Quality Characteristics of Frozen Beef Developed into Home Meal Replacement Products Under Various Storage Conditions

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Abstract

Blanching and freezing of beef are important techniques used in developing frozen home meal replacement (HMR) products. These pre-thermal treatments minimize the deterioration of beef during storage. Beefs are washed, defatted, sliced (5.0×0.5×0.5 cm, fiber direction), and blanched by immersion in hot water for 2 min. Thereafter, the blanched beefs are spin-dried and frozen by individual quick freezing (IQF) method. Finally, the frozen beefs are packed using two methods: vacuum packages and air-containing packages. Packed beefs are stored at -12°C, -18°C, and -24°C for nine months. One in every three months, they are thawed in a microwave (400W). While thawing, vacuum-packed samples possess lower thawing loss than air-containing-packed ones. Compared to raw beef, blanched beef have a higher L* and lower a* value. However, less changes are observed after blanching the beefs as the enzymes get inactivated in the blanching process. Shear force of beef also increase through blanching. Moreover, vacuum-packed samples have maintained their hardness to a greater extent than the air-containing-packed samples. All the samples have met microbial safety standards. Thus, it is inferred that vacuum-packaging and -18°C storage temperatures are the best condition for maintaining beef that is later developed into HMR product.

Key words: individual quick freezing, beef, freezing storage, home meal replacement, quality characteristics

Introduction

The growth in convenience food industry has been attributed to various reasons, including increasing number of working women and single household, variable meal time, shortage of time, and lack of cooking skills (Kanzler et al., 2015). Furthermore, single servings and products with small pack size are more in demand, which has boosted the growth of convenience food industry. In this context, home meal replacement (HMR) has emerged as a great solution.

To manufacture processed meat products, the meat processing industry has frozen and thawed only raw meat untill date. The meat products processed from raw meat require a long time for thawing, so a considerable amount of time is lapsed before they can be served during meals. Apart from this, there may be problems associated with the cooking aspect of these products, such as irregular heating, inadequate thawing, and microbial contamination. Frozen convenience food requires minimum heat treatment before they could be served in meals. In summary, pre-thermal treatment must be used in meat processing industry for cooking frozen meat products either partially or completely; these are convenience foods that have undergone extensive processing.

Hot water blanching has been used as a sub-cooking method in this research study. It was expected that blanching would inactivate enzymes and decrease microbial activity (Cano, 1996). In addition, blanching treatment prevents the development of unpleasant odors in meat (Gonçalves et al., 2009). Furthermore, Individual Quick Freezing (IQF) technology is used to minimize tissue deterioration of blanched beef, a process that is caused by ice crystal formation in beef that is frozen and stored. With the help of IQF technology, food samples are frozen through ultra-fast freezing in an air blast freezer at an extremely low temperature range of -30 to -40°C; this process leads to the formation of fine intracellular ice crystals and diminishes thawing loss (Zhou et al., 2010; Jo et al., 2014). Frozen storage not only helps in prolonging the shelf life of meat but also helps in preventing microbial and chemical changes in the meat (Lawrie & Ledward, 2006).

In this research, beef was chosen as an ingredient as it is widely used in Korean cuisine and generates tremendous public interest (Lee et al., 1990; Yoon & Woo, 1999). The aim

of this research is to devise an optimum storing condition for frozen beefs that could be used in preparing HMR products.

Materials and Methods

Materials

The fresh beefs (round of beef) were purchased from a wholesale market in Suwon, Korea. Plate count agar (PCA) was purchased by Difco Laboratories (Detroit, MI, USA).

Sample preparation

Before treatment, the fatty portions of raw beefs were removed. Then, the remaining lean meat of raw beefs was washed and cleaned with distilled water. Parallel to the fiber direction, the beefs were sliced, each slice having a dimension of $5.0 \times 0.5 \times 0.5$ cm^2. The beef slices were subjected to hot water boiling blanching for two minutes. The ratio of beef slices to hot water was about 1:4. After blanching, these thermally treated beefs were immediately soaked in cold water to reduce the heat of beefs. The beefs were cooled and then spin-dried for 3 minutes in a spin-dryer. This process helped in removing water from the exterior of beefs. Thermally treated beefs were frozen individually through individual quick freezing (IQF) technology at -40°C temperature. For this purpose, the IQF freezer (Chunil food Ltd., Seoul, Korea) was used. Then, beefs were packed using two packing methods: vacuum packaging and air-containing packaging. Vacuum-packed beefs were packed using 200 g of frozen beefs in every package; the vacuum package machine was operated for packaging these beef items. On the other hand, air-containing packed beefs were packed using 200 g of same frozen beefs in a package: air-containing package machine was operated for packaging these beef items. After packaging, all the packed samples were stored for 9 mon in a freezer at the following temperatures: -12°C, -18°C, and -24°C respectively, which means general temperature of freezing storage for consumer (-18°C) and its above and below. Once in every three months, the samples were thawed by heating in a microwave (400 W, 5 min). Then, physico- chemical properties of these samples were evaluated.

Thawing loss

The thawing loss of thawed beefs was calculated by taking into consideration the known weights of beefs before and after thawing. Thawing loss was defined as per the following formula:

Thawing loss (%)

$$= \frac{\text{weight of frozen beef} - \text{weight of thawed beef}}{\text{weight of frozen beef}} \times 100$$

Color measurement

The color changes of samples were measured using a colorimeter (CR-300, Konica Minolta Sensing Inc., Kyoto, Japan) and calibrated with the white standard plate (L*=77.1, a*=2.1, b*= 2.2). The CIE (International Commission on Illumination; abbreviated CIE for its French name) L*, a*, and b* values were measured as indicators of L* (brightness), a* (redness), and b* (yellowness), respectively. For the measurement of color, three pieces of samples were attached to the long direction. Total color differences (ΔE) were calculated as the color difference between the raw beef and treated samples using the following equation:

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

pH measurement

Two grams of a sample was added to 18 mL of distilled water and homogenized at 12,000 rpm for 1 min using a homogenizer (HP-91, SMT Co. Ltd., Tokyo, Japan). The pH of homogenized samples was measured using a pH meter (Orion 3 star, Thermo scientific, Waltham, MA, USA).

Shear force measurement

All the cuboids ($5.0 \times 0.5 \times 0.5$ cm^2) formed samples were placed individually on a flat board in the vertical direction against the muscle fiber. The hardness of samples was measured using a texture analyzer (CT3-1000, Brookfield Co. Ltd., Middleboro, MA, USA) having a TA3 probe made from stainless steel; this probe was used for cutting. The samples were measured on the basis of the following parameters: compression type, 10 kg force load cell, 300 g trigger load, 2.5 mm/s test speed, and a target distance 5 mm. The hardness (Maximum peak force, g) was a texture parameter of samples. All these treatments were replicated five times.

Statistical analysis

Statistical analysis was conducted using software SPSS 20.0 (SPSS Institute, Chicago, IL, USA). Duncan's test was performed for analyzing variance at a confidence level of 95% (p=0.05) in two-ways.

Results and Discussion

Effects on beefs with blanching treatment

Thermal treatment is a necessary step to cooking for meat and makes it digestible (Shabbir et al., 2015). Blanching treatment of beef changed its properties such as hardness, pH and color (Ma & Ledward, 2004). In this research, the hardness of beef increased from 2.7 kg to 4.1 kg with thermal treatment (Table 1). The L^* value had an increase, whereas the a^* value showed a decline. The b^* value didn't showed any large change, reducing from 11.94 to 11.35. As expectedly, an increase of pH and a decrease of total aerobic bacteria level were observed. These changes were attributed to the unfolding and denaturation of protein through thermal treatment (Shabbir et al., 2015).

Thawing loss

During the freezing process, intracellular juice of beefs is expelled by osmosis into the extracellular region. This facilitates the formation of ice crystals, causing juice loss from beefs during thawing. These effects can influence the quality of beefs (Pietrasik & Janz, 2009).

In this research study, all the frozen samples were thawed in amicro wave before evaluating physicochemical properties. Moreover, the extracellular juice generated during thawing was removed. In all the samples, thawing loss increased with increase in temperature of freezing (Fig. 1). It was observed that the tendency that increased thawing storage loss intensified at higher storing temperature. The beefs stored at -12°C had the highest thawing loss when the samples were packaged by the two packaging methods: vacuum packaging and air-containing packaging. In vacuum-packed beefs, the samples stored at -12°C had the highest thawing loss, whereas the thawing loss of samples stored at -18 and -24°C were less than

Table 1. Change in the physicochemical properties of raw and blanched beefs

Measurements	Treatments[1]	
	Raw	Hot water blanched
Hardness (kg)	2.7±0.20	4.1±0.30
L^*	37.16±1.63	50.37±1.48
a^*	21.94±1.42	6.15±0.12
b^*	11.94±1.09	11.35±0.30
pH	5.67±0.02	5.78±0.03
Total aerobic bacteria (log CFU/g)	3.29±0.07	2.26±0.24

[1]Raw beef without thermal treatment; Hot water blanched beef before freezing treatment.
*Mean ± standard deviation of multiple determinations (n>3).

1.3%. At the same storage temperatures, atmosphere-packed beefs underwent higher thawing loss than vacuum-packed ones. The samples stored at -12 and -18°C had higher thawing loss, which ultimately exceeded 10% in the 9-mon duration of freezing. The atmosphere-packed beef samples stored at -24°C also had around 4% loss in the thawing process, which was comparatively higher than that undergone by vacuum-packed ones.

As only drip loss of thawing process affects the properties of beef, it is possible to enhance the entire quality of meat (Tsukamasa et al., 1992; Yu et al., 2010). Kim et al. (2013) have reported that microwave is the best thawing method for frozen beefs. The thawing losses of frozen beef, which is obtained from the round, were in the range of 1.3-2.5%. Considering drip loss after thawing treatment, vacuum packaging was more effective for freeze storing of beef than air-containing packaging.

Color

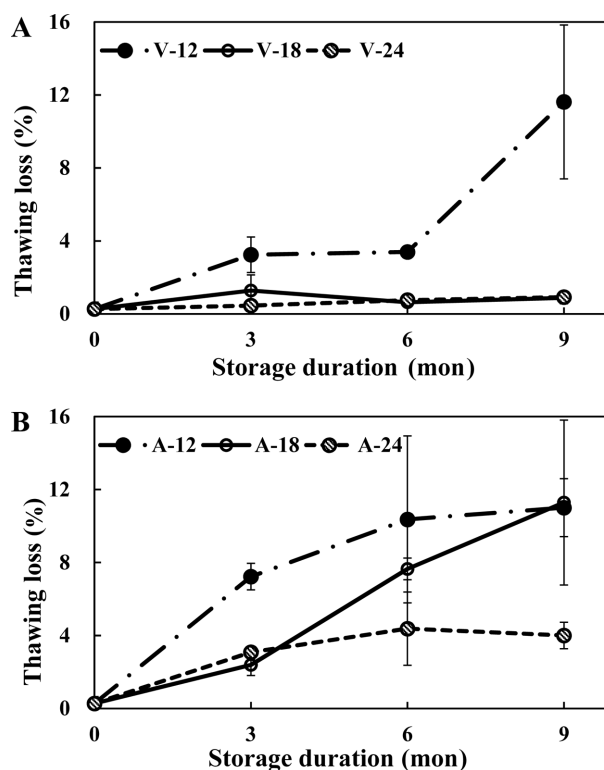It has been reported that 74% of consumers consider the

Fig. 1. Changes in thawing loss of frozen beefs subjected to vacuum or air contained packaging system during refrigerated storage. V-12: vacuum-packed frozen beefs stored at -12°C, V-18: vacuum-packed frozen beefs stored at -18°C, V-24: vacuum packed frozen beefs stored at -24°C, A-12: frozen beefs in air containing packs stored at -12°C, A-18: frozen beefs in air containing packs stored at-18°C, A-24: frozen beefs in air containing packs stored at -24°C.

color of a food product as an important property that influences their purchase decisions (Lynch et al., 1986). In this study, Tables 1 and 2 display the instrumental color parameters (L*, a* and b*) for round of raw beef samples and treated samples, respectively. Among all the samples, raw beefs had the lowest L* value and highest a* values. The L* value of beefs increased from 37 to 50, while a* value decreased from 22 to 6 when the samples were subjected to thermal treatment. In the 0 mon, beefs were measured the CIE color values immediately after freezing, packing, and thawing. Similar color values of 0 mon samples were obtained at lower storage temperature, regardless of the type of package. Among vacuum-packed samples, the samples stored at -18 and -24°C showed lower change in L* value compared to the samples stored at -12°C samples. In samples backed by both the methods, the ones stored at -12°C stored samples obtained the highest b* values ($p<0.05$). After freezing for 9 mon, the b* value of vacuum-packed and air containing-packed beef samples stored at -12°C

was higher than 16, while as the b* value of samples stored at other temperatures was significantly lower than 12 ($p<0.05$). There was a consistency in a* values of all the samples. As shown in Tables 1 and 2, hot water blanching is the most effective treatment for dealing with color change of beefs. When the beefs were stored at lower temperatures after freezing, there were smaller differences in the color of 0-mon samples than the ones stored at -12°C ($p<0.05$). The color of frozen meat changes when it is stored for a consideration period of time. During this period, it is subjected to freeze-thaw cycles that cause temperature and color changes due to the increasing activity of α-glucosidase and β-N-acetyl-glucosaminidase in catfish (Benjakul & Bauer, 2001). The frozen meat changes color owing to changes in the state of myoglobin: the pigment exists in this muscle tissue of meat products. In the post-mortem stage, the myoglobin of meat exists in the form of oxymyoglobin, a muscle tissue that has red color. When this meat is subjected to thermal treatment,

Table 2. Changes in the color of frozen beefs subjected to vacuum or air contained packaging system during refrigerated storage

Treatments[1]*		Storage periods (mon)			
		0	3	6	9
L*	V-12	55.81 ± 4.46^a	51.25 ± 0.56^{Bb}	57.09 ± 1.22^{Aa}	51.11 ± 2.36^{Bb}
	V-18	55.81 ± 4.46^a	56.05 ± 0.15^{Aa}	56.80 ± 0.77^{Aa}	57.87 ± 1.33^{Ba}
	V-24	55.81 ± 4.46^a	55.79 ± 0.31^{Aa}	58.58 ± 1.20^{Aa}	56.96 ± 0.98^{Aa}
	A-12	55.81 ± 4.46^a	54.30 ± 1.07^{Ba}	54.80 ± 1.24^{Aa}	55.19 ± 2.16^{Aa}
	A-18	55.81 ± 4.46^a	56.95 ± 0.41^{Aa}	54.51 ± 1.14^{Aa}	57.38 ± 1.74^{Aa}
	A-24	55.81 ± 4.46^a	54.44 ± 0.17^{Ba}	55.59 ± 2.16^{Aa}	56.41 ± 2.12^{Aa}
a*	V-12	5.66 ± 0.80^b	8.45 ± 0.26^{Aa}	7.11 ± 0.89^{Ab}	6.37 ± 0.68^{Ab}
	V-18	5.66 ± 0.80^b	7.95 ± 0.29^{Ba}	7.51 ± 0.38^{Aa}	6.24 ± 0.21^{Ab}
	V-24	5.66 ± 0.80^a	6.15 ± 0.08^{Ca}	6.74 ± 0.51^{Aa}	7.35 ± 1.16^{Aa}
	A-12	5.66 ± 0.80^b	6.35 ± 0.70^{Ba}	4.92 ± 0.80^{Bc}	5.33 ± 0.11^{Bab}
	A-18	5.66 ± 0.80^c	7.79 ± 0.20^{Aa}	6.39 ± 0.45^{Ab}	6.28 ± 0.61^{Ab}
	A-24	5.66 ± 0.80^b	6.80 ± 0.32^{Ba}	6.44 ± 0.53^{Aa}	6.43 ± 0.50^{Aa}
b*	V-12	11.75 ± 1.07^b	10.24 ± 0.09^{Cb}	13.27 ± 0.25^{Ab}	16.88 ± 3.03^{Aa}
	V-18	11.75 ± 1.07^a	11.34 ± 0.13^{Ba}	11.77 ± 1.12^{Ba}	11.75 ± 0.77^{Ba}
	V-24	11.75 ± 1.07^a	11.72 ± 0.19^{Aab}	11.32 ± 0.39^{Bb}	11.99 ± 0.22^{Bab}
	A-12	11.75 ± 1.07^c	13.01 ± 0.42^{Ab}	7.68 ± 5.30^{Bd}	16.30 ± 1.23^{Aa}
	A-18	11.75 ± 1.07^a	11.68 ± 0.25^{Ba}	11.84 ± 0.93^{Ba}	12.00 ± 0.91^{Ba}
	A-24	11.75 ± 1.07^a	11.68 ± 0.25^{Ba}	11.63 ± 0.97^{Ba}	11.61 ± 0.20^{Ba}
Total color difference (ΔE)	V-12		5.57 ± 0.38^{Aa}	2.70 ± 0.67^{Ab}	7.53 ± 1.92^{Aa}
	A-18		2.45 ± 0.06^{Aa}	1.83 ± 0.84^{Aa}	1.95 ± 1.70^{Ba}
	A-24		1.80 ± 0.34^{Aa}	1.90 ± 1.42^{Aa}	1.99 ± 0.53^{Ba}

[1]Control: blanched beefs without freezing V-12: frozen beefs with vacuum packaging stored at -12°C V-18: frozen beefs with vacuum packaging stored at -18°C V-24: frozen beefs with vacuum packaging stored at -24°C A-12: frozen beefs with air containing packaging stored at -12°C A-18: frozen beefs with air containing packaging stored at -18°C A-24: frozen beefs with air containing packaging stored at -24°C.
*Mean ± standard deviation of multiple determinations (n>3).
[a-b] Means with different superscripts within the same row are significantly different ($p<0.05$).
[A-B] Means with different superscripts within the same column are significantly different ($p<0.05$).
*The color of raw and blanched beef was same as Table 1

oxymyoglobin is oxidized to metmyoglobin, which has brown color (Warren et al., 1996). As a result, after subjecting the beefs to hot water blanching, the L* values of beefs increased, while a* values decreased. During the storage period, the color changes in the meat were less drastic than the changes witnessed during thermal treatment the drastic changes in color occur as enzymes in the beef get inactivated when subjected to thermal treatment.

pH

In this research study, pH increased from 5.67 to 5.78 when the beefs were subjected to thermal treatment (Fig. 2). After blanching the beefs, its pH increased to 5.78. Thereafter, when the beefs were frozen and thawed, the pH increased to a value greater than 5.8. When the beefs were stored under frozen conditions for a considerable period of time, the pH of all the samples showed a tendency to decrease the decreases in the pH of all the samples were similar in the first three months of storage. Interestingly, the pH of frozen beefs started increasing again from the sixth month. In case of air-containing samples, the pH values of samples after 6 mon of storage were similar with the pH values of samples in the 0-mon. It has been reported that the pH of thermally treated meat is higher than that of raw meat, which is in turn attributed to the concealing acid groups of unfolding proteins (Ma & Ledward, 2004). Yang et al. (1989) had reported that the pH of frozen pork and beef declined initially when they were subjecting them to freezing storage however, in the later months of storage period, the pH of frozen pork and beef increased again due to denaturation of proteins and lipids. This finding was in good agreement with the results of our study. In addition, Boles & Swan (2002) had reported increase after decline of pH with freezing storage, assuming the relevance with purge and pH of beef. The pH of beef had a decline with an increase of purge. The variation of purge in frozen beef during freezing storage
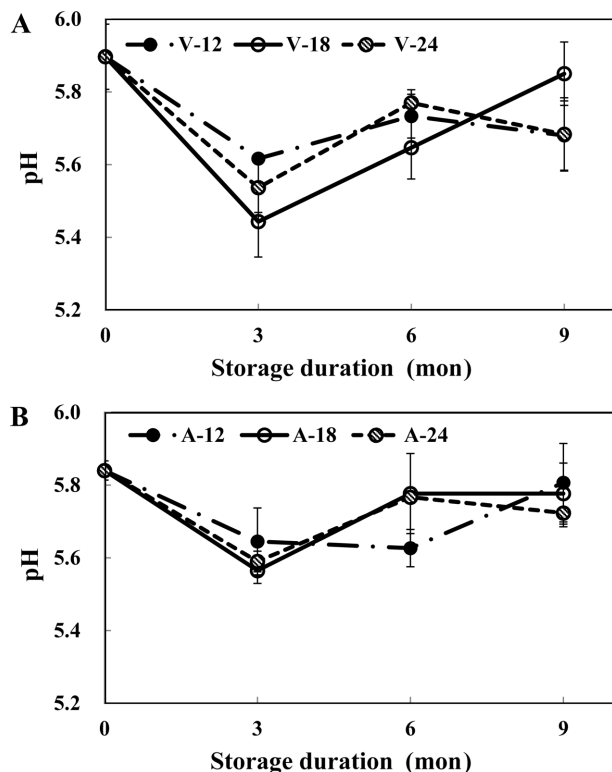

Fig. 2. Change in pH of frozen beefs subjected to vacuum or air contained packaging system during refrigerated storage. V-12: vacuum packed frozen beefs stored at -12°C, V-18: vacuum packed frozen beefs stored at -18°C, V-24: vacuum packed frozen beefs stored at -24°C, A-12, frozen beefs in air containing packs stored at -12°C, A-18: frozen beefs with air containing packs stored at -18°C, A-24: frozen beefs with air containing packs stored at -24°C. *The pH of raw and blanched beef was same as Table 1.
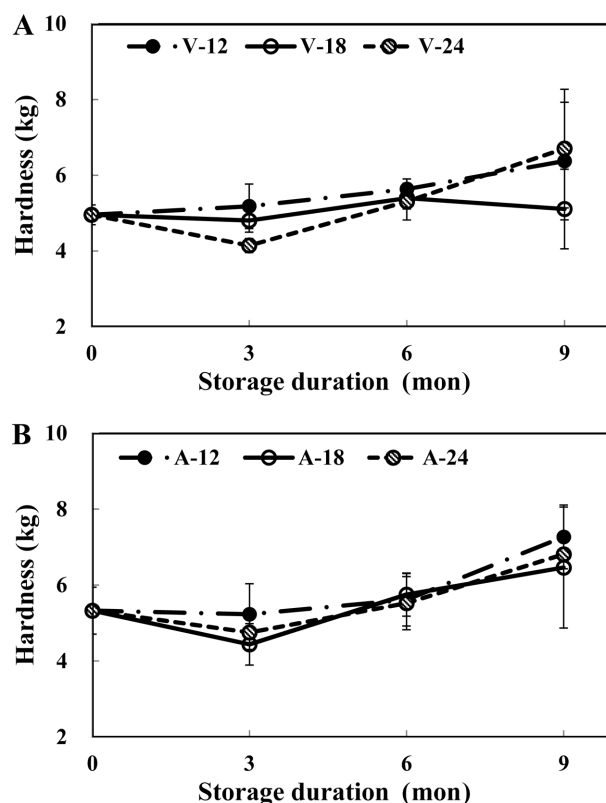

Fig. 3. Change in the hardness of frozen beefs subjected to vacuum or air contained packaging system during refrigerated storage. V-12: vacuum packed frozen beefs stored at -12°C, V-18: vacuum packed frozen beefs stored at -18°C, V-24: vacuum packed frozen beefs stored at -24°C, A-12: frozen beefs in air containing packs stored at -12°C, A-18: frozen beefs in air containing packs stored at -18°C, A-24: frozen beefs in air containing packs stored at -24°C. *The hardness of raw and blanched beef was same as Table 1.

may affected to pH.

Shear force

Fig. 3 depicts the shear force of thawed beefs that were subjected to freezing storage for a specific duration of time. Raw beef weighing 2.7 kg was subjected to blanching treatment changed shear force of beefs weighing 4.1 kg. After freezing and thawing, shear force of beefs was increased again to 5.0 kg. During freezing storage, shear force was steadily increased. Shear forces of beefs stored at -18°C had the lowest values; the values of shear forces of beefs were similar to those of samples stored in the 0-mon. These samples were first packaged using any of the two different packaging methods used in this study. Vacuum-packed samples that were stored at -18°C for 9-mon exerted about 5.1 kg for shear force, while the other samples exerted shear forces that were greater than 6.0 kg. But, the vacuum-packed sample stored at -24°C was an exception in this case; it produced shear force of about 6.5 kg. After storing the samples for six month, it was found that there was little difference between the shear force values of samples stored at -12°C and -24°C.

It have been observed the shear force of meat increased with increasing temperature, which has been attributed to the structural changes of myofibrillar components and shrinkage of connective tissues (Ma & Ledward, 2004). Furthermore, Bhattacharya et al. (1988) have reported that an increase in the shear force of beef occurs with the passage of time provided the beefs are subjected to freezing. Moreover, they also found that the value of shear force exerted by the vacuum packed samples was lower than that exerted by air-containing packed samples. These results were similar to the findings of this research study.

In the context of HMR, it is necessary to ensure that pretreated beefs maintain their shear force during freezing storage without getting hardened. In case of HMR products, vacuum-package and storage at -18°C is the proper storage condition. This would maintain the shear force of pre-heated and frozen beefs.

Conclusions

In this study, the IQF method was applied on beef and determined whether frozen HMR products could be prepared from beefs. In the 9-mon period of freezing storage, it was found that vacuum-packaging and -18°C were the ideal conditions for storing beefs as it minimized the changes of physicochemical properties. Furthermore, it was convenient to store beefs at -18°C as it is already adopted as the general temperature for storing frozen foods.

Acknowledgement

References

Benjakul S, Bauer F. 2001. Biochemical and physicochemical changes in catfish (*Silurus glanis* Linne) muscle as influenced by different freeze-thaw cycles. Food Chem. 207-217.

Bhattacharya M, Hanna MA, Mandigo RW. 1988. Effect of frozen storage conditions on yields, shear strength and color of ground beef patties. J. Food Sci. 53: 696-700.

Boles JA, Swan JE. 2002. Meat and storage effects on processing characteristics of beef roasts. Meat Sci. 62: 121-127.

Cano MP. 1996. Vegetables: Freezing effects on food quality. In L. E. Jeremiah (Ed), Marcel Dekker, New York, NY, USA p. 520.

Gonçalves EM, Pinheiro J, Alegria C, Abreu M, Brandao TR, Silva CL. 2009. Degradation kinetics of peroxidase enzyme, phenolic content, and physical and sensorial characteristics in broccoli (*Brassica oleracea* L. ssp. *Italica*) during blanching. J. Agr. Food Chem. 57: 5370-5375.

Jo YJ, Jang MY, Jung KH, Kim JH, Sim, JB, Chun JY, Yu SM, Han GJ, Min SG. 2014. Effect of novel quick freezing techniques combined with different thawing processes on beef quality. Korean J. Food Sci. An. 34: 777-783.

Kanzler S, Manschein M, Lammer G, Wagner KH. 2015. The nutrient composition of european ready meals: protein, fat, total carbohydrates and energy. Food Chem. 172: 190-196.

Kim YB, Jeong JY, Ku SK, Kim EM, Park KJ, Jang A. 2013. Effects of various thawing methods on the quality characteristics of frozen beef. Korean J. Food Sci. An. 33: 723-729.

Lawrie RA, Ledward DA. 2006. Lawrie's Meat Science. Seventh English, edition ed. Cambridge England: Woodhead Publishing Limited. Sawston, Cambridge, UK.

Lee YM, Joung YK, Yang IS, Sohn KH, Moon SJ, Kim KJ, Lee SG. 1990. A study on food behavior and preference of military personnel. Korean J. Dietary Culture. 5: 463-472.

Lynch NM, Kastner CL, Kropf DH, Caul JF. 1986. Flavor and aroma influences on acceptance of polyvinyl chloride versus vacuum packaged ground beef. J. Food Sci. 61: 266-267.

Ma HJ, Ledward DA. 2004. High pressure/thermal treatment effects on the texture of beef muscle. Meat Sci. 68: 347-355.

Pietrasik Z, Janz JAM. 2009. Influence of freezing and thawing on the hydration characteristics, quality, and consumer acceptance of whole muscle beef injected with solutions of salted and phosphate. Meat Sci. 81: 523-532.

Shabbir MA, Raza A, Anjum FM, Khan MR, Suleria HAR. 2015. Effect of thermal treatment on meat proteins with special reference to heterocyclic aromatic amines (HAAs). Crit. Rev. Food Sci. 55: 82-93

Tsukamasa Y, Fukumoto K, Ichinomiya M, Sugiyama M, Minegishi Y, Akahane Y, Yasumoto K. 1992. Characterization and utilization of a drip exuding from frozen thawed pork. J. Jap. Soc. Food Sci. Technol. 39: 862-869.

Warren KE, Hunt MC, Kropf DH. 1996. Myoglobin oxidative state affects internal cooked color development in ground beef patties. J. Food Sci. 61: 513-519.

Yang SY, Kim YH, Lee MH. 1989. The effect of cryoprotectants on the quality changes of pork and beef during frozen storage. Korean J. Food Sci. Technol. 21: 364-369

Yoon GS, Woo JW. 1999. The perception and the consumption behavior for the meats in Koreans. J. Korean Soc. Food Sci. Nutr. 28: 246-256

Yu XL, Li XB, Zhao L, Xu XL, Ma HJ, Zhou GH, Boles JA. 2010. Effects of different freezing rates and thawing rates on the manufacturing properties and structure of pork. J. Muscle Food. 21: 177-196.

Zhou GH, Xu XL, Liu Y. 2010. Preservation technologies for fresh meat - A review. Meat Sci. 86: 119-128.