; Sorenson *et al.*, 2011). Consumers prefer fast or convenient food owing to a lack of time, increasing numbers of working women, lack of cooking skills, and a growing number of small- and single-households (Kanzler *et al.*, 2015). When consumers do not have time to have dinner at a restaurant, they are likely to have meals that can provide tasty, nutritional, and high quality food. An HMR is a meal solution that has been produce away from the home for in-house consumption. There are diverse types of HMR products that offer consumers the option of partially or fully replacing homemade meals (Costa *et al.*, 2001).

Recently, HMR products have attracted significant attention in Korea. In general, the Korean style of HMR products consists of rice, vegetables, and/or meat. In particular, meat has been recognized as the most important component of a main dish for supplying protein and is preferred by consumers. The quality of the meat mostly depends on the color, tenderness, and flavor. Many studies have reported the quality of cooked meat following heat treatment in terms of flavor, color, and hardness (Kim *et al.*, 2012; Mancini and Hunt, 2005; Tornberg, 2005; Vasanthi *et al.*, 2007). Thermal treatment of HMR products is the most important process for determining the final quality of the product and its shelf life. A wide range of treatments have been used in the food industry, such as preheating, cooking, blanching, pasteurization, sterilization, and extraction of food products (Lemmens *et al.*, 2009). One significant process is the blanching of meat and vegetables, which can help prevent the deterioration of food quality during conservation by freezing or in the cold chain system (Mukherjee and Chattopadhyay, 2007).

It was reported that blanching does not affect the firmness of vegetables, fruits, and meat products. In addition,

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this process provides safety of decomposition and excellent texture preservation (Verlinden *et al*., 2000). Thermal treatment (blanching) is commonly carried out before freezing because it inactivates the enzymes responsible for quality degradation and destroys vegetative microbial cells, allowing for stabilization and product quality retention during storage (Gonçalves *et al*., 2009). In addition, blanching prevents discoloration and the development of an unpleasant taste. Immersion in boiling water is one heating process that is commonly used to inactivate enzymes in fruits and vegetables. This process can also remove air from the intercellular spaces in fruits or vegetables (Krokida *et al*., 2000; Lin and Brewer, 2005). Many researchers have reported steam blanching to be superior to conventional blanching methods for reducing the amount of nutrients lost owing to cooking time, as well as keeping the cell structures intact (Kowalska *et al*., 2008). A short heating step at the beginning of processing maintains the original color of vegetables and fruits through the inactivation of enzymes and reduces the initial microbial levels in meat. However, this heating could also increase the oxidation of meat and reduce the quality of the processed vegetables, fruits, and meat products (Jesus *et al*., 2014). Thus, most studies have been designed to investigate the effects of different blanching methods on various vegetables, fruits, and meats before undergoing conventional freezing (Quenzer and Burns, 1981).

Although there are a few studies on the heat treatment of meat for HMR products, researchers have mostly studied blanching treatments for vegetables. Therefore, the objectives of this study were to evaluate the quality characteristics of blanched beef under varying conditions for use in HMR products.

Materials and Methods

Materials

Fresh beef samples (eye of round) were purchased from a commercial market (48 h postmortem, pH 5.7-5.9). Lactic acid, succinic acid, fumaric acid, and 3M-Petrifilm (plate count agar, coli-form) were obtained commercially from Sigma-Aldrich (USA).

Blanching treatment

Before thermal treatment, the fatwas removed from the beef samples, and then the lean meat was washed with distilled water. The beef was sliced into 0.5 × 0.5 × 5 cm pieces parallel to the fiber direction. The sliced beef was heated using a hot water boiling treatment, a steaming treatment, or a pan-frying method with vegetable oil. For the hot water boiling treatment, 500 g of sliced beef was immersed in 2.5 L boiling water. For the steaming treatment, 500 g of sliced beef was put in a pot with steam vapor. For these treatments, samples were collected every 1 min for 10 min and subsequently cooled down in ice water for 30 s. To remove water, the samples were centrifuged at 300 rpm for 2 min. For the pan-frying method, 500 g of sliced beef was cooked using a frying pan. Samples were collected every 30 s for 240 s. The fried beef was cooled down to room temperature.

Color measurement

The color change of each sample was determined using a colorimeter (CR-300, Minolta Camera Co. Ltd, Japan) that was calibrated with a white standard plate (L*=77.1, a*=2.1, b*=2.2). The CIE L*, a*, and b* values were determined as indicators of brightness (L), red to green color (a), and yellow to blue color (b). To measure the color changes, four pieces of beef were arranged in the direction of long length. The total color difference (ΔE) was numerically calculated using the color difference between the fresh meat and the treated samples using the following equation:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

pH measurement

Two grams of each sample was mixed with 18 mL of water and homogenized at 12,000 rpm for 3 min using a homogenizer (HP-91, SMT Co. Ltd., Japan). The pH of the prepared samples was measured using a pH meter (Orion 3 Star, Thermo Scientific, Japan).

Shear force measurement

Samples from each batch were cut into cuboids (5 × 0.5 × 0.5 cm). Each sample was placed on a flat board. The hardness of the samples was determined using a texture analyzer (CT3; Brookfield Co. Ltd., USA) with a stainless steel TA3cutting type probe. The measurements were obtained using the following parameters: texture profile analysis (TPA) type, 10 kg force load cell, 300 trigger load, 2.5 m/s test speed, and target distance 5 mm hardness. The maximum peak force (g) was used as the indicator of texture parameter. Five replicate measurements were performed for each treatment.

Proximate composition

The moisture, protein, fat, and ash contents of the beef

samples were determined according to the standard methods (AOAC, 1990). The moisture content was determined by drying the sample in an oven at 105°C to a constant weight. Subsequently, for ash estimation, the dried samples were placed in a muffle furnace at 550°C for 24 h. The protein content was determined by the Kjeldahl method (N × 6.25) using a Kjeltec 2050 Analyzer (Foss, Sweden). The fat content was analyzed using a Soxhlet apparatus (Soxtec 2050, Foss, Sweden) with ether as the solvent.

Microbial count

For the determination of microbial contamination, 25 g of sample was diluted ten times with sterilized 0.85% NaCl solution. The diluted samples were homogenized for 60 s with a stomacher (Steward Laboratory, UK). Subsequently, decimal dilution series were prepared and placed on a 3M Petrifilm (Petrifilm, 3M, USA). The dishes were shifted to an incubator (GSP-9080 MBE, Shanghai Boxun Industry & Commerce Co., Ltd., China) for 2 d at 35°C. The colonies in each sample were counted (CFU/mL) by multiplying with the reciprocal of the dilution. The results were expressed as log colony-forming units (CFU)/mL of sample.

The pour plate method was used to determine the total yeast and mold counts. A known amount (39 g) of potato dextrose agar (PDA) powder was dissolved in 1 L of distilled water to prepare the media. To avoid cross contamination, tartaric acid in distilled water (1:9, w/v) was added to the PDA. All petri dishes containing PDA were placed in an incubator at 32±1°C. After two days, the yeast and mold in each petri dish were counted and the results were shown as CFU/mL. All determinations were carried out in triplicate.

Statistical analysis

All reported values are the average of three (or more) experiments. Analysis of variance and Duncan's test were carried out at the 95% confidence level ($p \leq 0.05$) using the SPSS 20.0 software (SPSS Institute, USA) to determine significant differences in the results.

Results and Discussion

Color

The color of the treated samples was compared with that of raw beef; all thermal treatments had higher L* and b* values and lower a* values than raw beef, except for the fried samples (Table 1). In the case of the pan-frying thermal treatment, the L* and b* values increased up to 60 s of heating time, and above 60 s these values decreased significantly ($p<0.05$), mainly owing to over-cooking at the relatively higher oil temperature. In general, thermal treatment resulted in the denaturation of meat pro-

Table 1. Quantitative changes in the color in beef using different blanching treatments

Treatments[1]		Time (s)									
		60	120	180	240	300	360	420	480	540	600
Boiling-water	L	42.50± 3.75[a]	47.05± 2.15[a]	39.35± 0.35[cd]	41.00± 1.70[c]	41.60± 1.10[bc]	42.60± 1.50[bc]	41.65± 0.15[bc]	40.35± 1.55[c]	43.15± 3.15[bc]	35.30± 2.10[e]
	a	13.45± 0.45[c]	14.80± 0.90[bc]	14.25± 1.25[bc]	14.35± 0.05[bc]	15.50± 0.55[b]	14.35± 0.05[bc]	15.15± 1.65[bc]	13.70± 1.20[c]	15.10± 0.20[bc]	15.55± 0.15[b]
	b	15.70± 0.50[ef]	16.45± 0.35[bcde]	15.90± 0.60[def]	16.20± 0.30[cdef]	18.25± 0.55[a]	16.10± 0.80[def]	17.35± 1.65[abc]	16.10± 0.40[def]	17.55± 0.15[ab]	17.10± 0.01[abcd]
Steaming	L	46.60± 2.01[ab]	46.10± 1.10[bc]	44.75± 4.05[bc]	45.25± 2.05[bc]	49.25± 1.75[a]	47.90± 0.80[ab]	47.05± 1.95[ab]	42.70± 0.80[c]	47.20± 0.20[ab]	45.40± 0.80[bc]
	a	24.10± 0.60[a]	14.90± 1.30[bc]	13.70± 2.10[c]	15.90± 0.10[b]	15.70± 0.40[b]	15.55± 0.05[b]	15.30± 0.01[bc]	15.50± 0.90[b]	14.90± 0.30[bc]	14.55± 0.25[bc]
	b	18.60± 0.90[a]	17.05± 1.45[ab]	16.20± 2.60[bc]	17.80± 0.10[ab]	18.30± 0.30[a]	17.90± 0.10[ab]	18.00± 0.10[ab]	17.95± 0.55[ab]	17.95± 0.25[ab]	17.40± 0.40[ab]
		30	60	90	120	150	180				
Pan-frying	L	40.20± 1.40[a]	40.45± 4.25[a]	36.50± 0.80[a]	27.70± 2.90[b]	22.20± 5.50[c]	16.95± 0.35[c]	-	-	-	-
	a	15.85± 0.55[c]	16.95± 1.35[bc]	18.45± 0.05[b]	16.80± 0.20[bc]	12.75± 1.15[d]	13.30± 0.60[d]	-	-	-	-
	b	18.05± 0.35[b]	20.30± 0.70[a]	20.45± 1.45[a]	14.90± 1.90[c]	11.60± 0.50[c]	9.85± 0.15[d]	-	-	-	-

[a-f]Means within the same row with different superscript letters are different ($p<0.05$).
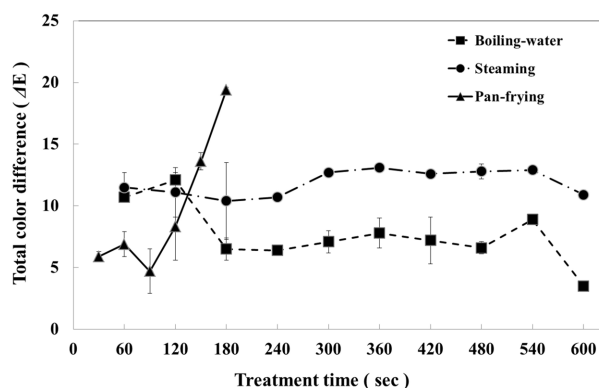[1]The color of raw beef: L*, 36.54±2.01; a*, 24.47±1.47; b*, 15.10±0.1.

Fig. 1. Quantitative changes in the total color difference (ΔE) of beef using different blanching treatments. Mean± standard deviation of triplicate determinations (n=3).

teins, and the beef samples became lighter in appearance and had less red color (Shabbir et al., 2015). Among the treatments, cooking time had no significant effect on the L*, a*, or b* values, except for the frying treatment. The L* and b* values decreased for frying times greater than 90 and 120 s, respectively, and the a* value was higher for the 90 s cooking time.

It is likely that the pan-frying blanching method provided a higher blanching temperature than the other methods and the chemical state of the meat pigment shifted from oxymyoglobin to hemichrome (Filiz et al., 2006; Young and West, 2001). Although the steaming treatment tended to produce a slightly lighter beef color than the boiling treatment, the color change obtained with these two blanching methods was similar. Consequently, the color changes manifested as an increase in the total color difference, as depicted in Fig. 1. In the case of the steaming and boiling treatments, ΔE did not change with an increase of the blanching time ($p > 0.05$). However, a pronounced increase in ΔE from 8.5 to 19.4 units was observed between 120 and 180 s for the pan-frying treatment, whereas a distinct decrease from 13.5 to 7.5 units was observed between 120 and 180 s for the boiling treatment. Consumers find the discoloration of meat a nega-

tive attribute, and the color obtained in the present study using the pan-frying method would be more favorable for use in HMR products (Lee, 2009).

pH

In this study, the pH of the samples obtained using the boiling and steaming treatments changed from 5.63 (fresh control) to 5.89 (blanching for 600 s), and the pH of the treated samples did not vary significantly during the processing time (Table 2). On the other hand, the pH of the samples that were pan-fried steeply increased compared with the other two methods ($p < 0.05$) and a pH of 5.94 was obtained after 180 s of blanching. The pH of meat is an important indication of the physical state of the muscle proteins (Kim and Lee, 2011). Meat proteins have been identified to undergo spontaneous unfolding and denaturation through thermal treatment (Shabbir et al., 2015). Thermal processing can eventually cause the structural integrity of the natural proteins to disappear and the protein structure to change (Christensen, 2000; Demeyer et al., 1979).

The most well documented mechanism that accounts for the increase of the pH of meat after thermal processing involves burying acidic amino acids and exposing basic amino acids (Fletcher et al., 2000). Therefore, the larger pH increase observed with the pan-frying treatment indicated that the proteins were more denatured owing to the higher blanching temperature than when the boiling or steaming treatments were used.
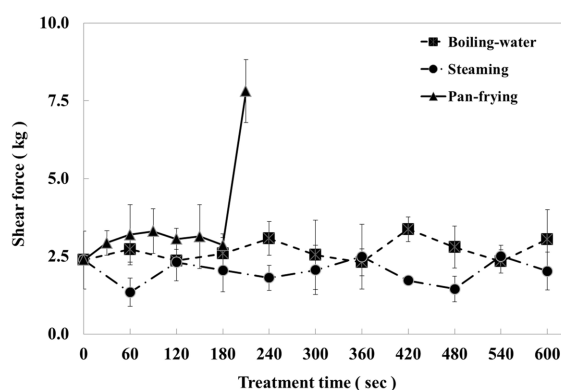
Shear force

Fig. 2 presents the shear force of blanched beef with processing time. Fresh beef had a shear force of 2.4 kg, which was not significantly changed by blanching. However, a steep increase in the shear force of beef was observed for samples pan-fried for more than 180 s, with the shear force increasing to 8 kg ($p < 0.05$). This phenomenon can be explained by the increased surface firmness following frying. The actual frying temperature of the oil is more than 190°C, and the moisture in the beef is easily

Table 2. Quantitative changes in the pH in beef using different blanching treatments

Treatments[1]	Time (s)									
	60	120	180	240	300	360	420	480	540	600
Boiling-water	5.81±0.02[b]	5.84±0.01[ab]	5.86±0.02[ab]	5.91±0.04[a]	5.86±0.02[ab]	5.88±0.02[a]	5.91±0.01[a]	5.89±0.02[a]	5.88±0.01[ab]	5.89±0.03[a]
Steaming	5.79±0.02[a]	5.84±0.01[a]	5.80±0.01[a]	5.83±0.01[a]	5.80±0.04[a]	5.81±0.02[a]	5.84±0.01[a]	5.83±0.01[a]	5.82±0.02[a]	5.80±0.01[a]
	30	60	90	120	150	180	-	-	-	-
Pan-frying	5.83±0.01[c]	5.84±0.01[bc]	5.85±0.02[b]	5.87±0.01[b]	5.92±0.01[a]	5.94±0.01[a]	-	-	-	-

[a-c]Means within the same row with different superscript letters are different ($p < 0.05$) according to Duncan's multiple range test.
[1]pH of raw beef: 5.63±0.05.

Fig. 2. Quantitative changes in the shear force of beef using different blanching treatments. Mean±standard deviation of triplicate determinations (n=3).

evaporated. As a result, the pan-fried beef had a firm and crispy surface, which resulted in a higher shear force (Shabbir *et al*., 2015). An interesting investigation of an HMR product showed that, in particular, the tenderness of beef is essential to the cooked beef quality (Yang and Ko, 2010). From this point of view, the steaming process appears to be the most suitable method to obtain a tender texture. In the present study, the shear force of steamed beef was similar or slightly lower than that of the fresh control. For the boiling treatment, there was no change in the tenderness of the beef with blanching time in this study; however, one could expect that this method would result in nutritional loss (Clariana *et al*., 2011; Lee, 2009). Overall, the pan-frying method is acceptable to maintain the quality of the beef in terms of low shear force and minimization of nutritional loss. Yildiz-Turp *et al.* (2013) reported that meat cooked by super-heated steam resulted in rapid denaturation of the meat surface, which prevented drip loss during thermal processing.

All materials included in HMR products have to be completely cooked prior to packaging because of the ready-to-eat characteristics of these products. The above results indicate that pan-frying has a potential advantage in minimizing the blanching time of beef compared with steaming or boiling. To avoid a high shear force of beef, it is suggested that the pan-frying blanching should not exceed forces.

Proximate composition

The optimal time of each treatment were selected through the results from physicoproperties such as the contents of the color, pH and texture. The selected time at each treatment is the change point of hardness or color. In order to compare the different properties between more rigid texture and more soft texture for the frozen food, the time of heating was selected such as hot water treatment at 2 min, 4 min, steam treatment at 3 min, 5 min and pan frying treatment 1 min, 2 min, respectably. The proximate compositions of the raw and cooked beef samples are presented in Table 3. The moisture, protein, fat, and ash contents in fresh beef were 69.96, 16.64, 3.49, and 1.13%, respectively. The proximate composition of beef was significantly ($p<0.05$) affected by cooking. Cooking significantly ($p<0.05$) increased the protein contents (21.72-25.26%) and reduced the moisture (61.10-63.93%) and ash contents (0.48-0.92%). Water is probably lost from the beef samples owing to heat-induced protein denaturation during cooking, which causes less water to be entrapped within the protein structures (Juárez *et al*., 2010). The increases in protein content could be explained by this reduction in moisture. In addition, the decreases in ash content may be caused by diffusion into the cooking water. The fat content significantly ($p<0.05$) increased during frying owing to the addition of oil.

It was expected that blanching manifested the moisture loss of beef, which compensated for the cooking loss. Normally, meat exhibits drip loss during cooking owing to the denaturation of muscle proteins (Juárez *et al*., 2010). The observed mineral loss was consistent with moisture loss, and the highest loss was observed for the steaming me-

Table 3. Quantitative changes in the general composition of beef using different blanching treatments

Treatments	Time (s)	Cooking loss (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude ash (%)
Control	0	-	69.96±0.95[a1)]	16.64±0.75[e]	3.49±0.14[b]	1.13±0.09[a]
Boiling-water	120	37.17	61.10±0.60[c]	24.52±0.73[ab]	3.34±0.16[b]	0.57±0.01[d]
	240	39.20	61.68±1.26[c]	25.26±1.34[a]	3.37±0.09[b]	048±0.01[e]
Steaming	180	35.60	61.26±0.49[c]	23.92±0.56[ab]	3.28±0.40[b]	0.75±0.02[c]
	300	38.04	61.46±0.31[c]	23.21±0.84[bc]	3.27±0.11[b]	0.68±0.02[c]
Pan-frying	60	31.23	63.93±0.35[b]	21.72±0.21[d]	4.66±0.22[a]	0.92±0.02[b]
	120	35.61	62.27±1.11[c]	22.32±0.03[cd]	4.74±0.21[a]	0.88±0.07[b]

[a-e]Means within the same column with different superscript letters are different ($p<0.05$) according to Duncan's multiple range test.

Table 4. Quantitative changes in the mineral composition of beef using different blanching treatments

Treatments	Time (s)	Na (mg%)	Mg (mg%)	Fe (mg%)	Ca (mg%)
Control	0	63.44±3.52 [a]	25.24±0.46[a]	2.95±0.36[c]	5.28±0.10[c]
Boiling-water	120	54.39±6.51[ab]	19.73±0.46[c]	3.88±0.07[a]	5.73±0.63[bc]
	240	52.16±3.51[b]	17.54±0.14[e]	3.76±0.12[ab]	5.28±0.47[c]
Steaming	180	57.49±2.82[ab]	18.81±0.29[d]	2.83±0.15[c]	5.71±0.27[bc]
	300	54.62±7.06[ab]	18.49±0.77[d]	2.85±0.33[ab]	5.43±0.08[c]
Pan-frying	60	54.49±4.75[ab]	21.55±0.74[b]	3.08±0.15[c]	6.30±0.20[ab]
	120	58.04±0.05[ab]	21.75±0.02[b]	3.46±0.00[b]	6.53±0.01[a]

[a-e]Means within the same column with different superscript letters are different ($p<0.05$).

Table 5. Quantitative changes of the microbial count in beef using different blanching treatments

Treatments	Time (s)	Microorganism (Log CFU/g)					
		Thermophilic bacteria	Total bacteria	Psychrophilic bacteria	Coliform	Mold	Yeast
Control	0	ND[1]	4.54±0.03[a]	4.74±0.06[a]	ND	ND	ND
Boiling-water	120	ND	2.44±0.05[c]	2.56±0.03[de]	ND	ND	ND
	240	ND	2.27±0.09[d]	2.45±0.10[ef]	ND	ND	ND
Steaming	180	ND	2.47±0.08[c]	2.42±0.13[f]	ND	ND	ND
	300	ND	2.21±0.08[d]	2.61±0.05[cd]	ND	ND	ND
Pan-frying	60	ND	3.51±0.09[b]	2.71±0.05[bc]	ND	ND	ND
	120	ND	2.47±0.08[c]	2.84±0.05[b]	ND	ND	ND

[a-f]Means within the same column with different superscript letters are different ($p<0.05$).
[1]ND, Not detected.

thod. The mineral compositions of the raw and cooked beef samples are presented in Table 4. The highest content of iron was observed in the boiled beef samples, followed by the pan-fried samples. The calcium content was high in the pan-fried samples, but the boiled and steamed samples had the same content. It was assumed that the iron content was not affected by thermal treatment; sometimes the water used for cooking increases the iron content in cooked foods (Park and Choi, 2004). To minimize mineral loss, therefore, pan-frying was recommended as the best blanching method for beef.

Microorganism count

These analyses were conducted to determine the effect of thermal treatment on the indigenous microorganisms in the beef samples. The reductions of microbial count (Log CFU g^{-1}) after blanching treatment using the various methods are shown in Table 5. The blanched beef samples showed lower initial counts of microorganisms than the fresh control sample ($p<0.05$), which indicates that the initial preheating of the beef effectively reduced the initial microbial count. The total bacteria, psychrotrophic bacteria, coliform bacteria, mold, and yeast counts were significantly reduced after thermal treatment. A reduction of 2-3 log scale units was observed for the total viable count and psychrophiles, whereas the thermophile and coli forms

were completely inactivated.

These pretreatments would increase the shelf life of the products after processing (Jun and Lee, 2014). An initial thermal blanching step is normally applied in industry to inactivate oxidative enzymes in food and to reduce the contamination by microorganisms (Lee et al., 2002; Lee et al., 2011). Jesus et al. (2014) reported that blanched samples showed lower initial counts of microorganisms than samples that had not been heat treated, which indicates that the initial thermal treatment was effective to reduce the original microbial count.

Conclusion

This study compared the effect of different blanching methods on the properties of beef for HMR products. Blanching techniques, such as boiling, steaming, and pan-frying of meat, reduced the microorganism content and nutritional loss during storage. Further research on storage and packaging systems will be required to apply this technique in HMR products.

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