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Microbiological, oxidative stability, physicochemical attributes, and sensory evaluation of beef meatballs with turmeric powder addition

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ABSTRACT

Meatballs are a popular dish in Indonesia, but they often spoil. To address this, researchers have tried adding natural, low-cost ingredients like turmeric powder. This study tested how different levels of turmeric powder affect meatball quality, including microbes, oxidation, physicochemical traits, and consumer acceptance. The experiment used a completely randomised design with four replications. Treatments were: T0 (no turmeric), T1 (1.5%), T2 (2.5%), and T3 (3.5%), all based on meat weight. Researchers measured total microbes, TBA, cooking yield, tenderness, emulsion stability, moisture content, water-holding capacity, pH, and taste-test scores. Adding turmeric up to 3.5% reduced microbes (by 1 log at 2.5%-3.5%), decreased oxidation, and improved tenderness and emulsion stability. But turmeric also lowered cooking yield, moisture, and pH. Folding test results and water-holding capacity stayed the same at all levels. Panellist preference dropped as turmeric increased.

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INTRODUCTION

Beef meatballs are a popular processed meat in Indonesia and other Asian countries, valued both as a cultural dish for communal events and as an economic driver supporting small to medium enterprises across urban and rural areas. In recent years, the methods of selling and serving meatballs have undergone significant changes. Meatballs are no longer sold only from pushcarts but are now also available in small shops, kiosks, and modern restaurants. The ways they are served have also diversified, ranging from traditional soup meatballs to innovative variations such as grilled, fried, and roasted meatballs. This diversification is driven by consumer demands for healthier, novel, and convenient products, as well as innovative marketing strategies like social media promotion, limited-edition flavors, and modern culinary trends to attract wider audiences and boost product visibility (Larina 2017).

However, meatballs are prone to spoilage, primarily due to microbial growth and oxidation (Tuffi et al. 2021), which adversely affect their physicochemical quality. To counter this, producers often add preservatives, typically synthetic preservatives and antioxidants, to the product. Although effective in extending shelf life, the use of synthetic preservatives and antioxidants may pose negative health risks to consumers (Ahmed 2022), such as potential toxicity and allergic reactions (Peng 2023, Sulieman et al. 2023).

Therefore, it is crucial to find safe and effective natural alternatives (Kumar and Rajput 2023) to enhance the microbiological, oxidative, and physicochemical stability of meatballs without compromising their sensory quality. One potential natural ingredient is turmeric (*Curcuma longa*). Turmeric is a natural ingredient rich in curcumin, a bioactive compound known for its potent antimicrobial and antioxidant properties (Mahato and Mahto 2023). While traditionally used in cooking (Fuloria et al. 2022), turmeric's potential in processed meats like beef meatballs remains underexplored. Its antimicrobial and antioxidant properties may help prevent spoilage and oxidation, thereby extending shelf life and preserving quality.

This study aims to evaluate the effects of adding turmeric powder on key aspects of beef meatballs, including microbial count, oxidation levels, several physicochemical properties, and panelist acceptability.

MATERIALS AND METHODS

Meatball preparation

The procedure for meatball preparation followed the method of Rahayu et al. (2023) as shown in the diagram, with the composition per batch shown in Table 1. All ingredients were thoroughly mixed to form a dough. The dough was shaped into balls with a diameter of 3 cm and boiled in boiling water for 10 minutes, then drained. The meatballs were then observed according to the study variables.

Variables measurement

Total microbial count was determined using the total plate count (TPC) procedure according to SNI 2897:2008 (BSN 2008). Oxidation levels were indicated by thiobarbituric acid (TBA) number. The pH of the meatballs was measured using a pH meter. Cooking yield was calculated as the difference in weight between the dough and the cooked meatballs, divided by the dough weight. Moisture content was determined following the procedure by Soeparno (2005). Water-holding capacity was measured using the Hamm method (Soeparno 2005). Emulsion stability was determined based on released fluid, with lower released fluid indicating higher stability (Yum et al. 2018). Tenderness was evaluated using a universal penetrometer following standard protocols.

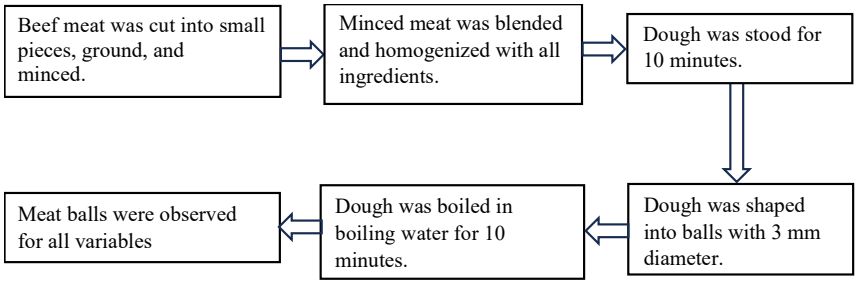


Figure 1 Meatballs preparation diagram

Table 1 Composition of beef meatball.

Ingredient	Treatments			
	T0	T1	T2	T3
Beef meat (g)	400	400	400	400
Tapioca flour (g)	100	100	100	100
Cubic ice (g)	100	100	100	100
Salt (g)	13	13	13	13
Pepper powder (g)	3	3	3	3
Garlic powder (g)	6	6	6	6
Turmeric powder	0	6	10	14

Composition for single batch processing

The folding test was scored based on the degree of cracking when the meatballs were folded with fingers (Lanier 1992). Meatballs were sliced into 3 mm thick and 25 cm long pieces, then folded using the index finger and thumb. The scoring criteria were as follows: a score of 5 if the meatball did not crack when folded, a score of 4 if it did not crack when folded into a semicircle, a score of 3 if it cracked slightly in a semicircle, a score of 2 if it cracked quickly in a semicircle, and a score of 1 if it cracked when pressure was applied to fold the sample.

Panelists' acceptability was assessed sensorially by 25 untrained panelists, who were students from the Animal Science Study Program, Faculty of Agriculture, University of Bengkulu. The panelists were given brief explanations before the evaluation. Assessments were conducted using a line scale from 0 (dislike very much) to 9 (like very much), with the panelists marking a point on the 0-9 cm line to indicate their preference, which was then measured from the 0 (zero) point as the evaluation data (Meilgaard et al. 1999).

Statistical analysis

The data obtained were analyzed using ANOVA, and if significant effects were observed, further analysis was conducted using Duncan's Multiple Range Test (DMRT). A-5% confidence interval was applied.

RESULTS AND DISCUSSION

Total Microorganisms, Oxidation Levels, and pH of Meatballs

The results indicated that the addition of turmeric powder to beef meatballs significantly reduced the total microbial count (TPC) ($P<0.05$), as shown in Table 2. The meatballs in the T0 group (without turmeric) had the highest TPC (4.12 log cfu/g), while the T3 group (3.5% turmeric) had the lowest TPC (3.86 log cfu/g). This reduction may be attributed to the antimicrobial properties of turmeric, which can inhibit microbial growth in food products. Turmeric contains bioactive compounds, especially curcumin, known for their strong antimicrobial effects. Studies have shown that adding turmeric powder to meat formulations significantly reduces total microorganisms during storage (Augustyńska-Prejsnar et al. 2022). Curcumin has been effective against various pathogens, including both Gram-positive and Gram-negative bacteria such as *Staphylococcus aureus* and *Escherichia coli*, with minimum inhibitory concentrations (MIC) that demonstrate antimicrobial activity (Al-Najjar et al. 2024, Wu et al. 2024). Its ability to inhibit the growth of several bacterial strains suggests that turmeric has potential as a functional food ingredient (Subtain et al. 2023).

The oxidation level, as measured by TBA number, showed a significant decrease ($P<0.05$) with the addition of turmeric (Table 2). T0 had the highest TBA number (0.86 mg/Kg), while T3 had the lowest TBA number (0.43 mg/Kg). The reduction in TBA number in meatballs with added turmeric can be linked to the antioxidant activity of curcumin, which effectively scavenges free radicals and prevents lipid peroxidation. Therefore, the use of turmeric in meatballs not only serves as an antimicrobial agent but also as an effective antioxidant. Curcumin can reduce oxidation in meat products (Amminikutty et al. 2023). Other studies have shown that meatballs with turmeric exhibit lower thiobarbituric acid-reactive substances (TBARS), indicating reduced lipid oxidation (Kilic et al. 2021). In duck burgers, turmeric powder significantly limited lipid oxidation, demonstrating its effectiveness in various meat products (Augustyńska-Prejsnar et al. 2022).

The pH of the meatballs tended to decrease (P<0.05) as the concentration of added turmeric increased, from 6.56 in T0 to 6.44 in T3 (Table 2). This pH reduction may be due to the acidic nature of turmeric itself. However, turmeric's pH can vary depending on environmental conditions (Musa et al. 2022). Some studies have also shown similar results, where the pH of products with added turmeric decreased. For example, in the fermentation of 'Doenjang', increased turmeric concentration led to a gradual reduction in pH and titratable acidity, indicating its acidifying effect (Kim and Kim 2020). The presence of turmeric in the meatball mixture may interact with other components, such as fats and proteins, potentially leading to pH changes, as is common when natural ingredients are added to foods. For instance, adding tomato paste to fenugreek-based meatballs was found to lower pH, suggesting that interactions between ingredients significantly affect overall acidity (Kök and Çiçek 2022). The antioxidant properties of turmeric may also alter the chemical environment, further contributing to pH changes (Saleh et al. 2022).

Cooking yield, moisture, water holding capacity, and emulsion stability

Cooking yield decreased (P<0.05) with increasing turmeric levels, from 9.31% in the meatballs without turmeric (T0) to 2.55% in the meatballs with 3.5% turmeric (T3) (Table 3). The sharp decline in cooking yield was observed from T0 to the turmeric-added meatballs, while the differences between T1-T3 (1.5%–3.5% turmeric) were significant but not as pronounced. The reduction in cooking yield in meatballs with added turmeric powder is likely due to several interrelated factors, particularly chemical components and their interactions during cooking. Curcuminoids in turmeric may alter the lipid profile of the meat, leading to reduced moisture retention during cooking (Mancini et al. 2015). While turmeric reduces lipid peroxidation, which benefits quality, it may also cause changes in the structural integrity of the meat, leading to higher losses during cooking (Augustyńska-Prejsnar et al. 2022).

The decrease in cooking yield was also closely related to the reduction in moisture content. This study showed that the moisture content of meatballs significantly decreased with the addition of turmeric powder (P<0.05), as shown in Table 3. The significant reduction in moisture from 61.49% in T0 to 59.66% in T3 might contribute to the decrease in cooking yield and tenderness of the product (Table 4).

While adding turmeric powder generally helps maintain product moisture (Augustyńska-Prejsnar et al. 2022), certain formulations can increase water loss during cooking (Kilic et al. 2021). Thus, careful consideration is important for the application of turmeric to achieve the desired quality. Although moisture content decreased, it remained within safe limits for processed meat products. The Indonesian National Standard (SNI) requires a maximum moisture content of 70% for meatballs (BSN 1995).

Table 2 Total Plate Count, TBA, and pH of beef meatballs with added turmeric powder

Meatballs	TPC (log cfu/g)	TBA (mg eq MDA/Kg)	pH
T0	4.12±0.00^{d}	0.86±0.06^{c}	6.56±0.01^{d}
T1	4.05±0.01^{c}	0.86±0.05^{c}	6.54±0.01^{c}
T2	3.98±0.01^{b}	0.58±0.05^{b}	6.49±0.01^{b}
T3	3.86±0.00^{a}	0.43±0.07^{a}	6.44±0.01^{a}

Different superscripts in the same column indicate a significant difference (P<0.05)

Table 3 Cooking yield, moisture, water holding capacity and emulsion stability of beef meatballs added with turmeric powder

Meatballs	Cooking yield (%)	Moisture (%)	Water holding capacity (%)	Released fluid (%)
T0	9.31±0.05^{d}	61.49±0.01^{d}	65.85±0.01	0.15±0.01^{a}
T1	2.96±0.03^{c}	60.84±0.00^{c}	65.85±0.01	0.11±0.00^{a}
T2	2.69±0.03^{b}	60.61±0.00^{b}	65.85±0.01	0.07±0.00^{b}
T3	2.55±0.04^{a}	59.66±0.00^{a}	65.85±0.01	0.07±0.01^{b}

Different superscripts in the same column indicate a significant difference (P<0.05)

Table 4 Tenderness, folding test, and panelists' acceptability of beef meatballs added with turmeric powder

Meatballs	Tenderness (mm/g/s)	Folding test	Acceptability
T0	0.54±0.01^{c}	4.84±0.37	6.12±0.75^{c}
T1	0.54±0.02^{c}	4.80±0.41	5.09±0.56^{b}
T2	0.48±0.00^{b}	4.72±0.54	4.72±0.60^{a}
T3	0.46±0.00^{a}	4.64±0.57	4.48±0.56^{a}

Different superscripts in the same column indicate a significant difference (P<0.05)

Water-holding capacity (WHC) did not show significant changes across treatment groups (P>0.05), with values around 65.85% in all treatments (Table 3). This indicates that turmeric addition, at the concentrations tested, did not affect the product's ability to retain water. The lack of effect on WHC up to 3.5% turmeric addition may be due to factors related to turmeric's properties and the meat matrix. Some studies have shown that turmeric supplementation at varying levels does not improve WHC in poultry (Negari et al. 2015), duck burgers (Augustyńska-Prejsnar et al. 2022), and chicken meatballs (Kilic et al. 2021). While turmeric positively contributes to meat quality and oxidative stability, its impact on WHC is negligible, suggesting that other factors, such as meat composition and cooking methods, play a more critical role in moisture retention.

Released fluid decreased with the addition of turmeric from 0.15% in T0 to 0.07% in T3. Lower released fluid indicates higher emulsion stability in the meatballs. Thus, this study demonstrates that adding 2.5%-3.5% turmeric (T2-T3) increased the emulsion stability of the meatballs. This enhancement in emulsion stability might be related to the reduction in moisture content and pH that occurred with turmeric addition.

Turmeric, rich in curcuminoids, enhances emulsion stability through various mechanisms. The use of natural emulsifiers, such as soy protein and polysaccharides, improves the stability of curcumin-loaded emulsions by increasing viscosity and reducing droplet size, preventing phase separation (Teixé-Roig et al. 2022, Lu et al. 2024). The preparation of meatballs in this study involved polysaccharides derived from tapioca. While turmeric addition can enhance stability, excessive amounts might increase viscosity, potentially affecting the texture (Rajab and Kareem 2023) of the food product. Balancing concentrations is crucial for optimal product properties.

Tenderness, folding test, and acceptability

Tenderness decreased with increasing turmeric levels, from 0.54 mm/g/second in T0 to 0.46 mm/g/second in T3 (Table 4). Adding turmeric powder to meatballs could reduce tenderness, likely due to decreased pH, reduced water-holding capacity (WHC), and altered protein interactions (Lestarini et al. 2015). A lower pH (as shown in Table 2) can lead to protein denaturation, limiting their ability to form a soft gel matrix, thus making the texture firmer. Reduced WHC means less moisture is retained within the meat matrix, leading to drier and tougher meatballs. Additionally, curcumin may interfere with protein-protein bonding during cooking, altering the structural integrity of the meat gel and contributing further to the reduced tenderness (Lestarini et al. 2015, Kilic et al. 2021, Augustyńska-Prejsnar et al. 2022).

The results showed that the Folding test scores did not decrease significantly (P>0.05) with the addition of turmeric (Table 4). The Folding test score decreased from 4.84 in meatballs without turmeric (T0) to 4.64 in meatballs with 3.5% turmeric powder (T3). This reduction indicates a negative impact of turmeric on the meatball structure, possibly due to changes in chemical and physical composition during processing. Several studies have shown that adding turmeric powder to processed meat products causes textural changes related to the product's moisture content (Augustyńska-Prejsnar et al. 2022, Draszanowska et al. 2022, Saleh et al. 2022). This study found that turmeric powder reduced moisture content and tenderness (Tables 3 and 4). However, it did not lead to a significant decrease in Folding test scores, indicating that the elasticity of the meatballs did not differ significantly between treatments.

The results also indicated that panelists' acceptability scores significantly decreased with turmeric addition, from 6.12 in T0 to 4.48 in T3. This

reduction could be related to changes in taste, texture, and aroma caused by turmeric in the meatball product. Turmeric has a strong and earthy flavor that may overpower other ingredients, leading to lower overall acceptance in products like meatballs (Lučan Čolić et al. 2023). Additionally, the addition of turmeric might alter the texture to be less appealing (Long et al. 2024). This study also showed that meatballs with added turmeric powder were less tender compared to those without turmeric (Table 4), which contributed to the decline in panelists' acceptability.

CONCLUSION

This study demonstrated that incorporating turmeric powder into beef meatballs significantly improves microbiological and oxidative stability, offering a natural strategy to extend shelf life and enhance safety. The observed improvements in pH, tenderness, and emulsion stability further highlight its potential. However, the study also revealed a trade-off, with slight decreases in cooking yield, tenderness, and sensory scores. Future research should focus on exploring synergistic effects with other natural additives, optimizing processing parameters, and conducting more detailed sensory evaluations to mitigate these minor drawbacks and fully leverage the benefits of turmeric in meat products.

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