

The Effect of Cooking Methods on Textural and Microstructure Properties of Veal Muscle (*Longissimus dorsi*)

¹Parang Nikmaram, ¹Mohamad Said Yarmand, ¹Zahra Emamjomeh and ²Hiva Karimi Darehabi

¹Department of Food Science, Engineering and Technology,
Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

²Department of Food Hygiene, Islamic Azad University,
Sanandaj Branch, Faculty of Veterinary Science, Kurdistan, Iran

Abstract: In this study the effects of cooking treatments (microwave, roasting and braising) on veal (*Longissimus dorsi*) were investigated. Cooking losses and physical properties (Color, Texture) of the meat cooked using the different treatments were compared. Microwave treatment implied the greatest weight loss. When color (CIE L*, a*, b* and ?E) was analyzed after the treatments, it was observed that L* and b* increased and there was a significant difference ($p < 0.01$) between raw and cooked meats. Heating treatments affected meat pigments and temperature caused a lighter color. Also, shear force and compression force showed a significant difference ($p < 0.01$) between raw and cooked samples. Changes in the microstructure of the endomysium and perimysium were assessed using scanning electron microscopy (SEM). The structural changes of raw meat were compared with treated samples. SEM Micrographs confirmed the result of shear force and compression force. Sensory evaluation was also done to compare results of devices and panelists.

Key word: Cook loss • Warner–Bratzler • Compression force • Color

INTRODUCTION

Generally, meat is known as an important source of B vitamins and trace elements and greatly contributes to the daily intake of these micronutrients. Veal is one of the meat provides mentioned essential materials. Some of the most important sensory attributes of meat are appearance, juiciness and flavor and texture [1]. Texture values in bovine meat mainly depend on zootechnical characteristics of the animal such as breed, age and sex [2, 3], on anatomical characteristics such as type of muscle [4], or meat cooking method [5]. The determination of meat texture can be made using a trained taste panel or by physical methods. Instrumental texture assessment on meat is made by means of a texturometer, a device that allows tissue resistance both to shearing and to compression to be measured [6, 7]. A large number of devices have been developed to evaluate mechanical tenderness. The most widely used to measure the toughness of meat is the Warner-Bratzler (WB) shear device [8, 9]. As the meat is usually cooked before being eaten, it is important to understand the physical changes of meat texture during heating. Davey and Gilbert [10]

defined cooking as the heating of meat to a sufficiently high temperature to denature proteins. The components of muscle that control toughness are the myofibrillar proteins and the connective tissue proteins, collagen and elastin. During heating, the different meat proteins denature and they cause structural changes in the meat, such as the destruction of cell membranes, shrinkage of meat fibers, the aggregation and gel formation of myofibrillar and sarcoplasmic proteins and shrinkage and solubilisation of the connective tissue [11]. Other factors, such as the solubility of the collagen, also have to be considered.

Meat structure can be considered in its simplest form as a collection of parallel fibers, a myofibrillar structure, bound together by a connective tissue network [12]. SEM is very useful in revealing details of the structure of muscle fibers both original and subjected to a variety of treatment [13]. Heat induced changes in connective tissue have a tenderizing effect while hardening of the myofibrillar proteins during cooking has a toughening one [14]. However, these investigations have focused mainly on effect of cooking method on microstructure and mechanical properties of camel meat.

MATERIALS AND METHODS

Longissimus dorsi (L.d) muscle of veal between one and three years old was purchased from Basingosht slaughter-house. The L.d muscle was separated by razor blade in order to determine physical properties. Muscle samples were cut cylindrically (5 cm diameter and 10 cm length). Any visible fat was removed from the muscle tissues. They were individually labelled and weighed. The steaks were sealed in nylon/polyethylene bags. Roasting at 100°C was done in a convention oven Model FT420 made in china. Braising was done in a water bath at 100°C. Microwaving was done in a domestic microwave oven at 2450 MHz and 600 W. A thermocouple was used for temperature control inside the slices.

Cook Losses: After cooking, steaks were cooled at room temperature; surface dried with filter paper and reweighed using an analytical balance (Mettler AE100-0.001 made in the USA). Cook losses were calculated from differences in raw and cooked weight.

Texture Assessment: An instron Model Testometric (M350-10CT, Rochdale, England) was used for shear force and compression of raw and cooked meat. Meat samples were cut by a cylindrical blade to make a core with 1.32 cm radius and approximately 2 cm length. The cores were cut by warner-bratzler blade perpendicular to direction of the fiber and speed was regulated on 200-250 mm/min and the angle of warner-bratzler blade was 60. A cylindrical flat ended plunger (diameter 1.13 cm, area 1 cm²) was used in compression test. The plunger is driven (100 mm/min) vertically 80% of the way through a 1 cm thick meat sample cut so that the fiber axis is perpendicular to the direction of the plunger penetration (Honikel, 1998).

Color Measurement: Color was recorded using a Minolta chroma meter CR-400 KON made in Japan. Readings at per sample, in the centre of the steak was taken. CIELAB system, L* (lightness), a* (redness) and b* (yellowness) were measured.

The individual differences in L*, a* and b* values of each cooking treatments in respect of the color of the raw samples were evaluated using ΔE according to Eq. (1) (CIE, 1978).

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

Chroma (C_{ab}^*) was calculated as Eq. (2):

$$C_{ab}^* = (a^{*2} + b^{*2})^{1/2} \quad (2)$$

Furthermore, the hue angel (h_{ab}^*) was calculated as Eq. (3):

$$h_{ab}^* = \text{arch tan}(b^*/a^*) \quad (3)$$

Microstructure Analysis: For SEM procedure pieces 2×2×3 mm were excised from raw and cooked steaks and dehydrated in 25, 50, 70, 95% and absolute ethanol (three times), 10-15 min in each solution. The fragments of dried tissue were mounted on holders with aluminum cement and coated by gold with sputter coating/Glow discharge EMITECH K350 Attachment made in U.K. The specimens were examined and photographed in a SEM VEGA II-TESCAN. The micrographs were taken at magnification of 500, 1000.

Sensory Evaluation: For sensory evaluation the muscles were cut into small slices and served to 18 untrained panelists to assess the color, flavor, texture and juiciness and range was between 1 and 5, a hedonic test was used, the best scored 5 and the worst scored number 1. Data were analyzed by a non-parametric test by Kroskal-Wallis (K-W) method.

Stastical Analysis: The experiments were replicated three times and the generated data were evaluated statistically by SAS software (9.1) in a randomized complete block design (RCBD). Duncan's multiple range tests were used for comparing the means. The least significant difference ($p < 0.01$) is reported.

RESULTS AND DISCUSSION

Cook Losses: The cooking losses of veal L.d muscle (*Longissimus dorsi* M.) are shown in Figure 1. A statistical analysis revealed significant differences between cooking treatments ($p < 0.01$). The overall percentage loss due to cooking for meat cooked by microwave is more than conventional methods so results were in agreement with previous studies [15-18].

It is likely that the high electromagnetic field, high power and short time to final temperature associated with microwaving cause protein denaturation, disintegration of the texture matrix, rapid protein destruction caused by heat shock to the proteins and finally liberalization of large amounts of water and fat.

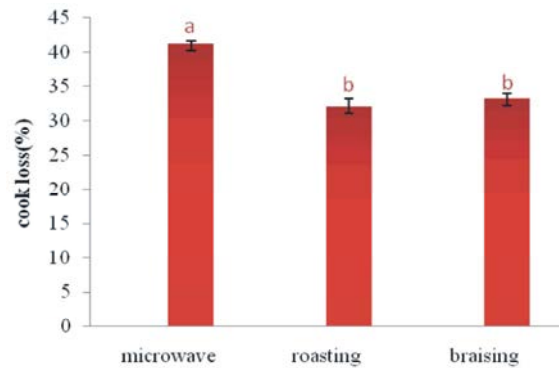


Fig. 1: Cook loss (%) of veal L.d muscle cooked by microwave, roasting and braising

Table 1: Mechanical properties of veal L.d muscle in various heating method
(Mean ± SE)

Treatment	Compression (N)	Shear force (N)
Raw	55.33±8.96 ^b	16.9±4.87 ^b
Microwave	100.17±5.13 ^a	37.00±2.64 ^a
Roasting	90.00±9.16 ^{ab}	37.64±1.16 ^a
Braising	84.04±0.22 ^{ab}	34.02±1.52 ^a

¹Mean values within a row with unlike superscript letters were significantly different ($P < 0.01$)

Mechanical Properties: Mechanical properties of cooked meat are functions of the myofibrillar mechanical properties and connective tissue network. Toughness increased by cooking and this increase has been ascribed to the denaturation of intramuscular collagen or changes in the myofibrillar structure due to cooking by different studies. As heat solubilizes the connective tissue leading to meat tenderization, while denaturation of myofibrillar proteins leads to meat toughening [19]. Shear force peak is not sensitive to the connective tissue changes, while compression of specimens seems to be very sensitive to the connective tissue changes [20]. Since the samples were tested longitudinally, the compression force showed strength of connective tissue and resistant muscle fibers.

Table1 shows the peak shear force value (N) and compression force (N) for each cooking process (microwave, roasting and braising) was measured and compared. Results of treatment means of compression force showed that microwave treatment had the highest average and there was a significant difference ($p < 0.01$) between microwave and raw meat. Therefore connective tissue proteins and actin were probably not denatured due to short time of heating in microwave treatment. On the other hand, in braising and roasting treatment collagen solubilization was more than microwave so it caused less compression in these two treatments. Moreover, shear force increased during cooking by all methods, so denaturation of myofibrillar proteins due to heating decreased tenderness in heated samples.

Color Measurement: Color analysis (Table 2) suggested that the cooked meat were generally lighter (higher L*) and more yellowness (higher b*), whereas less redness (a*) than raw meat. There was a significant difference ($p < 0.01$) between raw and heating treatments. There was no significant difference between the heating treatments for L*, a*, b*, C*_{ab}, h*_{ab} and ?E. A higher L value indicates a lighter color, which is desirable in order to ensure that the meat products will have high consumer acceptance [21]. Opacity increases on the meat surface caused by heat treatment can be explained by water losses while the capacity to reflect the light increases with which its color was modified [22]. Color brightness in heated samples was more than raw samples. In roasted samples due to dark surface, brightness was reduced but more bright colors were found inside of the samples. In general, the samples after heating due to pigment oxidation (heme group) become colorless. It seems that in microwaved samples, major and important color changes occur in short time.

The myoglobin protein is the primary heme pigment responsible for meat color, but there are other species contributing to color changes during the cooking of meat (deoxymyoglobin, oxymyoglobin, sulfmyoglobin, metmyoglobin and etc).

Table 2: Coordinates L*a*b* of veal L.d muscle in various heating method¹

(Mean ± SE)						
Treatment	L*	a*	b*	Chroma	Hue angle	ΔE
Raw	35.54±0.43 ^b	22.9±1.04 ^a	6.92±0.4 ^b	23.92±1.11 ^a	0.29±0.00 ^b	-
Microwave	54.84±2.31 ^a	5.93±1.1 ^b	13.86±0.62 ^a	15.12±0.91 ^b	1.17±0.05 ^a	26.72±2.05 ^a
Roasting	53.54±3.94 ^a	4.67±0.91 ^b	16.51±0.66 ^a	17.19±0.41 ^b	1.30±0.04 ^a	27.72±2.54 ^a
Braising	56.6±2.36 ^a	6.89±1.52 ^b	14.52±0.99 ^a	16.27±0.24 ^b	1.12±0.11 ^a	27.59±2.69 ^a

¹Treatment the letters within each column denotes a statistically significant difference

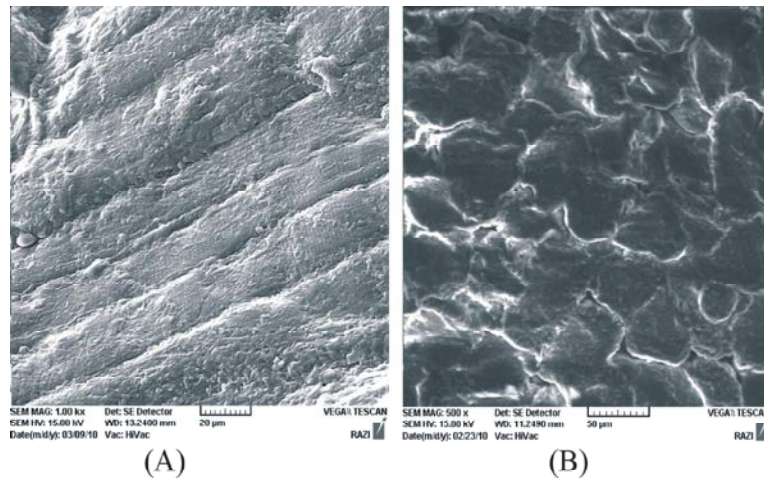


Fig. 2a: SEM micrographs of raw veal L.d muscle (a: 1000 $\times$, b: 500 $\times$)

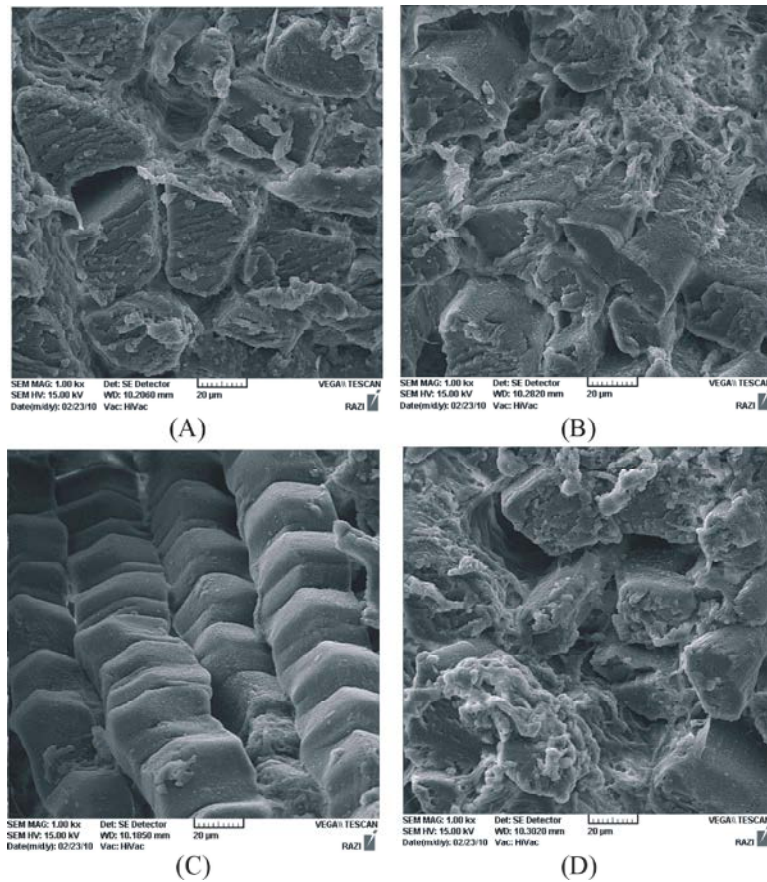


Fig. 3: SEM micrographs of cooked veal L.d muscle for 120 min using roasting method (1000 $\times$)

Microstructure Changes: Qualitative changes in the microstructure of raw and cooked veal L.d muscle are shown on the SEM micrographs. The samples were cut parallel to the direction of muscle fibers. Longitudinal section (Fig. 2a,b) shows coherence along fibers apparently. On the transverse section of raw muscle,

the gaps between the fibers and endomysial tubes were very clear and had typical dendrite structure.

Fig. 3 Cooked meat by roasting method revealed gaps between fiber and endomysial tubes. In general in the below micrographs coagulation of connective tissue around the muscle fibers can be observed

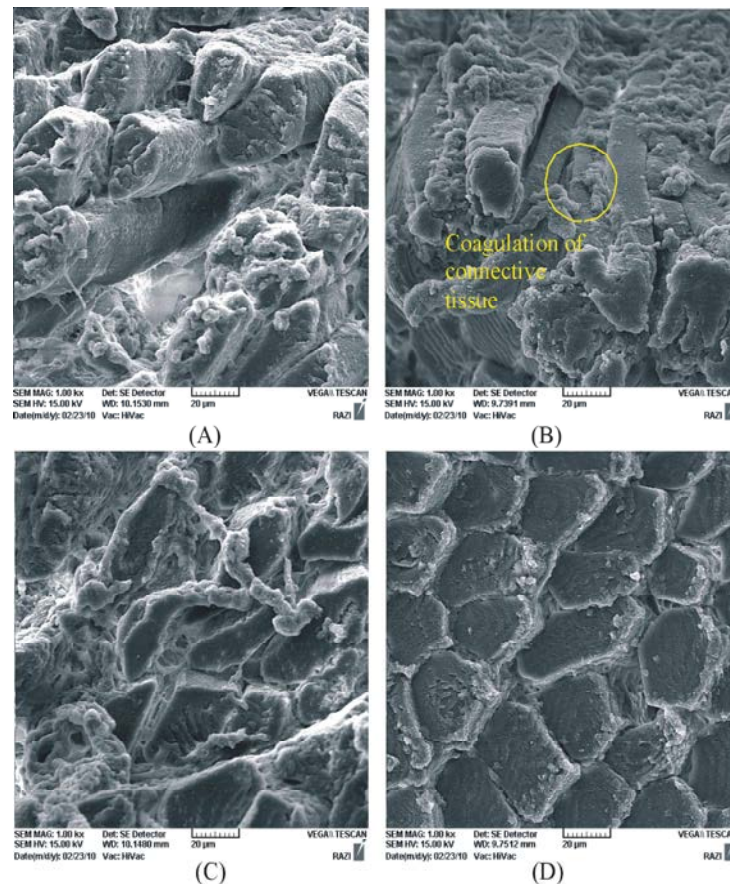


Fig. 4: SEM micrographs of cooked veal L.d muscle using microwave method (1000×)

Fig. 4 Shows that unlike thermal treatments, microwave made no visible shrinkage along muscle fibers, probably because of its short duration heating, lack of opportunity for the longitudinal accumulation of fibers and the structure of fibers shows as quite compact. Diverge rupture of muscle fibers are observed due to microwave heating mechanism, because this method of heating is generated inside unlike other methods that heat penetrate from outside to inside, therefore it causes to disintegration.

It seems that the shrinkage along muscle fibers in the braising method is more than roasting method (Fig. 5). Even some lines between the shrinkage can be seen that indicates very high compression and this shrinkage largely due to shrinkage of collagen and disposal water system from contracting proteins.

In the roasting and braising treatment connective tissue (endomysium) structure are more diffused and are not as compact as microwave treatment. This difference had explained by the greater collagen solubilization and the gel formation in roasting and braising and a smaller degree of aggregation, in microwave. These phenomena

would cause a greater softening of the connective tissue which correlated with the smaller shear and compression force that found in these samples. Palka and Daun [23] suggested that the first shrinkage might be due to the thermal denaturation of myosin and a very large decrease of water retention and the second with further dehydration of the denatured actomyosin complex. Wu *et al.* [24] observed no changes in the structure of epimysium when cooking beef muscles for 1 h at 60-80°C, but the perimysium and endomysium became granular at 60°C and gelatinized at 80°C.

After cooking to 60°C the granulation of the perimysium and sarcolem began. At 70°C, granulation of above-mentioned components intensified and larger granulates were observed, probably denatured sarcolem. This compression effect may have been due shrinkage of the endomysial collagen [25]. The greatest differences can be observed between raw meat and the cooked ones. Remarkable structural changes appear due to: the reduction of the water content, cellular membrane destruction, transversal and longitudinal shrinkage of muscular fibers, aggregation and gel formation of

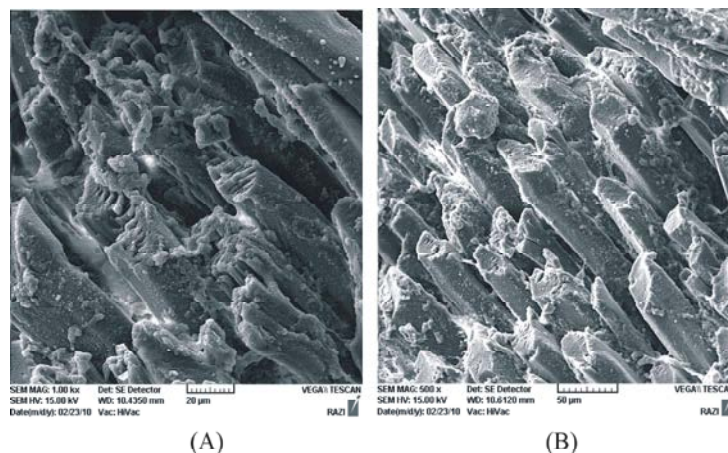


Fig. 5: SEM Micrographs of cooked veal L.d muscle for 90 min using braising method (a:1000×, b:500×)

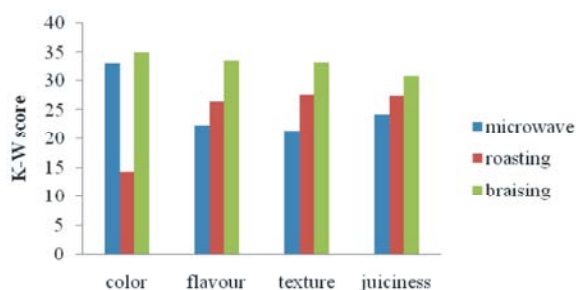


Fig. 6: Sensory evaluation of cooked veal L.d muscle by microwave, roasting and braising

sarcoplasmatic proteins and the shrinkage and solubilization of the connective tissue that cause the appearance of a granular aspect of the fibers [24, 27, 28]. Two different phenomena contribute to the texture of the cooked meat: (1) the mechanical rigidity of perimysium in the space endomysium-perimysium, (2) the shortening of endomysium supposes water loss of the muscle [25].

Sensory Evaluation: Results (Fig. 6) showed that there was a significant difference ($p < 0.01$) between treatments for color and according to obtained results, braising had the highest mean. Also there was a significant difference ($p < 0.05$) between treatments for flavor and braising scored higher figures. There was no significant difference between treatments in aspect of texture and juiciness.

CONCLUSIONS

Microwave had the highest mean of cook loss. Heating treatments imply no significant differences ($p > 0.01$) to peak shear force. Compression force of microwave had a significant difference ($p < 0.01$) with raw meat.

SEM micrographs of microwaved veal L.d muscle revealed that disintegration of fibers was considerable but no longitudinal shrinkage along muscle fibers was observed, due to untouched connective tissue proteins in microwave treatment which were not denatured completely because of short heating time. Longitudinal shrinkage was visible in roasting and braising methods and it shows structural changes in the connective tissue. Therefore it reveals solubilization of connective tissue and less compression force than microwave. However braising treatment was scored the highest number in aspect of color and flavor. Panelists did not realize any significant difference between heating treatments in aspect of texture, it may due to untrained panelists.

REFERENCES

1. Barbanti, D. and M. Pasquini, 2005. Influence of Cooking Conditions on Cooking Loss and Tenderness of Raw and Marinated Chicken Breast Meat, 38: 895-901.
2. Huff-Lonergan, E. and S.M. Lonergan, 2005. Mechanisms of water holding capacity of meat: The role of post mortem biochemical and structural change. Meat Sci., 71: 194-204.
3. Ouali, A., 1990. La maturation des viandes: facteurs biologiques et technologiques de variation. [Meat ageing: biological and technological factors of variation]. Viandes et Produits Carnes, 11(6, 6 bis, 6 ter). 281-290.
4. Zamora, F., 1997. Variabilite' biologique de l'attendrissage de laviande bovine. - Pre'diction en fonction du facteur animal et dufacteur type de muscle [Biological variation of bovine meat tenderisation. Prediction depending on animal or muscle-type factors].

5. Panea, B., F. Monso'n, J.L. Olleta, S. Mart'inez-cerezo, J.J. Pardos and C. San'udo, 2003. Estudio textural de la carne de vacuno. II. Ana'lisis sensorial. [A texture study of bovine meat. II. Sensory analysis]. Informacio'n Te'cnico-Econo' mica Agraria, 24: 31-33.
6. Piette, G., M.E. Buteau, D. Halleux, L. Chiu, Y. Raymond and H.S. Ramaswamy, 2004. Ohmic cooking of processed meats and its effects on product quality. J. Food Sci., 69: 71-78.
7. Tornberg, E., 2005. Effect of heat on meat proteins- Implications on structure and quality of meat products: A Review. Meat Sci., 70: 493-508.
8. Harris, P.V. and W.R. Shorthose, 1988. Meat Texture. In R. Lawrie, (Ed.), Developments in Meat Sci., pp: 245-296.
9. Lepetit, J. and J. Culioli, 1994. Mechanical properties of meat. Meat Sci., 36: 203-237.
10. Min, B. and D.U. Ahen, 2005. Mechanism of lipid oxidation in meat and meat products - A Review. Food Science and Biotechnolog, 14: 152-163.
11. Tornberg, E., 2005. Effects of heat on meat proteins - Implications on structure and quality of meat products. Meat Sci., 70(3): 493-508.
12. Icier, F., M. Engin and H. Bozkurt, 2009. Investigation of Applications of Ohmic Thawing and Ohmic Cooking in Meat Processing. Project Report: TUBITAK TOVAG 107O898, pp: 171 (in Turkish).
13. Voyle, C.A., 1981. Scanning electron microscopy in meat science. Scanning Electron Microscopy, 3: 405-413.
14. Laakkonen, E., 1973. Factors affecting tenderness during heating of meat. In C.O. Chichester, E.M. Mrak and G.F. Stewart, (Eds.), Advances in Food Res., pp: 257-323.
15. El-shimi, N.M., 1992. Influence of microwave and conventional cooking and reheating on sensory and chemical characteristics of roast veal. Food Chemistry, 45: 11-14.
16. Cipra, J.E., J.A. Bowers and A.S. Hooper, 1970. Precooking and reheating of turkey. J. Am. Dietet. Assoc., 58(1): 38.
17. Ruyack, D.F. and P.C. Paul, 1972. Conventional and microwave heating of beef: use of plastic wrap. Home Econ. Res. J., 1: 98.
18. Janicki, L.J. and H. Appledorf, 1974. Effect of broiling, grill frying and microwave cooking on moisture, some lipid components and total fatty acids of ground beef. J. Food Sci., 39(3): 715.
19. Laakkonen, E., G.H. Wellintong. and J.W. Sherbon, 1972. Low temperature, long-time heating of bovine muscle: 1. Changes in tenderness, water-binding capacity, pH and amount of water-soluble components. J. Food Sci., 35: 175-177.
20. McKenna, B.M., J. Lyng, N. Brunton and N. Shirsat, 2006. Advanced in radio frequency and ohmic heating of meats. J. Food Engineering, 77: 215-229.
21. Resurreccio'n, A.V.A., 2003. Sensory aspects of consumer choices for meat and meat products. Meat Sci., 66: 11-20.
22. Garcia-segovia, P., A. Andres-bello and J. Martinez-monzo, 2007. Effect of cooking method on mechanical properties, color and structure of beef muscle (*M. pectoralis*). J. Food Engineering, 80: 813-821.
23. Palka, K. and H. Daun, 1999. Changes in texture, cooking losses and myofibrillar structure of bovine *M. semitendinosus* during heating. Meat Sci., 51: 237-243.
24. Wu, F.Y., T.R. Dutson and S.B. Smith, 1985. A scanning electron microscopic of heat-induced alterations in bovine connective tissue. J. Food Sci., 50: 1041-1044.
25. Palka, K., 1999. Changes in intramuscular connective tissue and collagen solubility of bovine *M. semitendinosus* during retorting. Meat Sci., 53: 189-194.
26. Bendall, J.R. and D.J. Restall, 1983. The cooking of single myofibres, small myofibre bundles and muscle strips from beef *M. psoas* and *M. sternomandibularis* muscles at varying heating rates and temperatures. Meat Sci., 8: 93-117.
27. Cheng, C.S. and F.C.J.R. Parrish, 1976. Scanning electron microscopy of bovine muscle. Effect of heating on ultrastructure. J. Food Sci., 41: 1449.
28. Kong, F., J. Tang, M. Lin and B. Rasco, 2008. Thermal effects on chicken and salmon muscles: Tenderness, cook loss, area shrinkage, solubility and microstructure. LWT., 41: 1210-1222.