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RESEARCH ARTICLE

Quality Evaluation of Buffalo Meatballs Produced at Different Comminution Process Temperatures

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Abstract Buffalo meatballs were formulated and the effects of different comminution temperatures on the quality (cooking yield, water holding capacity (WHC), protein, texture, colour, and sensory) were evaluated. During the mixing of ingredients, the comminution temperature was adjusted using different types of water which were ice (0°C), ice water (4°C), cold water (10°C), room temperature water (22°C), and warm water (32°C). Following comminution for 3 minutes, the temperatures of the batters were recorded at 14, 25, 25, 29, and 27°C, respectively. The comminution took a total of 15 minutes had produced batters with similar final temperatures (ranging from 36 to 38°C), except ice temperature mixing (28°C). Cold water meatballs produced the highest cooking yield but significantly the lowest ($P<0.05$) water-holding capacity. The colour of the cold water meatball shows significantly ($P<0.05$) the highest L* (lightness), significantly ($p<0.05$) the lowest a* (redness), and the lowest b* (yellowness) values. While the textures (hardness, cohesiveness, gumminess, chewiness, and springiness) of all meatballs were similar ($P>0.05$). All meatball samples had nearly similar soluble protein concentrations (0.97 to 1.06 ug/ml) but ice water meatballs had the highest ($P<0.05$). The panellists gave all the meatballs a score ranging from 6.32 to 6.98, with ice meatballs receiving the highest mean score (6.98) acceptability score ($P>0.05$). In conclusion, comminuted buffalo meatballs can be produced using either ice, ice water, cold water, room temperature water, or warm water without affecting their quality. However, ice is suggested for safety purposes against microbial growth during processing.

Keywords: Comminution temperature, buffalo meatballs, meat emulsion, physicochemical, sensory.

Introduction

Malaysia fulfilled its domestic supply of meat by importation mainly from India, New Zealand, Australia, Brazil, and Thailand up to 81.6%. The meat consumption in Malaysia is from cattle and buffalo species and it is the fourth most consumed livestock product per capita (PPC) at 5.5kg/year [1]. Cattle, cow, ox, and bull produced meat called beef. While buffalo produce buffalo meat. Buffalo meat's physicochemical, nutritional, and functional properties and sensory attributes are comparable with beef's [2]. Buffalo meat possesses lower fat and cholesterol compared to beef, which makes it a healthier red meat source [2], [3]. Buffalo is also cheaper compared to beef, making it a preferable choice for food manufacturers to produce various kinds of meat products such as sausages, meat loaves, burger patties, corned buffalo meat, and meatballs [3–5].

The majority of buffalo meat products are comminuted meat products, which contain a mixture of meat and non-meat ingredients. The percentage of the ingredients might differ depending on the types of products and formulations. In meat processing, the comminution process is a process of reducing the material size to a fine particulate state before continuing with mixing the ingredients and forming them into the desired shapes of meat products. This process usually is carried out in the presence of salt that can provide ionic strength to the muscle protein of meat [6]. The ionic strength can induce swelling, water

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binding, and partial extraction of the myofibrillar protein component of the meat. These properties are important to achieve the comminution effect. The properties and quality of comminuted buffalo meat products depend on the effect of gross composition, ingredient quality, and processing variables [7]. Different comminution temperatures were recorded in different processing of various meat products [7–12].

The optimal comminution temperature is crucial to maintain the stability of the meat products' emulsion and meat product quality [7]. When comminution is carried out at a higher temperature than the optimal temperature, the emulsion stability breaks down, resulting in lower product quality [9]. At higher comminution temperatures, the cooking loss increased, softening the texture and darkening the colour [11]. There is no standard comminution temperature reported. The emulsion of meat products with higher fat content (25.7 to 30.6%) is stable at the final comminution temperature of 23 to 24°C [10]. Meat batter with lower fat content (13.5 to 17%) is stable when comminution is performed at 15°C or less [9]. Traditional frankfurter has higher batter loss when the comminution temperature is increased by more than 22°C [13]. English-type sausages can be comminuted at the highest temperature of 25°C [11]. Increasing the temperature up to 30°C does not cause a complete emulsion breakdown, but it causes off-flavours. However, Helmer and Saffle [12] reported that the complete emulsion breakdown of sausage happened at a temperature of 16°C and higher and was found similar in sausage studied by Webb *et al*. [14]. Buffalo meat nuggets are still acceptable in terms of emulsion stability, cooking loss, and texture profiles at comminution temperatures of 27.4°C [7].

During meat processing, generally, ice water (0 to 4°C) or crushed ice (0°C) were commonly added during ingredient mixing to lower the temperature of meat batter (0 to 4°C) so that the extraction of salt-soluble protein could be maximized, resulting in emulsion and chewy texture of meatball [15, 16]. Comminution temperature is a highly complex parameter that cannot be generalized for use in all meat product production. Usually, it is influenced by the ice water added during mixing or using a vacuum-jacketed mixer to control the temperature. Therefore, an optimal comminution temperature should be studied before finalising the processing parameters for any meat products. For the past few years, the effect of comminution temperature on the quality of buffalo meatballs is not well studied compared to other meat types. Therefore, this work aims to evaluate the effect of comminution temperature by adding different states of water including ice (0°C), ice water (4°C), cold water (10°C), room temperature water (22°C), and warm water (32°C) on the quality of buffalo meatballs.

Materials and Methods

Processing of Buffalo Meatballs

Deboned buffalo meat chunks (packed in low-density polyethylene (LDPE) bags) were purchased from Sri Ternak Supermarket, Seri Kembangan, Selangor, Malaysia. Salt (sodium chloride), sodium tripolyphosphate (STPP), onion powder, garlic powder, and flour were purchased from Harmoni shop, Serdang, Selangor, Malaysia.

The meat was cut into cubes and rinsed before being further processed. Different temperatures of water which were ice (0°C), ice water (4°C), cold water (10°C), room temperature water (22°C), and warm water (32°C) were used to manipulate the mixing temperature of the meat emulsion. Table 1 displays the formulation used in preparing buffalo meatballs. The processing steps involved are shown in Figure 1. The mixing process took 15 minutes and water was added to the bowl cutter at a mixing time of 1.5 minutes. The formed meatballs were left at 45°C for 20 min to allow the development of firmer outer layer through the gelatization process to prevent cracks on the surface and uneven shapes of the meatballs. Then, the meatballs were cooked at 90°C for another 20 min.

Temperature profile during comminution of buffalo meatball

The temperature and the thermal image of the meat batter during the mixing process were recorded (FLIR One Pro Thermal Imaging Camera, United States). During the mixing process, the camera was pointed at a fixed point on the surface of the meat batter. The temperatures and the thermal image of the meat batter were captured at time intervals of sixty seconds while the comminution process was in progress.

Table 1. Formulations used in the buffalo meatballs preparation

Ingredients	Amounts (%)				
	Formulation 1	Formulation 2	Formulation 3	Formulation 4	Formulation 5
Buffalo lean meat	70	70	70	70	70
Fats	10	10	10	10	10
Crushed ice (0°C)	10	-	-	-	-
Ice water (4°C)	-	10	-	-	-
Cold water (10°C)	-	-	10	-	-
Room temperature water (22°C)	-	-	-	10	-
Warm water (32°C)	-	-	-	-	10
Salt	2.00	2.00	2.00	2.00	2.00
STPP	0.50	0.50	0.50	0.50	0.50
Onion	0.75	0.75	0.75	0.75	0.75
Garlic	2.25	2.25	2.25	2.25	2.25
Flour	4.50	4.50	4.50	4.50	4.50

Cooking Yield

The cooking yield is an indicator to determine the influence of comminution temperature on the degree of shrinkage of the meatball samples during cooking. This was calculated based on the weight of meatballs before and after cooking as shown below [17].

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked buffalo meatballs}}{\text{Weight of uncooked buffalo meatballs}} \times 100\%$$

Water Holding Capacity

The ability of meatballs with different formulations in holding and retaining water is determined. The meatball samples (10 g) were placed in centrifuge tubes and centrifuged at 12,000 ×g at 4°C for 30 minutes (Kubota 3740, Japan). The water holding capacity (WHC) was expressed as the amount of retained water per 100 g of water present in the meatball's samples before centrifuging, using the following equation [18]:

$$\text{WHC (\%)} = \frac{W_{ac}}{W_{bc}} \times 100\%$$

Where W_{ac} is the weight of the meatball sample after centrifugation and W_{bc} is the weight before centrifugation.

Lowry's Protein Determination

The protein concentration of the meatball batter was determined using the method of Perchonok [19], and Lowry [20]. Lowry method is the biochemical assay to determine the total soluble protein content of the meatball batter, where the total protein concentration exhibited by the colour change of the sample solution is proportional to protein content. The total protein concentration was then measured by using a spectrophotometer at an absorbance of 750 nm.

Texture Profile Analysis (TPA)

The texture of the buffalo meatballs was determined using a Texture Analyzer (TA-XT Plus, Stable Micro Systems, United Kingdom). The attributes reported were the meatball samples' hardness, cohesiveness, chewiness, and springiness. A 75 mm steel round compression platen-type probe was used for evaluation. The texture analyser settings and parameters for TPA were pre-test speed at 1.00 mm/sec, test speed at 5.00 mm/sec, the post-test speed at 1.00 mm/sec, with 10.0 mm distance, and with a trigger force of 5.0 g.

Determination of Meatball's Colour

A chromameter (Konica Minolta, Japan) was used to examine the visual colour of the meatball samples. The colour parameters measured were L* for lightness (0 = black, 100 = white), a* for redness (+a) or greenness (-a), and b* for yellowness (+b) or blueness (-b).

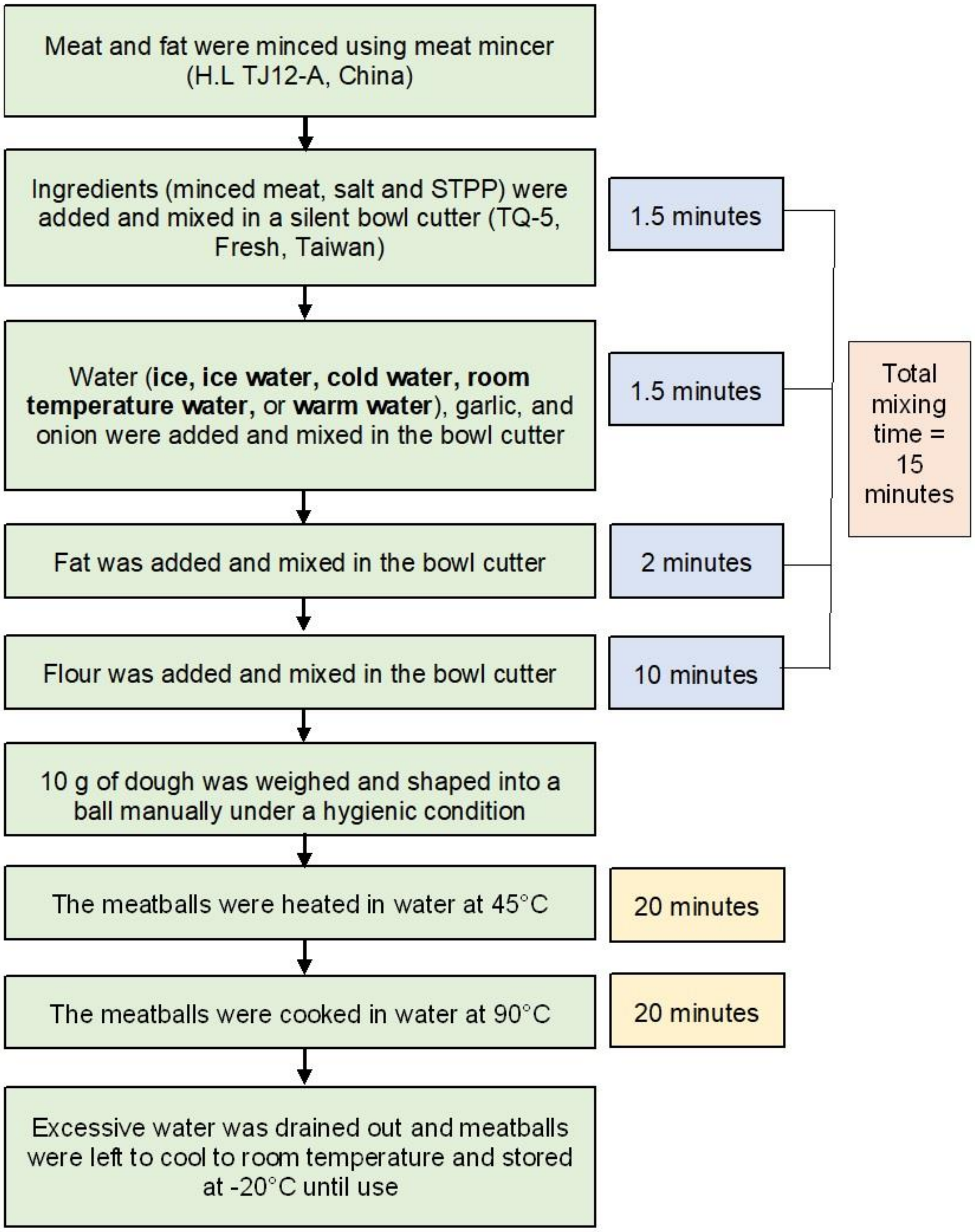

Figure 1. Processing steps in the production of buffalo meatballs.

Sensory Evaluation of the Meatballs

A preference test [21] using a 9-point hedonic scale was carried out to analyse the sensory properties of the cooked buffalo meatballs including appearance, taste, juiciness, texture, and overall acceptability. The scale for each sensory attribute were 1 = "dislike extremely", 2 = "dislike very much", 3 = "dislike moderately", 4 = "dislike slightly", 5 = "neither like nor dislike", 6 = "like slightly", 7 = "like moderately", 8 = "like very much", and 9 = "like extremely". A total of 50 untrained panellists aged ranged from 20 to 30 years old among the students and staff of the Faculty of Food Science and Technology, Universiti Putra Malaysia were involved in this evaluation. This evaluation was conducted in one session in a standard sensory laboratory located in the Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia. Each sample consisted of a quarter of cooked buffalo meatballs which were labelled with a 3-digit random code and the presentation was randomly arranged. Plain water was given to the panellists to rinse their mouths after tasting each sample.

Statistical Analysis

All collected data were analyzed using Minitab software (Minitab package version 19.0 Inc., USA). Each treatment were carried out in triplicate. The results were subjected to one-way ANOVA. The results are described as the means ± standard deviation. ANOVA was used to compare the means. Significant differences between treatments were established at a significance level (P<0.05) using Tukey's test.

Results and Discussions

Temperature Profile During Comminution of Buffalo Meatball Meatballs

The temperature of the meat batter during the mixing process for 15 minutes was observed in Figure 2.

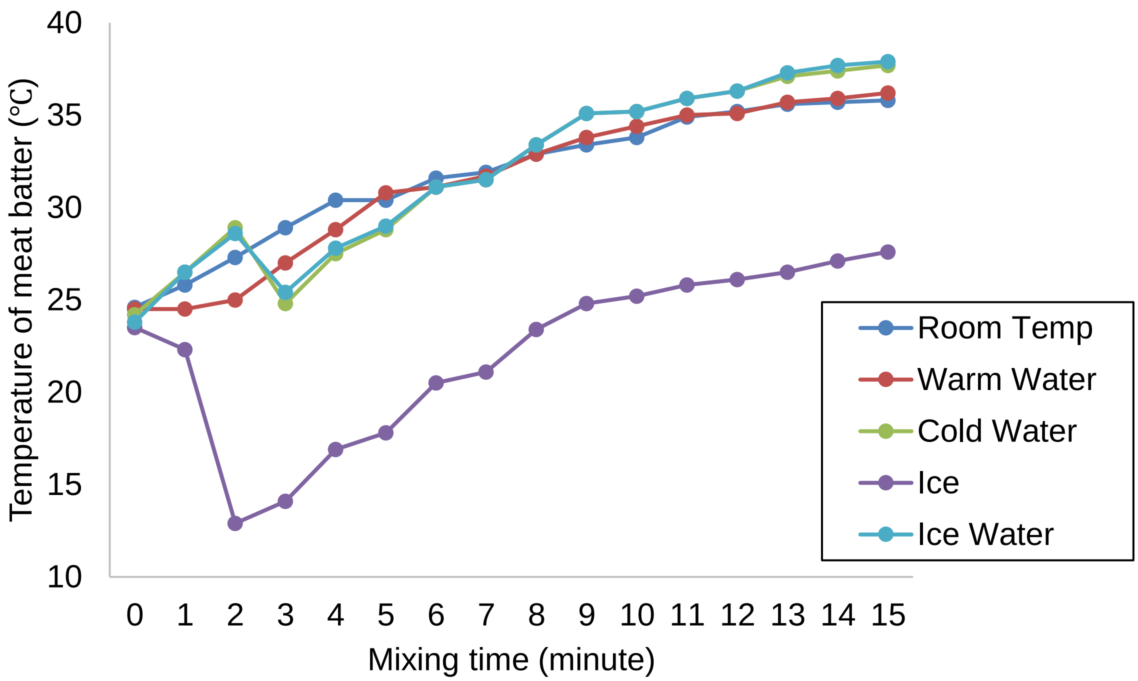

Figure 2. The temperatures of the meat batter during the mixing process to produce buffalo meatballs

Prior to the mixing process, the temperature of the lean buffalo meat is ranging from 23.5 to 24.6°C. Salt (sodium chloride), and STPP (emulsifier) were also added to the lean buffalo meat at the beginning of the mixing process. The bowl cutter was equipped with a set of very sharp knives to chop the meat pieces [22]. In the first minute of mixing in the bowl cutter, the muscle of the lean buffalo meat was reduced to a smaller size (can achieve microparticle size). The extraction rate of protein from the myofilament fragments increases, resulting in tissue disintegration and an increase in the water-binding capacity of the myofibrillar proteins. Sodium chloride switched the isoelectric point of myofibrillar proteins to a lower pH value by creating a larger net negative charge at the existing pH from the ionizable carboxyl groups of the protein. Protein molecules increase in hydration rate by opening up the spatial arrangement from the repulsion between these negatively charged groups, which results in the attraction of hydrated chloride ions strongly attracted to the positively charged protein molecules [23]. According to Acton *et al*. [24], the comminution process is the key determines whether the extraction process is efficient enough to disrupt the membrane and sarcolemma to free myofibrils and to cause the swelling of myofilament. The myofilament fragments swell and myofibrillar proteins hydrate, which caused the development of water binding with a concurrent increase in viscosity.

During mixing, the sharp knives of the bowl cutter bring ingredients into contact with each other. Figure 2 also showed that the temperature of the meat batters increased gradually during mixing. When the meat batter's surface and the knife's surface moved relative to each other, the friction between the two surfaces converted kinetic energy into thermal energy, eventually increasing the temperature of the meat batter. When the colder water (cold water, ice, ice water) was added at 1.5 minutes, the temperature dropped gradually. The temperature of the ice meatball batter dropped to 13°C at the 2nd minute. While the ice and ice water meatball batter dropped to 25°C at the 4th minute. Heat transfer happened as a result of a temperature difference between meat batter and water, in which meat batter released heat to achieve an equilibrium temperature. The temperature of the meat batters decreased. There was no temperature drop observed when warm water and room temperature water were added, due to the slight difference in temperature with other ingredients. At higher temperatures than 23 or 24°C, fat and water binding decreased gradually [10].

At the fifth minute of the comminution process, the fat was added to the meat batter to improve the stability of the meat batter. The knives of the bowl cutter turned fat into clustered and dispersed form. The clustered and dispersed fat droplets started to blend into the aqueous emulsion phase and slowly adsorbed with the myofibrillar protein coating. Protein-encapsulated fat globules started to form, resulting from the absorption and eventually scattered along the emulsion matrix. The fat was added and mixed at temperatures ranging from 29 to 31°C for most meat batters except ice meatballs (18°C). It is considered an acceptable comminution temperature when referring to Brown and Ledward [11]'s work that mentions that at 37°C, complete breakdown still does not occur. However, it did not agree with Thomas *et al*. [7]'s work that claimed that emulsion stability decreased with the increase of comminution temperature. Furthermore, the most suitable comminution temperature should not be more than 27.4°C. The high temperature decreased binding capacity, which resulted from a high protein denaturation rate and high-fat breakdown rate. The shear properties of meat batter also decreased and caused partial or total emulsion breakdown.

The continuous heat addition during the comminution process (due to the friction between the bowl cutter's knife and meat batter) increased the temperature of the meat batter. A considerable amount of energy went into the system, which created a thermodynamically unstable condition [25]. The salt-soluble protein (myosin) surrounds the fat globules, forming a stabilizing protein film or interfacial protein film (IPF) membrane. Myosin is the main protein that acts as the emulsifier, thereby reducing the interfacial tension and stabilizing the emulsion. At the end of mixing, the temperatures of the meat batter were nearly similar ranging from 36 to 38°C, except for ice (28°C).

Effect of Comminution Temperature On Meatball's Cooking Loss and WHC

Water holding capacity (WHC), colour, and pH of level have a direct impact on the appearance of fresh meat products to potential buyers [26]. WHC is the ability of the meat in retaining the water despite any application of force to the meat [27]. Processed meat products with poor WHC tend to lose liquid during the cooking process, increasing food manufacturers' production costs [28]. Meat products with good WHC or water retention will improve the cooking yield, texture, tenderness, and juiciness [6]. A reduction in WHC means the shrinkage of the myofibrillar and loss of water from the myofilament space to the sarcoplasmic and extracellular space [27].

Table 2. Cooking yield and water holding capacity of buffalo meatballs

Samples	Cooking Yield (%)	Water holding capacity (%)
Ice	88.50 ± 2.57^{a}	53.10 ± 0.87^{ab}
Ice water	92.59 ± 0.20^{a}	49.48 ± 0.70^{b}
Cold water	93.23 ± 0.39^{a}	48.86 ± 2.32^{b}
Room Temperature water	92.53 ± 0.76^{a}	57.81 ± 1.40^{a}
Warm water	89.98 ± 6.48^{a}	49.04 ± 3.81^{b}

The means that do not share the same letter and are significantly different (P< 0.05) in the same column.

Increasing the comminution temperature higher than 27.4°C reduced the quality and shelf life of buffalo meat nuggets (11% fat). The cooking loss was less than 9% when a comminution temperature below 27.4°C was used during mixing. When a high comminution temperature of 34.8°C was used, the cooking loss was almost 12% [7]. In the comminution of sausage (26 to 30% fat), the water and fat binding abilities decreased when exceeding the comminution temperature of 18 to 19°C [10]. Indeed, these were contradicted by the present study. The WHC and cooking yield of the meatballs in the present work are shown in Table 2. The cooking yield of the meatball samples ranged from 89 to 93% with cooking loss below 12%. No significant differences (P>0.05) were observed for the cooking yield between treatments, however, the cold water meatballs had the highest (93%) cooking yield while the ice meatballs had the lowest (89%). The room temperature water meatballs (58%) had a significantly higher (P<0.05) WHC compared to other samples except for ice meatballs.

Effect of Comminution Temperature on Meatball's Colour

Colour plays a major role in ensuring the marketability and acceptability of food products. Colour is a significant quality feature that influences consumers' purchasing decisions [26]. Myoglobin determines the colour of the meat [22]. The intensity of the colour of the meat muscle is determined by myoglobin's ability to fight with mitochondria for oxygen, resulting in oxygen penetration beneath the muscle surface [29]. The colour of meat products particularly redness (+a*) is associated with the amount of myoglobin present in muscle [22]. The high lightness (L*) value of raw meat depends on the predominant form of deoxygenated myoglobin [22]. Huda *et al*. [17] reported L* readings of 47.73 to 58.79, a* readings of 2.79 to 6.68, and b* readings of 15.83 to 19.68 in commercial beef meatballs. In reduced-fat meatballs, it was obtained that the value of L* ranged from 47.32 to 51.42, a* value ranged from 1.97 to 2.45, and b* ranged from 6.58 to 11.45 [30]. The lightness of buffalo meat patties ranged from 49.46 to 60.75, redness ranged from 10.42 to 16.60, and yellowness ranged from 13.34 to 15.16, depending on the type of mixer used [22].

Bright-coloured products are preferable by consumers. Meatballs with similar colour (lightness and redness) to existing market products are preferred. Table 3 shows the colour characteristics (L*, a*, and b*) of all meatball samples. The colour of the cold water meatball was the lightest (69.73), then followed by the ice water meatball (67.64), and the room temperature water meatball (66.73). There was no significant difference (P>0.05) in the lightness of the meatballs for these three meatballs (cold water, ice water and room temperature water meatballs). However, the colour of the cold water meatball was significantly (P<0.05) lighter compared to ice and warm water meatballs. A higher L* (lightness) value of meatballs produced using cold water might indicate the predominant form of deoxygenated myoglobin. In the present work, the values of L* (ranging from 64.38 to 69.73), were higher compared to commercial beef meatballs [17], reduced-fat beef meatballs [30], and buffalo meat patties [22]. While the redness of the buffalo meatballs was ranging from 5.14 to 8.95, which was lower compared to the buffalo meat patties [22]. The ice meatball was the reddest (a* value of 8.95), followed by warm water (a* value of 7.41), and ice water (a* value of 6.79). The redness of the ice meatball was significantly (P<0.05) the highest compared to other meatball samples (P<0.05) and this indicated the greater amounts of the oxygenated myoglobin form.

Table 3. Colour characteristics of buffalo meatball samples

Sample	Colour characteristics		
	L*	a*	b*
Ice	64.38 ± 1.13^{b}	8.95 ± 0.64^{a}	7.96 ± 0.52^{a}
Ice water	67.64 ± 1.31^{ab}	6.79 ± 0.61^{b}	8.30 ± 1.16^{a}
Cold water	69.73 ± 1.62^{a}	5.14 ± 0.12^{c}	7.16 ± 1.53^{a}
Room temperature water	66.73 ± 2.10^{ab}	6.04 ± 0.12^{bc}	7.28 ± 1.28^{a}
Warm water	65.37 ± 0.93^{b}	7.41 ± 0.72^{b}	8.21 ± 0.69^{a}

The means that do not share the same letter and are significantly different (P< 0.05) in the same column.

Effect of Comminution Temperature on Meatball's Texture

Cohesiveness and hardness are the primary mechanical parameters of the texture characteristics of food. While chewiness, springiness, and gumminess, are secondary mechanical parameters below cohesiveness [31]. The result of Texture Profile Analysis (TPA) was summarized in Table 4. Different temperatures of water during mixing meat batter did not affect significantly (P>0.05) the hardness, cohesiveness, gumminess, chewiness, and springiness of the buffalo meatballs.

The highest value of all texture characteristics (hardness, cohesiveness, gumminess, chewiness, and springiness) was obtained in the warm water meatball sample. The meat emulsion is formed when the protein is solubilised and the fat particles are suspended and entrapped within the protein matrix [25]. The thermal effect triggered by the warm water increased the emulsion stability, resulting in an acceptable texture [25]. According to Huda *et al*. [17], the higher carbohydrate content, significantly influence the hardness and chewiness of beef meatballs. However, the hardness and chewiness characteristics of reduced-fat beef meatballs were dependent on their protein content and starch properties [30]. The formulation of all meatballs used in the present study was exactly maintained instead of only the water temperature during mixing was different and this might be a reason why the characteristics and texture of all meatball samples are almost similar.

Table 4. Texture properties of buffalo meatball sample

Sample	Texture Properties				
	Cohesiveness	Gumminess (g)	Chewiness (g×mm)	Springiness (mm)	Hardness (g)
Ice	0.5250 ± 0.10[a]	6805 ± 466[a]	5277 ± 1078[a]	0.7720 ± 0.11[a]	13161 ± 1688[a]
Ice water	0.4683 ± 0.05[a]	6563 ± 1402[a]	4981 ± 1410[a]	0.7390 ± 0.07[a]	13924 ± 1673[a]
Cold water	0.4647 ± 0.02[a]	5587 ± 435[a]	4275 ± 634[a]	0.7630 ± 0.07[a]	12035 ± 892[a]
Room temperature water	0.4717 ± 0.04[a]	6635 ± 1327[a]	4559 ± 533[a]	0.6860 ± 0.05[a]	15686 ± 1300[a]
Warm water	0.5920 ± 0.20[a]	7471 ± 1431[a]	6021 ± 2431[a]	0.7857 ± 0.16[a]	13108 ± 1759[a]

The means that do not share the same letter and are significantly different ($P < 0.05$) in the same column.

Effect of Comminution Temperature on Meatball's Protein Concentration

As the comminution temperature rises, it can induce a complete breakdown of protein globules in the emulsion interface that is oriented with the polar and nonpolar molecules [13]. Protein denaturation can happen when exposed to high temperatures [32]. Denaturation changes the molecular structure without breaking any peptide bonds of a protein. Major components of myofibrillar protein such as myosin and actin start denaturing at a temperature of approximately between 40 and 60°C, and 80°C, respectively [33]. In this present work, the temperature of the meatballs batter during the 15 minutes of comminution does not exceed 40°C. Therefore, preventing any protein denaturation. The concentration of soluble protein in buffalo meatballs ranged from 0.97 to 1.06 ug/ml (Table 5). All the meatballs did not show consistent changes after being subjected to different comminution temperatures. Using Ice water, the meatball sample obtained significantly ($P<0.05$) the highest concentration of protein at 1.06 ug/ml. While the ice meatball sample obtained significantly ($P<0.05$) the lowest concentration of protein (0.97 ug/ml).

Table 5. The concentration of soluble protein in buffalo meatballs

Samples	The concentration of protein (ug/ml)
Ice	0.97 ± 0.01[c]
Ice water	1.06 ± 0.01[a]
Cold water	0.99 ± 0.03[bc]
Room temperature water	1.02 ± 0.02[abc]
Warm water	1.03 ± 0.02[ab]

The means that do not share the same letter and are significantly different ($p < 0.05$) in the same column.

Sensory Evaluation of the Meatballs

The result of sensory evaluation and the analysis of the result is shown and summarised in Table 6. The acceptance test of the sensory properties of different formulations of meatballs was carried out by a nine-point hedonic scale from a score of 1 to represent the meaning of dislike extremely to a score of 9 with the meaning of like extremely. The appearances and juiciness characteristics from the sensorial of all meatball samples were not significantly different ($P>0.05$). Moreover, there was no significant difference ($P>0.05$) in the overall acceptability of meatballs either, which shows that all meatballs are generally accepted by the panellists with mean scores ranging from 6.32 to 6.98.

However, the preference of panellists toward the meatballs' texture was found significantly differed ($P<0.05$) between the formulations. Even though the texture profile analysis obtained that cohesiveness, hardness, chewiness, springiness, and gumminess of all samples were similar($P>0.05$) (Table 4). The cold water meatball sample obtained significantly ($P<0.05$) the highest mean score (7.34) for texture.

While the ice water meatball sample showed the significant (P<0.05) lowest mean score (6.52). Nevertheless, it was still in the "like" category, which means all the meatball samples are still acceptable for the panellist's palate. The mean score of consumer panellists in taste attribute was similar (P>0.05) for ice water, cold water, and room temperature water meatballs. However, the taste of the ice meatball and warm water meatball affected significantly (P<0.05) consumer preference.

Table 6. Sensory evaluation of buffalo meatball prepared using different comminution temperatures

Sample	Sensory Attributes				
	Texture	Appearance	Taste	Juiciness	Overall Acceptability
Ice	7.20±1.28[ab]	7.28±1.25[a]	6.72±1.75[ab]	6.94±1.48[a]	6.98±1.48[a]
Ice water	6.52±1.39[c]	6.82±1.17[a]	5.84±1.88[c]	6.32±1.60[a]	6.32±1.66[a]
Cold water	7.34±1.15[a]	7.16±1.31[a]	7.02±1.39[a]	6.78±1.56[a]	6.94±1.25[a]
Room temperature water	6.84±1.00[abc]	6.92±1.16[a]	6.28±1.51[abc]	6.92±1.40[a]	6.72±1.54[a]
Warm water	6.64±1.34[bc]	7.30±1.13[a]	6.16±1.87[bc]	6.38±1.50[a]	6.40±1.70[a]

The means that do not share the same letter and are significantly different (P < 0.05) in the same column.

Conclusions

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Based on the evaluation of buffalo meatballs at different comminution process temperatures, the temperature patterns during the mixing process were observed to be similar for all meatball samples. The temperature of the meatball batter gradually increased over the 15-minute mixing period. When higher-temperature water was used, the temperature of the meatball batter continued to increase, while lower-temperature water resulted in an instant reduction in temperature, followed by a subsequent increase similar to the higher-temperature water samples. Despite the initial temperature differences in the water, the energy input from the bowl cutter's knife and the friction between the knife and meat batter compensated for the initial temperature variations. In general, different comminution temperatures did not affect the quality of the buffalo meatballs in terms of cooking yield, water-holding capacity, protein content, texture, colour, and sensory attributes. Therefore, manufacturers can reduce manufacturing costs by using water at room temperature, eliminating the need for heating or cooling processes. However, further studies are recommended to investigate the impact of comminution temperature on the survival of microorganisms and the shelf life of the meatballs. In the current study, it is suggested to use ice during the comminution process to ensure the safety of the final products.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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