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Effect of Different Thicknesses on Colour and Textural Characteristics of Beef Cooked with Ohmic and Conventional Method

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Abstract: The effect of different thicknesses (2.5, 4 and 5 cm) in cooking methods of ohmic and conventional on colour and textural attributes of beef was investigated in this study. At ohmic cooking three different voltage gradient (30, 50 and 70 V) was also used. Significant differences were found between the colour and majority of texture values of raw and cooked meat samples in both ohmic and conventional cooking methods (P<0.05). At ohmic cooking, while there was no significant effect on the colour values of 4 cm thick beef samples with the voltage gradient increment (P>0.05), a significant effect was observed on the colour values of 2.5 cm and 5 cm thick beef samples (P<0.05). The voltage gradient increment caused to obtain lower L, a, b values of 2.5 cm and 5 cm thick beef samples. At conventional cooking process, beef thickness did not affect "a" value significantly (P>0.05) but it affected L and b values significantly (P<0.05). Beef thickness affected significantly hardness, chewiness and gumminess values however cohesiveness, springiness and resilience values of the majority of samples were not affected significantly by the increase of beef thickness for both cooking methods. In this study, ohmic cooked beef samples showed lighter surface colour but also browner and more uniform colour compared to conventionally cooked samples while texture profile values of hardness, chewiness and gumminess in conventionally cooked samples were higher those of ohmically cooked samples.

Keywords: Beef thickness, conventional cooking, ohmic, voltage gradient.

Farklı Kalınlıkların Ohmik ve Konveksiyonel Pişirmede Etin Renk ve Tekstürel Özellikleri Üzerine Etkisi

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Öz: Bu çalışmada, ohmik ve konveksiyonel pişirme yöntemlerinde farklı kalınlıkların (2,5, 4 ve 5 cm) sığır etinin renk ve tekstür özelliklerine etkisi araştırılmıştır. Ohmik pişirmede üç farklı voltaj gradyanı (30, 50 ve 70 V) kullanılmıştır. Hem ohmik hem de konveksiyonel pişirme yöntemlerinde pişmiş sığır eti örneklerinin renk ve tekstür profili değerlerinin çoğunluğu çiğ sığır eti örneklerinden önemli ölçüde farklı bulunmuştur (P<0,05). Ohmik pişirmede voltaj seviyesinin artması 4 cm kalınlıktaki et numunelerinin renk değerleri üzerinde önemli bir etkiye sahip değilken (P>0,05), 2,5 cm ve 5 cm kalınlıktaki et numunelerinin renk değerleri üzerinde önemli bir etkiye sahiptir (P<0,05). Ohmik pişirmede voltaj seviyesindeki artış 2,5 ve 5 cm kalınlıktaki sığır etlerinde L, a, b değerlerinin azalmasına neden olurken, 4 cm kalınlıktaki et numunelerinde renk değerleri üzerinde önemli bir etki oluşturmamıştır. Konveksiyonel pişirme işleminde et kalınlığının "a" değeri (P>0,05) üzerinde önemli bir etkisi olmadığı görülürken, L ve b değerleri üzerinde önemli bir etkisi olduğu görülmüştür. Sığır eti kalınlığının sertlik, çiğnenebilirlik ve sakızımsılık gibi tekstür profili değerleri üzerinde önemli bir etkisi olduğu ancak örneklerin çoğunluğunun yaylanma, yapışkanlık ve esneklik değerlerinin her iki pişirme yönteminde de sığır eti kalınlığının artmasından etkilenmediği görülmüştür. Bu çalışmada, ohmik olarak pişirilmiş sığır eti örneklerinin, konveksiyonel olarak pişirilmiş et örneklerine göre daha açık yüzey rengine, aynı zamanda da daha kahverengi ve daha tekdüze et rengine sahip olduğu görülürken, konveksiyonel pişirilmiş et örneklerinde sertlik, çiğnenebilirlik ve sakızımsılık değerleri, ohmik olarak pişirilmiş örneklere göre daha yüksek çıkmıştır.

Anahtar kelimeler: Et kalınlığı, konveksiyonel pişirme, ohmik, voltaj derecesi.

INTRODUCTION

Meat has always constituted an important part of our diet (Mottram, 2017). Meat and meat products are necessity of the diet by reason of they are good reservoirs of nutrients which are proteins, fats, minerals and vitamins (Pathare et al., 2019). Before eating, meat and meat products are cooked. Eating superiority of meat has been influenced greatly by cooking method. Cooking method has great influence on eating quality of meat. Meat physical properties (such as thickness) and energy consumption are also other important parameters have to be considered for the choice of appropriate cooking method (Pathare & Roskilly, 2016). Moreover, the variety and strength of the heat treatment used for meat cooking has a prime effect on the meat products quality properties (Bejerholm & Aaslyng, 2014).

Cooking of meat by traditional methods for generally include heating the product by conventionally. In conventional cooking, heat penetration from the meat surface to the center is in lower rate so cooking takes long time and excessive heating of the surfaces was eventualized since meat exterior side takes in more heat which deteriorates the quality of the product (Richa et al., 2017; Li et al., 2017). Food is often heated in conventional cooking to recompense for the thermal lag of the particles, resulting in reduced nutritional properties of the food (Choi et al., 2011). There are impressive increases in the development of new alternative technologies that replace conventional technologies every day (Cummins & Lyng, 2017). Ohmic cooking is one of the alternative technologies and its popularity is increasing for meat cooking in recent years. Since there will be no temperature slopes in ohmic cooking, heat will not be transmitted from hot areas to cold areas through conduction, convection or radiation. Therefore, the properties of the food will be preserved without overheating and the food will be heated very quickly (5 to 20°C/min) and uniformly (De Halleux et al., 2005). Moreover, cooking of solid foods with in bigger amount by ohmic- supported has also been becoming popular (Gavahian et al., 2019). Conventional heating requires excessive heat processing and also consume more energy particularly when the particles are very large, in that case destruction of the exterior side of particles was occurred (Varghese et al., 2014).

Colour and textural properties are very important basic parameters in terms of the quality of cooked meat products and their acceptance by the consumer (Yang et al., 2016). Dependable information about eating quality attributes can be obtained by evaluating the colour values of cooked meats (Garcı´a - Segovia et al., 2007). The colour of cooked meat is viewed by many consumers as a dependable pointer of doneness and safety. The pink appearance is associated meat with uncooked, while dull brown interiors are seen as a sign of a well-cooked meat (King & Whyte, 2006). Tenderness is considered the most critical feature in meat consumption (Destefanis et al., 2008). The gratification of consumer has been considerably influenced by meat tenderness and it is important that meat tenderness is met according to consumers' needs. Cooking process is one of the main determinatives of tenderness and with the net effect of this tenderization and toughening, cooking conditions regulates the thermal sensitivity of meat after cooking (Silva et al., 2015).

In the literature, there is a limited study about the beef thickness that affecting quality character of ohmic and conventional cooking. It was aimed to investigate the effect of different thicknesses in ohmic and conventional cooking on colour and textural attributes of beef.

MATERIAL AND METHOD

Sample and Reagents: Three years old cattle meat was used as a sample. Beef (*Longissumus dorsi*) as loin was acquired from a local supermarket in Gaziantep, Türkiye. Two replicates have been used per each treatment at each level. The meat was frozen at -18 °C until used for cooking. The required meat samples were removed from the freezer and thawed at 4 °C for one day (Özcan Uzun et al., 2018).

Ohmic Cooking Procedure and Design: AC power supply with A 220 Volt input - 24 Volt output, a 5 kW conductor, a limit switch, an ampermeter, a voltmeter and a 10 A fuse were put into operation for the ohmic cooker designation. Ohmic cooking design is given in Figure 1. Tests cell with 5 cm long and three different diameters (2.5, 4 and 5 cm) were made in order to insert meat inside it. Stainless steel electrodes (430 type) were used that contacts and covers the whole meat surface. For this system, meat was given form into three different thickness (2.5, 4.0 and 5.0 cm) by sharpened carver and so situated into test cell. Then, type of 430 stainless steel electrodes were situated at the two open ends of the test cell and in full contact with the meat. There was no piece of meat left outside the electrodes. Voltage gradients of 30, 50 and 70 Volt levels were get used for ohmic cooking and the operation time was set right until the meat internal center temperature raised to 72 °C (Özcan Uzun et al., 2018).

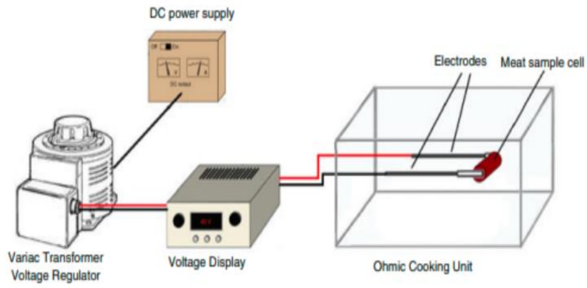

Figure 1. Ohmic Cooking Design (Özcan Uzun et al., 2018)
Şekil 1. Ohmik Pişirme Tasarımı (Özcan Uzun et al., 2018)

Conventional Cooking: Meat samples with three different thickness (2.5, 4 and 5 cm) were cooked conventionally at turbo oven (Dominox D0 42 ST XS, 1800 Watt). Temperature was adjusted to 200 °C and time was set right until the meat internal center temperature raised to 72 °C as it was in ohmic cooking.

Colour Analysis: Colour values (L, a, b) were measured by using a Hunter lab ColorFlex (Hunter lab, A60-1010-615 Model calorimeter, Reston, VA). Standardization of the instrument was performed by black and white ceramic plates (L_0 = 93.41, a_0 = - 1.11, and b_0= 1.06). Colour values of L, a, b represent to lightness (L), greenness (- a) or redness (+a), and blueness (-b) or yellowness (+b), respectively. The colour measurements of raw, ohmic and conventionally cooked meat samples were accomplished at room temperature (20 °C ±2) in duplicate for each batch (Özcan Uzun, 2018).

Texture Analysis: Texture profile values of hardness, cohesiveness, springiness, gumminess, resilience and chewiness was determined by performing TPA tests with operating a Texture Analyzer TA.XT2 (NY/Stable Microsystems, Texture Technologies Corp., Scarsdale, Godalming, UK). 5 cm radius aluminum circular probe, 30 % compression, 1 mm/s test speeding, 2 mm/s pre-test speeding, 1 mm/s post-test speeding, 25 kg load cell and 10 g initiation power were the conditions of test. The texture analysis of raw, ohmic and conventionally cooked meat samples were accomplished at room temperature (20 °C ±2) (Özcan Uzun, 2018).

Statistical Analyses: Colour and texture levels of beef samples as a function of thickness value for ohmic cooking at three different voltage level and conventional cooking, an ANOVA was performed. SPSS version 25.0 was used to determine the significant differences at α=0.05 level among the samples. Duncan's multiple range test was applied. When the compared parameters mean differed at a α=0.05 level, tendencies were considered as significant (Özcan Uzun et al., 2018).

RESULTS AND DISCUSSION

Colour: Colour is very important parameter in cooked meat since it provides reliable information about eating quality attributes for consumer preferences. Along the cooking process, beef colour turns from a dark red to a pinkish gray and ending as pale brown (Kondjoyan et al., 2014). Colour analysis (L, a, b) of ohmic and conventionally cooked beef samples with different thicknesses were followed during the process.

In this study, significant differences were found between the colour values of raw and cooked meat samples in both ohmic and conventional cooking methods ($P<0.05$). At ohmic cooking process L values of beef samples varied between 35.10 and 46.15 while at conventional cooking L values of beef samples varied between 29.78 and 41.68. These results were not far from the Bozkurt and İçier, (2010) research in the literature. In their study, they cooked the beef samples that containing three different fat ingredients (2, 9, 15 %) by ohmically (20, 30 and 40 V/cm) and conventionally. They reached the L values between 36.36 – 48.19 at ohmic cooking and 36.36 – 47.38 at conventional cooking. In this study, conventionally cooked samples had lower L and b values than ohmic cooked beef samples. Similarly, Engchuan et al., (2014) clearly stated in their study that ohmically heated meatballs had brighter colours compared to conventionally cooked samples. The lower lightness values represented the dark colour appearance due to the browning reaction. During conventional cooking, samples surface was exposed to higher temperatures for longer times but at ohmic cooking beef samples surface were exposed to fastest cooking rate. This is why, ohmic cooked beef samples had less colour advancement on their surface (Zell et al., 2010b; Yıldız-Turp et al., 2013). On the other hand, the lowest "a" values were obtained in the beef samples of ohmic cooked and the significant decrease in the "a" value occurred with the voltage gradient increment ($P<0.05$). Lower "a" values illusturated reddish reduction and brownish-red and greenish increasing.

At ohmic cooking, while there was no significant effect on the colour values of 4 cm thick beef samples with the voltage gradient increment ($P>0.05$), a significant effect was observed on the colour values of 2.5 cm and 5 cm thick beef samples ($P<0.05$). The voltage gradient increment caused to obtain lower L, a, b values and the lowest values were obtained at 70 V. In this study, it was observed that as the beef thickness increased, the cooking efficiency of ohmic treatment became difficult. Since electrical conduction was more convenient for beef samples of 2.5 and 5 cm thickness, heat transfer was better and significant effect were observed with the voltage gradient increment on colour values of this samples. At conventional cooking process, beef thickness did not affect "a" value significantly ($P>0.05$) but it affected L and b values significantly ($P<0.05$). The lowest L and b values were obtained in the beef sample of 4 cm thickness.

This study indicated as a general, colour values were affected differently from beef thickness at ohmic and conventional cooking methods and also ohmic cooked showed lighter surface colour but also browner and more uniform colour in the beef samples compared to conventionally cooked samples.

Texture: Hardness, cohesiveness, springiness, gumminess, resilience and chewiness values of beef samples were followed during the ohmic and conventional cooking processing. As a majority, in both cooking methods, significant differences were found between the texture profile values of raw and cooked meat samples ($P<0.05$).

Table 1. Colour values of raw and cooked beef samples.
Tablo 1. Çiğ ve pişmiş sığır eti örneklerine ait renk değerleri.

Sample	Beef Thickness	Voltage Gradient	L	a	b
Raw			31.48±0.09^{a}	13.82±0.03^{a}	11.45±0.01^{a}
Ohmic cooked	2.5	30	35.10±0.04^{ab}	8.14±0.21^{b}	14.82±0.07^{c}
		50	46.15±2.05^{c}	7.14±0.86^{b}	18.89±0.02^{d}
		70	38.46±4.24^{b}	5.27±0.17^{c}	13.43±0.45^{b}
	4.0	30	43.48±6.02^{b}	5.39±0.02^{b}	15.33±0.07^{b}
		50	40.47±0.22^{ab}	7.09±1.05^{b}	17.00±1.85^{b}
		70	44.07±2.91^{b}	6.42±1.08^{b}	15.77±0.11^{b}
	5.0	30	40.79±6.06^{b}	10.21±1.45^{b}	17.11±1.50^{c}
		50	41.17±1.34^{b}	5.47±0.50^{c}	15.38±0.99^{bc}
		70	37.62±1.78^{ab}	5.63±0.20^{c}	14.51±0.18^{b}
Raw			31.48±0.09^{ab}	13.82±0.03^{a}	11.45±0.01^{a}
Conventionally Cooked	2.5		34.82±6.44^{ab}	7.14±0.66^{b}	15.99±1.15^{b}
	4.0		29.78±0.93^{a}	6.40±0.72^{b}	11.71±1.11^{a}
	5.0		41.68±4.55^{b}	6.04±0.68^{b}	15.18±0.82^{b}

Results are reported as mean value ± standard deviation of two replicate analyses. Means with significantly different in the same column are indicated by different small letters at α=0.05 level.

Hardness, chewiness and gumminess values in conventionally cooked samples were greater than ohmic cooked ones. This might be the reason that a high surface temperature was established in the conventional cooking within a minute on the surface of meat and more heat conduction into the meat causes more water to be released, which moves outward, resulting in greater values of texture profile (Sheridan & Shilton, 2002). But cohesiveness, springiness and resilience values were found to be close to each other in ohmic cooking and conventional cooking. Many researchers indicated that there is no significant difference in texture profile values of beef samples between ohmic and conventional cooking methods (Zell et al., 2009; Zell et al., 2010a; Shirsat et al, 2004). But, Piette et al., (2004) investigated the cooking of bologna sausages by ohmic and smokehouse techniques and they found that smokehouse products were found to be harder compared to ohmic products.

At ohmic cooking, while a significant difference (P<0.05) emerged in the hardness, chewiness and gumminess values of beef samples by the voltage gradient increment, cohesiveness, springiness and resilience values of beef samples were not affected significantly (P>0.05) with the voltage gradient increment. At ohmic cooking, in the samples with 2.5 and 5.0 cm thickness, the voltage gradient increment 30 to 50 V resulted to significant increment in hardness value but in the meantime voltage gradient increment 50 to 70 V resulted to significant decrement in hardness value. For 4 cm beef thickness, voltage increment from 0 to 30 V caused to increase in hardness firstly, then the increase of voltage value 30 to 50 V and 50 to 70 V caused to decrease in hardness values. For 4 cm beef thickness meat could lose its firm texture at early stage due to improper heat conduction. Voltage gradient increment resulted to faster heating rates on the beef samples and denaturation of collagen could be occurred in the connective tissue and create more pressure on the water. Thus, the meat may shrink, release more of its water, and became tougher. Hardness value decreased by voltage gradient increment more. This might be the reason of losing the firm texture of meat since collagen turned into soft gelatin (Özcan Uzun, 2018).

At conventional cooking, the highest hardness, chewiness and gumminess values were obtained at a beef sample with 5.0 cm thickness. This might be the reason of more heat denaturation and more structural changes in the thickest sample which caused harder, chewy and gummy of it (Özcan Uzun, 2018). But, on the other side, cohesiveness, springiness and resilience values of the majority of samples were not affected by the increase of beef thickness at conventional cooking.

Table 2. Texture profile values of raw and cooked beef samples.
Tablo 2. Çiğ ve pişmiş sığır eti örneklerine ait tekstür profili değerleri.

Sample	Beef Thickness (cm)	Voltage Gradient (V)	Hardness (N)	Chewiness (N)	Gumminess
Raw			33.39±1.65^{a}	17.76±1.13^{b}	21.12±2.65^{a}
Ohmic cooked	2.5	30	22.42±3.35^{a}	10.40±1.21^{a}	17.38±3.06^{a}
		50	70.28±6.70^{c}	36.93±3.46^{c}	49.49±4.04^{d}
		70	47.94±3.26^{b}	26.63±1.25^{d}	35.32±2.89^{c}
	4.0	30	63.37±3.94^{c}	42.51±2.24^{d}	51.47±6.39^{c}
		50	43.30±3.37^{b}	25.55±1.48^{c}	31.06±2.03^{b}
		70	17.68±2.53^{d}	9.41±0.55^{a}	12.51±2.00^{a}
	5.0	30	36.37±1.76^{a}	17.24±1.11^{b}	25.35±2.53^{a}
		50	45.47±2.03^{c}	18.46±0.91^{b}	27.46±2.85^{a}
		70	23.55±3.91^{b}	14.18±3.22^{b}	18.26±1.76^{b}
Raw			33.39±1.65^{a}	17.76±1.13^{a}	21.12±2.65^{a}
Conventionally Cooked	2.5		75.9±4.85^{b}	38.95±4.68^{b}	50.89±5.57^{b}
	4.0		22.9±2.60^{a}	11.56±1.75^{a}	14.85±2.33^{a}
	5.0		92.72±5.76^{c}	46.19±2.72^{b}	62.76±5.68^{b}

Results are reported as mean value ± standard deviation of two replicate analyses. Means with significantly different in the same column are indicated by different small letters at α=0.05 level.

Table 3. Texture profile values of raw and cooked beef samples.
Tablo 3. Çiğ ve pişmiş sığır eti örneklerine ait tekstür profili değerleri.

Sample	Beef Thickness	Voltage Gradient	Springiness	Cohesiveness	Resilience
Raw			0.85±0.01[a]	0.67±0.01 [a]	0.27±0.01[a]
Ohmic cooked	2.5	30	0.77±0.01[b]	0.78±0.01 [c]	0.35±0.03[b]
		50	0.75±0.01[b]	0.70±0.03[ab]	0.35±0.01[b]
		70	0.75±0.01[b]	0.74±0.01[bc]	0.36±0.01[b]
	4.0	30	0.83±0.03[b]	0.81±0.04[b]	0.43±0.04[b]
		50	0.82±0.01[b]	0.72±0.01[a]	0.34±0.02[ab]
		70	0.75±0.01[a]	0.71±0.01[a]	0.34±0.04[ab]
	5.0	30	0.68±0.00[c]	0.70±0.03[a]	0.36±0.01[b]
		50	0.67±0.01[c]	0.60±0.02[b]	0.27±0.01[a]
		70	0.78±0.03[b]	0.78±0.01[c]	0.40±0.02[b]
Raw			0.85±0.01[b]	0.67±0.01 [a]	0.27±0.01[a]
Conventionally Cooked	2.5		0.77±0.03[a]	0.67±0.03[a]	0.33±0.01[b]
	4.0		0.78±0.03[ab]	0.65±0.01[a]	0.27±0.01[a]
	5.0		0.74±0.03[a]	0.68±0.02[a]	0.34±0.03[b]

Results are reported as mean value ± standard deviation of two replicate analyses. Means with significantly different in the same column are indicated by different small letters at α=0.05 level.

CONCLUSION

As a consequence, this study revealed that colour and texture values were affected differently by the thickness of the beef samples in ohmic cooking (also by voltage gradient) and conventional cooking. As beef thickness increased, heat transfer took more time to reach the center of the meat thus affecting colour and texture values significantly. Colour and texture values are important quality agents for cooked meat. In terms of colour, ohmic cooked beef samples showed lighter surface colour but also browner and more uniform colour compared to conventionally cooked samples. By the way in terms of texture, texture profile values of hardness, chewiness and gumminess in conventionally cooked samples were higher than ohmic cooked samples whereas springiness, cohesiveness and resilience values were closer at each cooking method. This study indicated that ohmic cooking could be a very good alternative method with the appropriate beef thickness and voltage gradient application in terms of desired colour and texture results.

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