OHMIC COOKING EFFECTS ON BEEF MEATBALLS

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Abstract – Ohmic cooking, a well-known electro-heating technique, is an alternative cooking method for meat products due to its ability to rapidly generate heat. The rate of heat generation depends on the voltage gradient applied and the electric conductivity of the meat product. In this work, cylindrical beef meatballs were ohmically cooked at voltage gradients of 17.5, 20 and 22.5 V/cm to a target end-point center temperature of 75°C. Texture, colour and microbiological properties of meatballs were significantly affected from voltage gradient difference. There was no significant difference in cooking yield of samples applied at different voltage gradients. Higher voltage gradients resulted in increases in hardness and chewiness parameters. The effects of ohmic treatments on total mesophilic aerobic bacteria and mould-yeast counts of meatball samples were compared. Under the studied conditions, ohmic cooking at 20.0 V/cm and 22.5 V/cm electric field strengths were the most effective treatments for reducing total mesophilic aerobic bacteria count of meatball samples.

Key Words – Meatball, Ohmic, Voltage

I. INTRODUCTION

Ohmic heating is the heating of materials throughout by passage of electric currents [1]. The obvious advantage of ohmic treatments over conventional methods is the departure from the limiting heat transfer coefficient and the need for high wall temperatures. Its other advantages compared to conventional heating include short processing time, higher yield, maintaining the colour and nutritional value of food [2,3,4] Although the technique appears both simple and advantageous and has proved to be a successful technology to process liquids, the ohmic processing of meat products has not yet been applied industrially due to several difficulties encountered [5]. In recent years, several studies have been conducted about the application of ohmic treatment to meat and meat products for cooking purposes [6, 7, 8, 5, 9, 10, 11, 12, 13, 14].

The efficiency of ohmic treatments is affected by a number of factors such as the ionic content, the moisture mobility, the field strength applied, soluble solids content, the melting of fats, and changes in the cell structure [15]. The main objective of this work was to investigate the effects of different voltage gradients applied in the narrow range (17.5-22.5 V/cm) during ohmic cooking on some quality properties of meatball samples.

II. MATERIALS AND METHODS

A. *Preparation and Cooking of Meatballs*

Lean beef as boneless rounds were sourced from a local processor. Round of beef was ground through a 3 mm plate grinder then mixed with the ingredients. Formulation of meatball was meat (96 % w/w), onion powder (1 % w/w), salt (0.5 % w/w), sodium carbonate (0.5 % w/w) and distilled water (2% v/w). Meatball samples were shaped by cylinder blocks having 0.05 m length and 0.025 m diameter. Samples were ohmically cooked at 17.5 V/cm (V17.5), 20 V/cm (V20) and 22.5 V/cm (V22.5). Total cooking times to reach 75°C center temperature for these voltage gradients were 60, 50 and 40 s respectively. All the production process of meatballs was carried out at 20±1°C room temperature. Experiments for each voltage gradient were conducted in three replicates. Replicates for an individual voltage gradient were from different replicated round of beef. Each analysis for samples treated by each individual voltage gradient (per treatment) was conducted in three parallel.

B. *Cooking Yield*

Percent cooking yield was determined by calculating weight differences for samples before and after cooking [16].

C. *Textural Properties*

Textural properties of samples were measured by TA-XT Plus (Stable Microsystems, Surrey, UK). Dimension of samples taken from meatballs was 1cm x 1cm x 1cm. A cylindrical compression cell having a 25 mm diameter and a 5 kg loading was used during measurements. Hardness, resilience, chewiness, gumminess, stickiness, fragility and internal adhesive properties of meatballs were determined by using the texture profile analysis method. Result for any parameter of cooked sample was given relative to that of the raw meat used in the meatball production.

D. *Colour Properties*

Colour properties of ohmically cooked meatball samples were measured. The measurements were made on HunterLab Colorflex model Colorimeter (Management Company, USA). Colour parameters were calculated according to the formulations below and rated to the raw material

$$Hue angle = \tan^{-1}\frac{b*}{a*}$$

$$DeltaE = \sqrt{(L*-L_0*)^2 + (b*-b_0*)^2 + (a*-a_0*)^2}$$

$$DeltaC = \sqrt{(b*-b_0*)^2 + (a*-a_0*)^2}$$

$$Chroma = \sqrt{b*^2 + a*^2}$$

E. *Microbiological Analysis*

Twenty-five (25) grams of sample were taken under aseptic conditions, and transferred into 225 ml 0.1 % peptone water (PW, pH 6.3±0.2, Oxoid-L37, Basignstoke, Hampshire, England) to determine the microbiological quality of ohmically cooked meatball sample. Appropriate ten-fold dilutions of the samples were prepared in PW and plated on/in growth media in duplicate to estimate microbial counts.

Total mesophilic aerobic bacteria count (TMAB) was determined by using a pour plate method on Plate Count Agar (PCA, pH 7.1±0.2, Oxoid-CM325) and the plates were incubated at 35°C for 48 h (17).

The counts of mould and yeast were determined by surface plating on Dichloran Rose Bengal Chloramphenicol Agar (DRBC, pH 5.6±0.2, Oxoid-CM0727) containing Chloramphenicol Selective Supplement (Oxoid-SR0078E) and plates were incubated at 25°C for 3-5 days (18).

F. *Statistical Analysis*

The differences in cooking yield, colour, textural and microbiological properties depending on voltage gradient were analyzed by ANOVA using the SPSS software version 15 [19]. Differences among the means were compared using Duncan's Multiple Range test. A significance level of $P \leq 0.05$ was used for all evaluations.

III. RESULTS AND DISCUSSION

The cooking yield has been reported as the most important criteria to predict behaviour of the meat products during cooking [20]. The lower cooking yield might be attributed to the excessive fat separation and the water release during cooking. The effect of voltage gradient on cooking yield was not statistically significant ($p>0.05$) (Table 1). It can be explained by the application of the voltage gradients in the narrow range in this study and hence they gave similar cooking yields. Shirsat et al. (2004) [6] determined that the ohmically cooked meat emulsions seemed to reduce the ability to retain fat at higher voltage densities.

Table 1 Cooking yield of meatball samples

Voltage Gradient (V/cm)	Cooking Yield (%)
17.5	90.83±1.70
20	88.5±1.10
22.5	89.01±0.76

Results for the texture profile analysis (TPA) are presented in Table 2. It was determined that the voltage gradient has a significant effect on most of the TPA parameters of meatball samples, except springiness parameter. Highest voltage gradient caused increases in hardness, adhesiveness and chewiness parameters in compared to lowest voltage gradient ($P<0.05$). On the other hand, cohesiveness parameter of V17.5 was detected significantly higher than V20 and V22.5 ($P<0.05$). The interesting point was that V20 samples had the highest values for resilience parameter than the other samples. Instrumental colour measurements taken from the center and surface of the samples are presented in Table 3 and Table 4.

Table 2 Texture profile analysis (TPA) of meatball samples ohmically cooked at at 17.5, 20, 22.5 V/cm.

Parameters	Samples		
	V17.5	V20	V22.5
Hardness (N)	3.23 ± 3.77^a	3.59 ± 2.40^b	3.52 ± 2.27^b
Adhesiveness	0.05 ± 0.02^a	0.05 ± 0.02^a	0.09 ± 0.01^b
Springiness (mm)	3.53 ± 0.04^a	3.51 ± 0.09^a	3.56 ± 0.01^a
Cohesiveness	2.05 ± 0.03^a	1.98 ± 0.04^b	1.98 ± 0.02^b
Gumminess (N)	6.53 ± 0.49^a	7.29 ± 0.76^b	6.97 ± 0.40^{ab}
Chewiness (N mm)	22.94 ± 1.85^a	26.16 ± 2.26^b	24.64 ± 1.34^b
Resilience	2.25 ± 0.05^a	2.40 ± 0.08^b	2.30 ± 0.04^a

$^{a\text{–}b}$ Means within a row with different superscript letters are significantly different (P<0.05).

Table 3 Instrumental colour measurements of center of samples ohmically cooked at 17.5, 20, 22.5 V/cm.

	Centre		
	V17.5	V20	V22.5
L*	1.48±0.02	1.48±0.02	1.47±0.02
a*	0.40 ± 0.05^{ab}	0.35 ± 0.03^a	0.45 ± 0.02^b
b*	0.78±0.02	0.79±0.01	0.76±0.01
Hue	1.50 ± 0.09^{ab}	1.59 ± 0.06^a	1.38 ± 0.02^b
Chroma	0.56±0.02	0.54±0.01	0.57±0.13
ΔE	21.02±1.25	22.04±0.94	20.12±0.22
ΔC	14.41 ± 1.19^{ab}	15.59 ± 0.59^a	13.33 ± 0.43^b

$^{a\text{–}b}$ Means within a row with different superscript letters are significantly different (P<0.05).

Table 4 Instrumental colour measurements of surface of samples ohmically cooked at 17.5, 20, 22.5 V/cm.

	Surface		
	V17.5	V20	V22.5
L*	1.09±0.03	1.09±0.02	1.15±0.08
a*	0.42 ± 0.03^a	0.35 ± 0.01^b	0.39 ± 0.00^a
b*	0.83±0.03	0.79±0.02	0.78±0.02
Hue	1.50 ± 0.05^a	1.58 ± 0.03^b	1.51 ± 0.02^a
Chroma	0.59 ± 0.02^a	0.55 ± 0.00^b	0.56 ± 0.01^b
ΔE	13.63±0.78	15.13±0.40	15.22±1.53
ΔC	13.78 ± 0.70^a	15.39 ± 0.18^b	14.61 ± 0.07^{ab}

$^{a\text{–}b}$ Means within a row with different superscript letters are significantly different (P<0.05).

The other interesting result in V20 was observed for colour changes. Although surface colour changes for V17.5 and V22.5 were similar, center a* value of V22.5 was significantly higher, and center Hue and ΔC values of V22.5 were lower than those of V20 significantly (P<0.05). V20 had significantly lower surface a* and higher surface Hue values than those of other voltage gradients (P<0.05). Ulu (2004) [21] discussed that Hue angle was the most appropriate combination colour property, which described the total colour changes of the meat samples during cooking process.

The initial microbial load of meatball sample was 3.79 log CFU/g. After ohmic cooking, microbial load of samples were significantly reduced (P<0.05). It is found that the reduction effect of ohmic cooking would be different depending on the voltage gradients used (Table 5).

Table 5 Effects of ohmic cooking on Total Mesophilic Aerobic Bacteria (TMAB) and Yeast-Mould counts of meatball samples.

Treatment	TMAB (log CFU/g)	Yeast- Mould (log CFU/g)
V17.5	2.42^a	$<1^a$
V20.0	1.73^b	$<1^a$
V22.5	1.16^b	$<1^a$

$^{a\text{–}b}$ Means within a row with different superscript letters are significantly different (P<0.05).

As it can be seen from Table 5, the reduction of TMAB count achieved after ohmic cooking of meatball samples at 17.5 V/cm was found 1.56 log level. Ohmic cooking at 22.5 V/cm resulted in a general trend of higher reduction (2.055 log) in TMAB count. On the other hand, the effects of ohmic cooking at 22.5 V/cm electric field strength was not significantly different from treatment at 20.0 V/cm, in reducing TMAB count of meatball samples (P>0.05). It is also found that mould and yeast load of meatball samples were reduced to undetectable levels (Table 5).

IV. CONCLUSION

In the present study, voltage gradient (17.5- 22.5 V/cm) applied in the narrow range during ohmic cooking of meatballs was found effective on texture, colour properties and microbiological quality of beef meatballs. However cooking yield of meatballs was not affected by this range of voltage gradients. Our work showed that ohmic cooking at 20.0 V/cm and 22.5 V/cm electric field strengths resulted in greater reduction of TMAB count of meatball samples than 17.5 V/cm of ohmic cooking. Detailed researches are needed to investigate the effects of specific voltage gradient values on meatball samples.

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