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Use of Ohmic Heating System in Meat Thawing and Its Effects on Microbiological Quality

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Abstract: *This study was conducted to determine the application of the ohmic heating system in meat thawing process and its effects on the microbiological quality of the meat. For this purpose, traditional thawing methods (room temperature and refrigerator) were compared with the ohmic system. Beef loin (Longissimus lumborum, LL) was used as the material in the experiments by cutting into 5x10cm pieces. The samples were divided into three groups by taking the thawing methods into consideration. The grouped meat samples were frozen at -35±1°C for 24 hours and stored at -18°C for 6 months. During the storage period, changes in color (L*, a*, b*) and microbiological condition of the samples were determined periodically throughout the storage period. In all experimental meat samples thawed by different methods, considering the period of frozen storage; There were statistically significant differences in total microorganism, Pseudomonas spp. and coliform numbers after the second month ($p<0.05$). It was also observed that decreases observed in the number of yeast-mold during storage period were not significant ($p>0.05$). When the thawing methods applied in this study evaluated in terms of L*, a*, b* values, there was no statistically difference between the groups ($p> 0.05$). As a result, it has been concluded that the ohmic heating system can be used as an alternative method for thawing frozen meat.*

Keywords: *Thawing, meat, storage, microbiology, ohmic heating*

1. INTRODUCTION

Ohmic heating is an effective method for thawing of frozen foods, but there are only a few studies in the literature describing the Electrical Conductivity (EC) values of foods. Liu et al. [1] examined ohmic heating thawing in three different tuna muscles experimentally over a range of temperatures. The EC values of tuna muscles were measured at several frequencies and temperatures, from 50Hz to 20 kHz and from −30°C to +20°C, respectively. The effect of the electric current direction and the presence or absence of the membrane in the muscle were analyzed. It was shown that EC values are influenced by frequency, temperature, moisture content, and fat content. Also, EC values were changed rapidly above −7°C. Their results also showed that the parallel current direction gives higher EC values than series. Furthermore, the membranes in the muscle and the fat distribution are important factors that affect EC values.

Meat taken into frozen storage must be properly thawed before consumption. Many methods are used to thawing frozen meats. It is stated that the dissolution of frozen meat and meat products is more important than the quality of the product, freezing and frozen preservation. As a result of inadequate thawing methods, excessive weight loss, a decrease in meat nutrient value due to increase of leach water rate and an increase of microbial flora are considered as the most important problems. Freezing process means that the storage of frozen meat at -10°C or lower temperatures while deep freezing process at from -20°C to -35°C. It has been reported that frozen meat should be stored at -18°C [2].

In freezing process, the meat starts to freeze at -0.6°C and water in meat starts to crystallize at -1.50°C. It is stated that the freezing and thawing process should pass the -3°C boundary quickly and the water should be crystallized in small size. Generally, it is assumed that the development of bacteria at -10°C, yeasts at -12°C and molds at -18°C stops [2]. Frozen food becomes liquid or soft due to the rising of temperature above the freezing point in thawing heating. Thawing is a critical procedure for controlling the microbial and physicochemical properties of a food product [3].

Total viable bacteria, yeast and mould counts are commonly used microbiological methods in determining the microbiological quality of foods. Total viable bacteria, yeast and mould counts have high importance for the demonstration of whether food is stored at suitable temperatures during processing, transport and storage phases and the adequacy of sanitation in food premises. These counts also help to take necessary precautions by informing about the beginning of the deterioration, the possible shelf life of food, uncontrolled dissolution of frozen foods, inadequate cooling, contamination and level of contamination at the production phase [4].

Inactivation of microorganisms is very important in many industrial food applications. Microbial inactivation is an important parameter that must be addressed in food production processes regarding product safety and quality management. The presence of undesirable or high amounts of certain microorganisms can lead to product spoiling (e.g. material spoiling) and the quality loss

(e.g. changes in appearance, unwanted odor, undesirable taste, discoloration, etc.) and/or health problems.

Cho et al. [5] observed that ohmic heating leads to lower thermal inactivation time when compared to conventional method in their research on the *B. subtilis* and *B. atrophaeus* inactivation kinetics. It is thought that this difference is probably due to the electric field in the environment.

For this reason, it is emphasized that ohmic heating is caused by a thermal effect and non-thermal killing effect on the microorganisms analyzed. According to Sun et al. [6], the effect of electrical inactivation is more important than heat. It has been shown that this effect is related to the electric voltage and frequency.

Tian et al. [7] compared long term ohmic and water bath cooking in their study. Water bath cooking takes 2 times more than long term ohmic to achieve equal cooking level. The bacterial diversity decreased weekly similar between the two methods and the bacterial community structure in samples were similar at the end of storage and were mainly composed of *Carnobacterium*, *Pseudomonas*, *Kluyvera*, and *Bacillus*. But, the TVB-N (Total volatile basic nitrogen) value was higher in water bath cooked samples. As a result, long term ohmic cooking has the potential to produce safe and high-quality meat products with a shorter cooking time.

Ohmic heating is also promising new technology for the fruit juice industry. Park and Kang [8] demonstrate that the electric effect of ohmic heating is a very important factor for reducing process times and temperatures for inactivation of *E. coli* O157:H7, *S. typhimurium*, and *L. monocytogenes*. Especially, ohmic heating is an effective technology for processing acidic fruit juices, because it has a dramatic pasteurization effect on food-borne pathogens due to low pH, thermal treatment, and the electric effect.

Aguilar-Machado et al., [9] showed that ohmic heating has a higher effect on the pigments than conventional heating treatment. However, this effect is less noticed than microbial inactivation. Degradation can be negligible depending on the target microorganism with ohmic heating at optimum microbial inactivation conditions.

The microbial inactivation associated with ohmic heating is more widespread in nature, such as conventional heating. Cho et al. [10] showed that electrical pretreatment of ohmic heating can reduce the severity of additional thermal applications for subsequent microbial inactivation. The similarity of microbial inactivation curves of ohmic heating to the traditional heating curves, except for differences in curves, is probably more likely to be explained by the electrical field.

Zell et al. [11] applied ohmic heating to the meat samples (*M.semitendinosus*) inoculated *L. innocua*. They specified that ohmic heating method is significantly effective on *L. innocua* and results of their study can be used at the microbial safety point.

İçier et al. [3] investigated the effect of ohmic thawing on the structural changes of shredded beef samples and showed that the samples thawing with conventional method were more flexible than the samples thawing with ohmic heating.

Bozkurt and İçier [12] compared ohmic and traditional methods in their study, and they found that there was no difference between liquid loss, solubilization homogeneity and some color parameters (*L**, *a**, *b**) in thawing frozen beef samples but there are differences in thawing time, level, and energy use. Researchers also indicate that the size of the meat is an important factor in thawing process.

Li and Sun, [12] declared that freezing and thawing are complex processes including chemical transfer and heat transfer which greatly affect the product quality. Researchers have indicated that new thawing methods, such as microwave, ohmic heating, high pressure thawing, and sound thawing, shorten the thawing time, thereby reducing water loss and improving product quality.

The thawing of frozen foods is known to be a very critical process, especially in terms of the microbial safety of the thawing food. For this reason, thawing of the food must be carried out as rapidly as possible at low temperatures. This method is particularly thought to be used as an alternative method of thawing the meat.

In this work, the effects of traditional thawing methods, as well as the use of ohmic heating, and the effects on the microbiological quality of the food have been investigated.

2. MATERIALS AND METHODS

In this study, beef loin samples (*Longissimus lumborum, LL*) were used as material. Experimental meat samples were prepared in a size of 5x10cm and weighing 200-250g. Experimental meat samples were subjected to color (*L**, *a**, *b**) and microbiological (total mesophilic aerobic microorganism, *Pseudomonas* spp., coliform and yeast-mold) analysis before freezing. The prepared meat praperats were coded and divided into 3 groups that have 18 samples in each group. Group I samples were thawed at the room temperature; group II samples were thawed by ohmic heating and group III samples were thawed in the refrigerator environment. The samples were frozen at -35°C for 24 hours in a special freezer (UCF 20SF, Uğur Deep Freezer, Turkey) by rapid freezing method. After freezing process, the experimental samples were stored in the same freezer at -18°C for 6 months.

The frozen conserved meats were thawed in different ways every month from the 1st month to the 6th month of the conservation. For each group, 3 samples were dissolved by different thawing method in each month. group I samples were dissolved at room temperature (20 ± 2°C), group II samples were subjected to an ohmic heating system applied with 50volt electric current in the same environment, group III samples were dissolved in a refrigerator set at +30°C. The dissolution process was continued until the internal heat of the meat was 0 ± 1°C, and the dissolution was terminated when this value was reached. The internal temperature was measured throughout the

dissolution of frozen meat by a data logger (TESTO 175 Data Logger, TESTO AG, Germany). Color (*L*, a*, b**) and microbiological (total mesophilic aerobic microorganism, *Pseudomonas* spp., coliform and yeast-mold counts) analysis of samples were conducted at each month from the 1st to the 6th in terms of quality qualifications. All analysis were carried out in 2 parallel lines.

1.1. Reflectance Color Analysis

Reflectance color analysis was performed by using a Minolta-brand colorimeter (CR-400 model, Konica Minolta, Osaka, Japan) having D65 illuminant, 2° observers, 8mm illumination range in Diffuse/O mode. *L** represents the value of brightness, *a** represents the value of redness and *b** represents the value of yellowness. For each samples, three color readings were taken from the surface of the samples[14].

1.2. Microbiological Analyses

Microbiological enumerations were performed by the reference cultural methods [15, 16,17] on Plate Count Agar (PCA, CM-0325, Oxoid), Dichloran Rose Bengal Chloramphenicol Agar(DRBC, Merck 1.00466), Violet Red Bile Agar (VRBA CM-0107,Oxoid) and Pseudomonas Selective Agar (CFC Agar Base, Merck 1.07620) for total viable count (TVC), yeast and mould (YM), coliform, *Pseudomonas*, respectively. Initial suspensions were prepared by adding 225 mL maximum recovery diluent (MRD, Merck 1.12535) into stomacher bags containing 25 g sample. Inoculated PCA and VRBA plates were incubated at 35°C for 48h for TVC and coliform, while DRBC agar and CFC agar plates were incubated at 25°C for 5 and 2 days for YM and *Pseudomonas* counts, respectively.

After incubation, all colonies grown on PCA and DRBC agar plates were counted and microorganism counts were calculated as log CFU/g. Characteristic coliform colonies with a red center on VRBGA (CM 1082, Oxoid) plates were confirmed on glucose agar. Pigmented or fluorescent colonies on CFC agar plates, considered as presumptively *Pseudomonas*, were firstly subjected to oxidase test (Merck 1.133000). Oxidase positive colonies were transferred to Kligler agar (Merck 1.03913) in order to check aerobic growth. Colonies verified as *Pseudomonas* were identified at species level using a biochemically-based identification system [18].

1.3. Statistical Analyses

SPSS 16.0 package program was used for statistical evaluations. The Kruskal-Wallis test was employed for microbiological data, the General Linear Model was used in color analyses, the Duncan test and Paired t-test were employed in paired comparisons of the parametric data, the Mann-Whitney test and Wilcoxon test, were used for nonparametric data.

3. RESULTS AND DISCUSSION

Thawing times of experimental samples taken into frozen storage were determined by thawing with different methods each month periodically. The internal temperature values of the frozen meat have

been determined between -14.4±1.6°C and -15.7±0.7. The internal temperature of frozen meats reached these temperature values in 83.3-86.7 minutes by ohmic method98.0-106.7 minutes at room temperature, and 500-606.7 minutes in the refrigerator environment. (Thawing criterion was set at 0±1°C). According to the obtained results, it was observed that the thawing process was performed in the shortest time by using ohmic method. Similar results have been observed by Bozkurt and İçier [12]. Bozkurt and İçer [12] compared ohmic and traditional methods in their research and found that differences in thawing time, rate and energy use in dissolving frozen beef samples, and specified that the meat size is an important factor in thawing process.

It is thought that ohmic heating system can be used as an alternative method, especially in meat thawing. As a matter of fact, Li and Sun[13]stated that ohmic heating could be used in order to thaw frozen food, therefore it was possible to thaw frozen tuna fish from -3^0C to 3^0C in a very short time. In the research, shorter time was needed to thaw frozen meat through ohmic heating system, so this point confirms the opinions of Li and Sun [13].

As the experimental modeling, the total viable bacterial counts, *Pseudomonas* spp., coliform, and yeast-mould counts were investigated periodically in the thawed samples by using the three separate methods. The mirobial differences among the methods are displayed in Table 1.

Table 1. *Microflora of the experimental samples thawed by using different thawing methods during storage period (log_{10} cfu/g).*

		Thawing Method			
		Conventional	Ohmic	Refrigerator	
Storage Time (Month)	Microorganism	X± Sx	X± Sx	X± Sx	*p-value*
0	TVC	4.23±4.13	4.22±3.51	4.30±3.19	0.778
	Pseudomonas spp.	2.18±1.58	2.16±1.57	2.54±2.24	0.144
	Coliform	2.17±1.54	2.19±1.35	2.29±1.45	0.166
	Yeast-Mould	2.52±2.25	3.10±2.46	2.81±2.73	0.809
1	TVC	3.76±3.19	4.11±3.12	4.12±3.36	0.304
	Pseudomonas spp.	2.46±1.89	2.37±1.66	2.67±2.13	0.138
	Coliform	ND	ND	1.72±1.46	0.161
	Yeast-Mould	2.41±2.19	2.36±2.12	2.69±2.48	0.724
2	TVC	4.37±3.50[a]	4.24±3.31[b]	3.67±3.35[c]	0.001
	Pseudomonas spp.	3.88±3.12[a]	3.41±3.31[ab]	2.93±1.45[c]	0.039
	Coliform	2.15±1.99	1.41±1.32	1.15±0.4	0.235
	Yeast-Mould	2.59±2.20	2.69±2.38	2.38±2.19	0.719
3	TVC	4.64±4.51	3.60±3.16	4.28±3.77	0.400
	Pseudomonas spp.	2.90±1.96	2.34±1.70	3.35±3.20	0.171
	Coliform	1.83±1.51[a]	<10	2.10±1.61[a]	0.294
	Yeast-Mould	2.47±2.15	2.70±2.24	2.66±2.49	0.879
4	TVC	4.37±3.76[a]	3.78±3.16[b]	4.17±3.19[b]	0.012
	Pseudomonas spp.	1.57±1.40	ND	ND	0.261
	Coliform	1.42±1.31	ND	ND	0.302
	Yeast-Mould	2.66±2.23	2.35±2.13	2.66±2.35	0.627

5	TVC	2.35±1.68[b]	2.86±2.18[a]	2.88±2.21[a]	0.004
	Pseudomonas spp.	ND	ND	ND	-
	Coliform	ND	ND	ND	-
	Yeast-Mould	2.76±2.12	2.49±2.12	2.58±2.35	0.688
6	TVC	2.90±2.34[a]	2.30±2.17[b]	3.10±2.24[a]	0.001
	Pseudomonas spp.	1.32±0.91	1.36±0.42	1.47±1.10	0.508
	Coliform	ND	ND	ND	-
	Yeast-Mould	2.45±2.12	2.22±1.25	2.42±2.28	0.949

TVC: Total viable count. ND: Not Date.a,b,c:The valueswith different letters in the same row are significantly different ($p<0.05$)

Ferna´ndez et al.[19]determined the total viable bacterial counts in raw meat (*M.longissimus dorsi*) as 3.53±0.23$\log_{10}$/g. The researchers stated that the microorganisms which belong to *Enterobacteriaceae* family were below the detectable number.

When thawing methods are taken into consideration, no differences were found in the microbiological analyses conducted on fresh meat samples which would be subjected to freezing operation between groups in terms of all investigated parameters (*P>0.05*).

In consequence of thawing operation carried out on the experimental samples, which were taken to frozen storage and kept there for 6 months, periodically at the end of each month by using different methods, differences in the total number of viable microorganisms were observed among groups in thawing at the end of 2nd, 4th, 5th and 6th months (*p<0.05*).

When thawing methods are considered and the number of *Pseudomonas* spp.in the experimental samples is evaluated, it is seen that there were significant differences in thawing at the end of 2nd month and 3rd month among groups (*p<0.05*). No differences were found among groups in other periods (*P>0. 05*). No reproduction of microorganisms from the mentioned group was detected in the 4th month and 5th month in the samples which were thawed in the refrigerator and by using ohmic heating system and in the 5th month in the samples which were thawed at room temperature.

The yeast-mold values of the experimental samples followed a fluctuating course in all thawing methods applied. The determined differences were not statistically significant (*p>0.05*).

When the number of coliform microorganisms of the experimental samples was considered, no coliform microorganism reproduction was detected in the samples which were thawed by using ohmic heating system at the end of 1st, 3rd, 4th, 5th and 6th month, in the samples which were thawed at refrigerator temperature at the end of 4th, 5th and 6th month and in the samples which were thawed at room temperature at the end of 1st, 5th and 6th month. The differences among groups in terms of number of microorganisms in the mentioned group were determined only in the 3rd month (*p<0.05*).

In general, a reduction with changing rates in microflora is provided by freezing meat. The great variance that the reduction in the microflora exhibits may result from the operations which are carried out while obtaining meat and the reproduction occurring during thawing.

The microbiological data obtained in consequence of the research support the opinions and thoughts given above. The general number of viable microorganisms which was found as 4.22-4.30$\log_{10}$cfu/g at the beginning was determined as 2.30-3.10 $\log_{10}$cfu/g in the 6th month thawing after frozen storage and a considerable reduction was observed in the microflora. A similar situation was determined for coliform microorganisms and the reproduction of microorganisms in this group completely stopped depending on the progress of the storage period. The reproduction of coliform microorganisms, which is also considered as the hygiene indicator, revealed the security of frozen storage in the sense of food security.

When *Pseudomonas* microorganisms are taken into consideration in general, it is emphasized that they would dominate meat microflora over time in cold environments. When research findings are evaluated, it is seen that the microorganisms in this group reached the highest level after 2nd month thawing (2.93-3.88 $\log_{10}$cfu/g), but they lost their activity in the following periods. This situation can be explained with the number of *Pseudomonas* at the beginning of the preservation. On the other hand, yeasts and molds followed a fluctuated course and continued their liveliness. This can be explained by the capacity of yeasts and molds to reproduce in low water activity values and at low temperatures (-10……-15^{0}C).

With the purpose of identification of *Pseudomonas* spp., in consequence of identification of different colonies which reproduced in Pseudomonas Agar Base medium, it was observed that the colonies reproducing in all groups included a considerable amount of *Pseudomonas aeruginosa*. In addition, *Pseudomonas stutzeri* was also identified in one of the samples which were coded in order to thaw in the refrigerator. In microorganism identification conducted on fresh meat samples before starting freezing operation, the bacteria of *E.coli, Stenotrophomonas maltophilia, Pantoea agglomerans, Sphingomonas paucimobilis* were identified.

The reflectance values for colors (*L**, *a**, *b**) of the meat samples which were kept in frozen storage were determined after thawing in each month with a different method at the beginning and during the storage period. *L**, *a**, *b** values of the samples which were thawed at room temperature are given in Table 2, *L**, *a**, *b** values of the samples which were thawed by using ohmic heating system are given in Table 3 and *L**, *a**, *b** values of the samples which were thawed in the refrigerator are given in Table 4.

Table 2. *L*, a*, b* values of the experimental samples which were thawed at room temperature*

			Before Freezing	After Thawing	
Checking Property	Storage Time(Month)	N	X± Sx	X± Sx	*p-value*
*L**	1	6	42.41±3.88	37.55±1.25	0.261
	2	6	38.02±2.86	34.41±0.40	0.266
	3	6	39.86±5.18	35.62±1.08	0.457
	4	6	40.48±3.61	39.38±1.72	0.790
	5	6	44.13±3.64	38.11±1.10	0.166
	6	6	41.24±3.36	36.97±1.01	0.271
	P		**0.907**	**0.067**	

*a**	1	6	20.08±0.79 [ab]	18.94±0.64	0.292
	2	6	21.86±0.57 [a]	20.04±0.36	**0.024****
	3	6	22.51±1.23 [a]	18.62±0.42	**0.024****
	4	6	20.50±1.17 [a]	17.86±0.95	0.112
	5	6	16.29±1.94 [b]	17.46±0.44	0.582
	6	6	18.92±1.58 [ab]	19.11±1.22	0.925
	P		**0.028**	**0.208**	
*b**	1	6	10.48±1.89	4.29±0.99	**0.016****
	2	6	9.52±1.49	5.90±0.33	**0.039****
	3	6	10.74±2.48	3.93±1.01	**0.030****
	4	6	9.79±2.42	4.83±0.90	0.084
	5	6	8.30±1.85	4.95±0.39	0.131
	6	6	10.69±2.52	5.19±1.10	0.087
	P		**0.965**	**0.657**	

a,b: The values with different letters in the same column are significantly different ($p<0.05$).
: represents the difference in terms of *L,*a**,*b** values before freezing and after thawing. ($p<0.05$).
*L**: Brightness *a**: Redness *b**: Yellowness

Table 3. *L*, a*, b* values of the samples which were thawed by using ohmic heating system*

			Before Freezing	After Thawing	
Checking Property	Storage Time(Month)	N	X± Sx	X± Sx	*p-value*
*L**	1	6	40.26±5.505	36.73±0.812	0.553
	2	6	37.25±0.978	37.42±0.792	0.900
	3	6	45.29±4.051	36.44±1.402	0.066
	4	6	41.05±4.402	36.81±0.880	0.385
	5	6	38.86±2.814	36.84±0.512	0.497
	6	6	43.29±4.525	36.21±0.912	0.181
	P		**0.745**	**0.961**	
*a**	1	6	18.75±2.100	19.43±0.613	0.762
	2	6	18.45±1.821	17.04±0.673	0.494
	3	6	15.27±1.419	18.24±0.936	0.112
	4	6	18.38±1.254	17.64±0.282	0.589
	5	6	16.88±1.636	17.33±0.561	0.807
	6	6	19.63±1.472	18.17±0.564	0.377
	P		**0.492**	**0.143**	
*b**	1	6	8.44±1.636	5.05±0.750	0.302
	2	6	7.69±0.692	3.23±0.808	**0.002****
	3	6	7.54±2.565	3.33±1.091	0.176
	4	6	7.40±2.049	4.81±0.322	0.266
	5	6	8.11±2.304	4.41±0.390	0.172
	6	6	11.58±1.527	4.37±0.438	**0.004****
	P		**0.739**	**0.330**	

: represents the difference in terms of *L,*a**,*b** values before freezing and after thawing. ($P<0.05$).
*L**: Brightness *a**: Redness *b**: Yellowness

Table 4. *L*, a*, b* values of the samples which were thawed in the refrigerator*

Checking Property	Storage Time(Month)	N	Before Freezing X± Sx	After Thawing X± Sx	*p-value*
*L**	1	6	41.37±2.84	36.29±0.60	0.136
	2	6	35.58±2.22	37.74±0.64	0.156
	3	6	43.89±5.62	35.37±0.85	0.192
	4	6	42.82±4.57	37.02±0.26	0.262
	5	6	43.32±3.33	37.40±0.85	0.116
	6	6	42.57±4.90	36.77±0.62	0.293
	P		**0.716**	**0.191**	
*a**	1	6	20.34±2.76[a]	18.38±0.82	0.523
	2	6	18.99±0.58[a]	19.50±0.46	0.507
	3	6	19.83±0.65[a]	19.80±0.27	0.966
	4	6	20.93±0.69[a]	18.61±0.57	**0.028****
	5	6	14.67±1.21[b]	17.60±0.63	**0.057****
	6	6	18.48±0.57[ab]	18.81±1.20	0.810
	P		**0.033**	**0.335**	
*b**	1	6	10.76±2.95	3.83±1.04	0.067
	2	6	8.58±0.95	5.86±0.74	**0.048****
	3	6	9.32±2.54	5.84±0.29	0.231
	4	6	11.07±2.38	5.11±0.58	0.054
	5	6	7.92±2.22	4.48±0.45	0.159
	6	6	9.55±3.02	6.16±0.40	0.314
	P		**0.937**	**0.100**	

a,b: The values with different letters in the same column are significantly different ($p<0.05$).
: represents the difference in terms of *L*,a*,b values before freezing and afterthawing. ($P<0.05$).

No statistical differences were detected between *L** values of the experimental samples which were thawed at room temperature and the values which were measured before freezing the meat and the values measured in the experimental samples which were thawed at the end of preservation (*p>0.05*). In terms of *a** values, differences were determined in the 1st, 2nd and 3rd months between the meat thawed at the end of storage and the values measured in the fresh meat before preservation (*p*<0,05). It was also observed that there were meaningful differences in the values measured in fresh meat before preservation (*p<0.05*). In the context of *b** values, it was observed that there were differences in the values measured after thawing at the beginning in the 1st, 2nd and 3rd months (*p<0.05*).

No statistical differences were determined between *L*, a*, b** values of the samples which were thawed by using the ohmic heating system and the values measured in fresh meat before preservation (*P<0.05*). After thawing, significant differences were observed only in *b** values in the 2nd and 6th months in comparison to fresh meat before preservation (Table 3; *p<0.05*).

In terms of *L** values of the experimental samples which were thawed at refrigerator temperature, there were no statistical differences between the values measured in fresh meat and the values measured in the experimental values after storage time. Differences were determined in terms of *a** values between the values measured in the 4th month of meat samples which were thawed at the

end of storage period and the values measured in fresh meat before storage. In addition to this, meaningful differences were also observed in values measured in fresh meat before the preservation. When b^* values are considered, it has been determined that there are statistical differences between the values measured in the 2nd month just at the beginning after thawing ($p<0.05$).

When L^* values of the samples are considered in general, it is seen that the mentioned values in the samples which were thawed at room temperature were between 38.02-44.13 before freezing, between 34.41-39.38 after thawing (Table 2), in the samples which were thawed using ohmic heating system were between 37.25-43.29 at the beginning, between 36.21-37.42 after thawing (Table 3), in those samples which were classified in order to thaw in the refrigerator were between 35.58-43.89 at the beginning and between 35.37-37.74 after thawing (Table 4). Based on these determined values, it was observed that there were decreases in L^* values of fresh meat and the same values in frozen and thawed meat. This situation was also detected by Boles and Swanb [20]. The researchers determined L^* values which were kept at -1.5^{0}C for 8 weeks and measured periodically every week as 33.8 at the beginning and as 34.1 after 8-week preservation. L^* values were determined by many researchers. Hernández et al.[21] established the L^* value in animals which were slaughtered under stress as 28.9; and in animals which were slaughtered under normal conditions as 37.94.

Apple et al., [22] determined that L^* value of *M.gluteus medius* muscle in an animal belonging to USDA eminent classes 36.8. The researchers reported that there were differences between inner, central and outer surfaces of the same meat preparation in terms of color measurement.

Farouk and Swan, [23] found L^* values in beef as 49.7; Liu et al., [24] determined L^* values belonging to steak as38.07; Fernández et al.,[19]found this value in raw meat (*M.longissimus dorsi*) as 26.35, and 26.98 in frozen meat and they claimed that there were no differences in these values before and after freezing.

When L^* values are interpreted in general terms, it is seen that there are differences among researchers. It is possible to explain this situation with the meat preparation, slaughter, storage and preservation conditions applied. In fact, Apple et al., [22]suggested that there were differences between inner, central and outer surfaces of the same meat preparation in terms of color measurement. This suggestion seems to support the idea.

In general, no differences were detected among the groups in terms of a^* values obtained from the experimental samples. It was determined that a^* values of the samples before freezing were between 14.67 - 22.51, a^* values of the samples after thawing were between 17.04 - 20.04 . In the conducted researches, Hernández et al.,[21]found a^* value as 22.3 in animals slaughtered under stress, as 15.68 in animals slaughtered under normal conditions; Apple et al., [22]determined the same value in *M. gluteus medius* muscle of an animal belonging to eminent class as 14.8; Farouk and Swan, [22] determined it as 13.1 in beef; Boles and Swan, [20] determined the same value in

meat that they preserved at -1.5^{0}C for 8 weeks and measured periodically every week as 17.6 at the beginning, as 16.5 after preservation; Liu et al., [23] detected the value as 17.27 in steak; Fernández et al., [19] detected *a** value in fresh meat (*M.longissimus dorsi*) as 8.86 and as 7.43 in frozen meat. In general, the obtained findings in regard to *a** value and the finding of the researchers show a partial similarity. The observed differences probably result from different samples used by researchers, conditions of slaughter, conditions of storage and preservation. A similar situation is also valid for *b** values.

Consequently, color is the most important criterion for the visual quality and consumption of meat. Particularly, the transition of myoglobin, which is known as the color pigment in muscles, into oksi, deoksi and metmiyoglobine is significant.

4. CONCLUSION

As a result, frozen storage still maintains its importance in terms of reliability for the preservation of the meat, if it is carried out under suitable conditions. However, it is also important occurred physical, chemical and microbiological activities in thawing process of the meat as well as the preservation. In conventional thawing methods, there are some negativities such as long thawing time, weight loss due to the high amount of leakage, nutritional losses with leaking liquid and microbial activities occurred at unexpected rate especially during thawing, so it is necessary to develop and apply new and more reliable dissolution methods. When the results are taken into account, it has been concluded that the ohmic heating system can be a useful method for thawing frozen meat and studies should be continued in this regard.

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