JURNAL AGROEKOTEKNOLOGI TERAPAN
Applied Agroecotechnology Journal
Agroteknologi Universitas Sam Ratulangi **e_ISSN:2797-0647**

Physicochemical Quality of Broiler Chicken Meatballs Prepared with Cassava Flour as a Tapioca Substitute

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Manuscript received: 27 June 2026
Revision accepted: 15 Sept 2026

Abstract. *Cassava flour is a locally available alternative to tapioca starch in processed meat products, but its effects on the physical characteristics of chicken meatballs require evaluation. This study examined the pH, water-holding capacity (WHC), and cooking loss of broiler chicken meatballs prepared with different cassava flour–tapioca blends. A completely randomized design with four formulations and four replications was used. Each formulation contained 300 g of chicken meat and a constant 70 g of flour: P0, 0 g cassava flour and 70 g tapioca; P1, 20 g and 50 g; P2, 50 g and 20 g; and P3, 70 g and 0 g, respectively. According to the reported analysis of variance and Duncan's multiple range comparisons, pH differed between the tapioca-only control (7.400) and the cassava-containing formulations (6.550–6.875), while WHC showed no statistically significant treatment effect ($p > 0.05$). Cooking loss decreased from 18.402% in P0 to 15.390% in P3, with distinct Duncan groupings for the four formulations ($p < 0.05$). The findings indicate that cassava flour can replace tapioca within the evaluated formulations while reducing cooking loss. This conclusion is restricted to the three measured physical attributes; sensory quality, shelf life, and nutritional composition were not examined.*

Keywords: ***cassava flour; chicken meatballs; cooking loss; tapioca; water-holding capacity.***

INTRODUCTION

Chicken meatballs are widely consumed processed meat products in Indonesia. Their quality depends on the composition of the meat batter, interactions between meat proteins and added ingredients, and the thermal conditions of processing. Physical attributes such as pH, water-holding capacity (WHC), and cooking loss are useful indicators because they describe aspects of the meat matrix before and after cooking. Kartikasari et al. (2020) evaluated these properties in broiler chicken meatballs, while Meng et al. (2022) summarized how raw materials, fillers, and heating conditions contribute to variation in meatball quality.

Tapioca starch is commonly included as a filler in meatball formulations because starch contributes to product structure during heating. Gelatinization can influence the distribution and retention of water within a protein-rich matrix, and these effects vary according to starch type, availability of moisture, and the presence of other ingredients (Li, 2022). Experimental work with myofibrillar protein–cassava starch gels has also demonstrated that starch incorporation can change gel properties and water retention, although those controlled systems differ from complete meatball formulations (Hu et al., 2023).

Cassava flour is a different ingredient from extracted tapioca starch. Cassava flour is produced from milled cassava material and may retain non-starch constituents, whereas tapioca is a more purified starch fraction. This distinction is relevant because the

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characteristics of the filler can influence processing properties and the final product. Herlambang et al. (2019) reported that substituting cassava flour for tapioca affected the physical and sensory properties of meatballs. Hendrik and Lunatri (2025) likewise examined the sensory response of chicken meatballs to cassava flour substitution. These studies indicate the practical relevance of evaluating cassava flour as a locally available substitute, rather than assuming that its behavior will match that of purified tapioca.

Other investigations have tested different agricultural flours as meatball fillers. Malini et al. (2016) assessed durian seed flour, Nubatonis et al. (2022) evaluated taro flour in lamb meatballs, and Ninu et al. (2022) investigated red sorghum flour as a replacement for tapioca. More recently, Mudawaroch and Rinawidiastuti (2025) considered several local tuber flours in relation to physicochemical and sensory meatball characteristics. Collectively, the findings suggest that substituting different flour sources can alter product characteristics, but the direction and magnitude of responses depend on the ingredients and formulations used.

Evidence from other meatball systems further shows that changes in fillers and protein–polysaccharide interactions do not always lead to the same response across quality indicators. Tiven and Simanjorang (2024) examined substitution of meat and tapioca with alternative ingredients, while Hajrawati et al. (2025) observed formulation-dependent changes in chicken meatballs supplemented with purple sweet potato flour. Studies of hydrocolloid–meat protein systems also illustrate that the properties of the heat-induced protein network can change with ingredient composition (Li et al., 2023). Thus, cooking loss and WHC should be examined as separate response variables rather than treated as interchangeable measurements.

Despite the availability of studies on alternative fillers, information remains useful on the physical responses of chicken meatballs to clearly defined cassava flour–tapioca combinations under a constant total flour mass. This study aimed to compare pH, WHC, and cooking loss in broiler chicken meatballs containing four blends of cassava flour and tapioca. Its applied contribution is the description of the observed product responses when the 70-g filler fraction is progressively replaced with cassava flour, providing information for the utilization of local cassava-based ingredients in agricultural food processing.

MATERIAL AND METHODS

Study design and formulation

The experiment was conducted at Campus 1 of Gowa Agricultural Development Polytechnic, South Sulawesi, Indonesia, during February–March 2026. A completely randomized design with four formulations (P0–P3) and four replications was reported. The formulation unit contained 300 g of chicken meat and a constant 70 g total flour, with the cassava flour and tapioca fractions varied as shown in Table 1. The actual ingredient masses, rather than inconsistent percentage labels, were used to define the treatments.

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Table 1. **Ingredient composition of the four chicken meatball formulations**

Ingredient	P0	P1	P2	P3
Chicken meat (g)	300	300	300	300
Cassava flour (g)	0	20	50	70
Tapioca flour (g)	70	50	20	0
Egg white (eggs)	2	2	2	2
Ice or chilled water (g/mL, as reported)	60	60	60	60
Minced garlic (g)	5	5	5	5
Salt (g)	5	5	5	5
Ground pepper	To taste	To taste	To taste	To taste
Seasoning (g)	5	5	5	5
Cassava fraction of total flour (%)	0	28.6	71.4	100

Note. The percentages in the final row are calculated directly from cassava flour mass divided by the fixed 70-g total flour mass; they are not additional experimental measurements.

Processing and physical measurements

The principal materials were broiler chicken meat, cassava flour, tapioca flour, egg white, ice or chilled water, garlic, salt, pepper, and seasoning. Meatballs were prepared from the listed ingredients using the laboratory's meatball-processing procedure. The source document did not specify a complete mixing sequence or shaping conditions, and these steps were therefore not reconstructed in the analysis.

Cooking loss was evaluated by weighing each meatball sample before heating (W_1), boiling it in water at approximately 100 °C for 10–15 min, and weighing it again after cooking (W_2). Cooking loss was expressed as a percentage of initial mass using the equation: cooking loss (%) = $[(W_1 - W_2)/W_1] \times 100$. The measurement reflects the mass lost during cooking and does not separately quantify water and fat released from the sample.

Meatball pH was determined with a digital pH meter. The method described an approximately 10-g test portion and calibration with pH 4.0 and pH 7.0 buffer solutions; at least two readings were obtained for each sample at room temperature. WHC was evaluated on the uncooked batter and reported as a percentage based on sample mass and separated water. The available procedure did not unambiguously specify the mechanical separation conditions; therefore, WHC was interpreted using only the recorded values and statistical comparison.

Statistical analysis

Data were reported as means with accompanying dispersion values for the four replicates. The study described analysis of variance (ANOVA) under a completely randomized design, followed by Duncan's multiple range test for post-hoc comparisons at the 5% significance level. The significance statements and letter groupings in this manuscript reflect the results originally reported; no new statistical tests or unreported test statistics were introduced.

RESULTS AND DISCUSSION

Physical quality of chicken meatballs

The observed means for pH, WHC, and cooking loss are presented in Table 2. The reported ANOVA and Duncan

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comparisons indicated treatment differences for pH and cooking loss, whereas WHC did not differ significantly among the formulations.

Table 2. **Reported pH, water-holding capacity, and cooking loss of chicken meatballs**

Formulation	pH	WHC (%)	Cooking loss (%)
P0 (0:70 g)	7.400 ± 0.294[b]	28.365 ± 2.010	18.402 ± 0.109[a]
P1 (20:50 g)	6.550 ± 0.129[a]	25.477 ± 2.061	17.765 ± 0.369[b]
P2 (50:20 g)	6.600 ± 0.141[a]	28.257 ± 2.411	16.737 ± 0.1132[c]
P3 (70:0 g)	6.875 ± 0.377[a]	29.742 ± 5.543	15.390 ± 0.095[d]

Note. Formulation labels indicate cassava flour:tapioca flour within a 70-g total flour fraction. Values are mean ± reported dispersion (interpreted as SD in the source discussion). Different superscript letters within the same response column indicate different Duncan groups at $p < 0.05$, as reported. No letters were provided for WHC because the reported overall treatment effect was not significant. The original reported dispersion for P2 cooking loss was 0.1132 and has been displayed here with four decimals to preserve the source value.

pH response

The pH of the tapioca-only formulation P0 (7.400 ± 0.294) was higher than the values in P1 (6.550 ± 0.129), P2 (6.600 ± 0.141), and P3 (6.875 ± 0.377). According to the reported Duncan groups, P0 differed from all three cassava-containing formulations, but P1, P2, and P3 were not distinguishable from one another at the 5% level. Importantly, the response was not monotonically decreasing with increasing cassava mass: the lowest pH occurred in P1, followed by higher means in P2 and P3.

The pH difference could reflect compositional differences between cassava flour and purified tapioca and their interactions with the chicken meat batter. However, the acidity of the separate flours, buffering capacity of the mixture, and the organic-acid composition were not measured. The observed pattern therefore does not establish a specific biochemical mechanism. Studies of meatball quality have similarly treated pH as one aspect of product quality that may respond differently from other physical variables (Kartikasari et al., 2020; Nubatonis et al., 2022).

Water-holding capacity

The recorded WHC values ranged from 25.477 ± 2.061% in P1 to 29.742 ± 5.543% in P3. P0 and P2 showed intermediate means of 28.365 ± 2.010% and 28.257 ± 2.411%, respectively. The original ANOVA reported no statistically significant effect of the flour formulations on WHC ($p > 0.05$). Although the mean was numerically highest in P3, it cannot be described as a demonstrated improvement because the variation among replicates was substantial and the treatment differences were not significant.

WHC of meat batters depends on the interaction between water, meat proteins, and added non-meat ingredients. Research on starch–protein gel systems suggests that starch and hydrocolloid additions may modify water distribution and gel behavior, but the direction of change varies with composition and process conditions (Hu et al., 2023; Li et al., 2023). The present WHC measurements do not establish a change in the molecular binding mechanism, and the lack of significant differences should be interpreted specifically for the uncooked samples tested here.

Cooking loss

Cooking loss decreased successively across the formulations, from 18.402 ± 0.109% (P0) to 17.765 ± 0.369% (P1), 16.737 ± 0.1132% (P2), and 15.390 ± 0.095% (P3). The originally reported Duncan letters differed for all four

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formulations, indicating pairwise differences at the 5% significance level. Relative to P0, the mean cooking loss in P3 was lower by 3.012 percentage points. Figure 1 illustrates these values and the reported dispersion without introducing any additional observations.

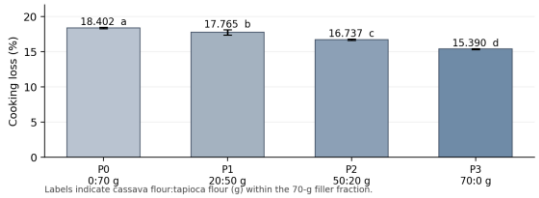


Figure 1. Cooking loss of chicken meatballs prepared with four cassava flour–tapioca formulations. Error bars show the dispersion reported in the original results; different letters reproduce the reported Duncan groupings ($p < 0.05$).

Lower cooking loss indicates that a smaller proportion of the product's initial mass was lost during boiling. The direction of the present results is compatible with the possibility that alternative flour components altered the heat-induced food matrix, but the study did not measure gelatinization, protein structure, or the individual fractions of water and fat lost during cooking. Accordingly, the observed differences are attributable to the tested formulations at the product level, rather than to any confirmed mechanism. Earlier studies on alternative meatball fillers have also shown that physical outcomes vary across flour sources and processing conditions (Herlambang et al., 2019; Malini et al., 2016; Ninu et al., 2022; Tiven & Simanjorang, 2024).

The distinction between cooking loss and WHC is important. Cooking loss was measured after boiling, while WHC was reported for uncooked batter samples. A reduction in cooking loss therefore does not contradict a non-significant WHC response. Heating can change the behavior of starch-containing matrices, and gelatinization is affected by several interacting components (Li, 2022). Similar formulation-dependent outcomes have been reported in chicken meatballs containing other alternative flours (Hajrawati et al., 2025; Hasanuddin et al., 2026; Mudawaroch & Rinawidiastuti, 2025).

Applied implications and study limitations

Within the evaluated formulation range, the complete substitution of the 70-g tapioca filler fraction with cassava flour produced the lowest mean cooking loss. This result supports further consideration of cassava flour as a locally sourced ingredient for chicken meatball processing. However, a recommendation about overall product superiority cannot be based on cooking loss alone. Texture, sensory acceptance, microbial quality, shelf life, and nutrient composition were not assessed in this study. Previous research highlights the relevance of sensory and storage-related evaluations for meatball applications (Hendrik & Lunatri, 2025; Natari & Mutaqin, 2021).

The findings should also be interpreted in view of the available methodological detail. The provided experimental record identified ingredient quantities and selected analytical conditions but did not fully document the mixing and shaping sequence or the precise WHC separation procedure. These limitations do not change the descriptive results reported here, but they restrict independent replication of some steps and the scope of mechanistic interpretation. The study therefore provides a comparison of three reported physical attributes rather than a comprehensive assessment of chicken meatball quality.

CONCLUSION

Replacing tapioca with cassava flour within a constant 70-g filler fraction was associated with differences in pH and cooking loss of broiler chicken meatballs. The tapioca-only control had the highest pH (7.400), whereas the cassava-

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containing formulations showed lower pH values (6.550–6.875), without significant differences among those three treatments. The reported WHC differences were not statistically significant. Cooking loss decreased from 18.402% in the tapioca-only formulation to 15.390% when the filler fraction consisted entirely of cassava flour. These findings indicate that cassava flour is a feasible substitute for tapioca in the tested formulations with respect to the measured cooking-loss response. Assessment of sensory quality and other product properties would be needed before drawing broader conclusions about consumer acceptance or overall product quality.

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