Full Length Article

DEVELOPMENT OF PROTEIN ENRICHED GLUTEN FREE KODO MILLET MUFFINS INCORPORATED WITH CHICKEN MEAT POWDER

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ABSTRACT

The increasing demand for nutritious, gluten-free food options necessitates the development of innovative products. Many commercially available millet-based products fail to leverage the nutritional benefits of millets, incorporating them in minimal quantities while maintaining refined wheat flour (maida) as the primary ingredient in baked goods. This research aims to develop a Kodo millet muffin formulated entirely from Kodo millet flour and enriched with animal protein through the addition of chicken meat powder (CMP). The CMP was prepared and its inclusion level was optimized by varying from 0% to 20% in increments of 5%, based on sensory evaluation using a 9-point hedonic scale. The formulation containing 10% CMP was identified as the most acceptable. The optimized muffins were then analyzed for their textural, physicochemical and nutritional properties. The incorporation of CMP significantly affected the muffin's texture. This Kodo millet-based, protein-enriched muffin offers a gluten-free alternative while maximizing the health benefits associated with Kodo millet.

Keywords: Kodo millet, Chicken meat powder, Gluten free muffins,

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INTRODUCTION

Celiac disease is an immune-mediated disorder of the small intestine triggered by the ingestion of gluten in genetically predisposed individuals (Catassi and Fasano, 2018). The only effective treatment for celiac disease is strict adherence to a gluten-free diet. However, as many staple foods such as bread, biscuits, pasta, cakes, cookies, breakfast cereals, bagels, and soups are predominantly made from wheat, avoiding these items requires a significant lifestyle change that is not always feasible (Jnawali *et al*., 2016). As a result, the demand for gluten-free products has been steadily increasing.

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Kodo millet, a gluten-free cereal, offers a promising alternative due to its easy digestibility, attributed to its high lecithin content, which supports nervous system function. Regular consumption of Kodo millet has been shown to benefit postmenopausal women at risk of cardiovascular diseases, such as hypertension and hypercholesterolemia. Additionally, Kodo millet is rich in antioxidants that help combat oxidative stress and regulate glucose levels in individuals with type-2 diabetes (Bunkar *et al*., 2021). Given these health benefits, there is a growing interest in developing millet-based products to provide nutritional solutions, especially in developing countries with increasing populations.

Despite the availability of gluten-free bread, muffins, cakes, and other baked goods designed to replicate the texture and taste of their wheat-based counterparts, these products often suffer from quality defects and lower nutritional value (Mastos *et al*., 2014). While the use of dairy and plant-based proteins in the bakery industry is well-established (Mastos *et al*., 2014), the incorporation of animal proteins remains limited.

Recent studies have explored the potential of animal proteins in bakery products. Cakmak *et al*. (2013) introduced an innovative bread formulation incorporating both chicken meat and chicken meat powder as sources of animal protein, demonstrating a significant increase in protein content, particularly with chicken meat powder. Further research by Cakmak *et al*. (2016) on baguettes showed that the inclusion of chicken meat powder resulted in significantly higher protein levels compared to using chicken meat alone. Moreover, they found that the form of chicken meat used impacted the texture of the final product, with snacks made from chicken meat powder being softer than those made with whole chicken meat. These findings suggest that chicken meat powder could be a valuable ingredient for enhancing protein content while also optimizing texture in baked goods.

Building on these insights, this study aims to utilize chicken meat powder to improve the protein content and address the textural challenges of gluten-free millet-based baked goods, thereby providing a more nutritionally rich snack option.

MATERIALS AND METHODS

Preparation of chicken meat powder

Chicken meat powder was prepared based on studies of Saini *et al.* (2020)

Deboned chicken meat

↓

Cut into small cubes

↓

Minced using meat mincer

↓

Boiled in a pressure cooker (15 mins)

↓

Dried in hot air oven @ 80°C for 9hrs

↓

Grinding into powder

↓

Chicken meat powder (CMP)

Preparation of muffins

The raw materials for muffin preparation were sourced from a local supermarket in Sathuvachari, Vellore. Six different formulations represented in Table 1, were created by substituting Kodo millet flour with Chicken Meat Powder (CMP) at varying levels from 0% to 20%, with increments of 5%. The muffin batter was prepared by mixing the dry ingredients separately and gradually folding in the wet ingredients, ensuring a smooth, lump-free mixture.

Muffins were prepared according to Mastos *et al.* (2014) with slight modifications. Paper muffin liners, approximately 50 mm in diameter, were arranged in an aluminium muffin tray with 12 grooves (three rows of four). Using a scoop and a weighing scale, each liner was filled with 30 g of batter. The filled muffin tray was baked in a preheated conventional oven at 180°C for 25 minutes. The oven, baking tray, and tray position remained consistent for all batches. After baking, the muffins were allowed to cool for 1 hour at room temperature on a rack to prevent moisture from condensing on their undersides. The cooled muffins were then evaluated for various quality characteristics.

Sensory evaluation

The sensory evaluation of the muffins was conducted using a 9-point hedonic scale by a panel of 14 members, including professors and students from the College of Food and Dairy Technology, Koduveli, Chennai, Tamil Nadu. Each panelist was given muffin samples with randomized codes to ensure unbiased evaluation. The assessment took place at room temperature between 10:00 and 11:00 a.m. under natural daylight. To cleanse the palate between samples and prevent carryover effects, plain water and puffed rice were provided. The panelists rated the muffins on sensory attributes such as color, texture, sponginess, taste, flavor, and overall acceptability following the method outlined by Shaik *et al.* (2018). Based on the average sensory scores given by 14 panelists, the formulation of muffin incorporated with chicken meat powder was optimized.

Proximate composition of optimized muffin

The proximate composition of optimized muffins was analyzed and reported on a dry matter basis. The methods used included AOAC (2000) standards: moisture (method no. 44-15), crude protein (method no. 46-10), crude fat (method no. 30-25), crude fiber (method no. 32-10), and ash (method no. 08-01) and the carbohydrates were calculated by difference.

Physicochemical properties

Water activity

The water activity of the optimized muffins was determined using the method described by Suriya *et al.* (2017) with an electrical dew point water activity meter.

Texture profile analysis

The texture profile analysis (TPA) of the muffins followed the method described by Goswami *et al.* (2015) and was conducted using a Texture Analyzer (Stable Microsystems, Model-TA. XT plus, UK) at Department of Dairy Science, Madras Veterinary College, Chennai. A double compression test was performed with a 75 mm flat-ended cylindrical probe (P/75), using the following settings: pre-test speed of 1.00 mm/sec, test speed of 5.00 mm/sec, post-test speed of 5.00 mm/sec, distance of 10 mm, strain of 75%, trigger force of 5 g, and data acquisition rate of 200 points per second.

The peak force recorded during the first compression cycle was noted as the hardness (N). Additional texture parameters were measured, including resilience (the ratio of the area during withdrawal to the area during the first compression), cohesiveness (the ratio of the work done during the second compression to the first), springiness (the recovery height between the first and second bites), and chewiness, calculated as one-quarter of hardness multiplied by cohesiveness and springiness.

Physical Properties

Height, specific volume, and weight loss

The height, specific volume, and weight loss of the optimized muffins after baking were determined following the method outlined by Bala *et al*. (2019). Muffin height was measured using a digital vernier caliper (accuracy of 0.01 mm) from the base of the paper cup to the highest point of the muffin after cooling for one hour at room temperature. The volume of the muffins was assessed using the rapeseed displacement method, and the specific volume was calculated as the ratio of volume to weight. Weight loss was determined by calculating the difference between the weight of the muffins before and after baking and cooling, expressed as a percentage.

Crust/crumb ratio and baking yield

The crust/crumb ratio was calculated based on the method of Ureta *et al.* (2014). Optimized muffins were removed from the oven and allowed to cool briefly. The crust, defined as the dried and browned upper surface of the muffin, was separated from the crumb using a scalpel, and the crust-to-crumb ratio was expressed as the mass ratio on a wet basis, as described by Jusoh *et al*. (2009). The baking yield was calculated using the formula provided by Lee *et al.* (2020), which is the ratio of muffin weight to batter weight, expressed as a percentage:

Baking yield (%) = (muffin weight/batter weight) × 100

Statistical analysis

All the data obtained were statistically evaluated by one-way analysis of variance (ANOVA) and the significance of differences between means were determined by Duncan's multiple comparison test at a 5% (Reddy, 2024) significance level ($P<0.05$) by using IBM SPSS statistics software, version 20.0 (IBM, SPSS, Inc., Chicago, IL, USA). For comparison of the two samples, independent t-test was done using SPSS (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

Optimization of chicken meat powder in kodo millet muffin based on sensory evaluation

The sensory parameters of the muffins, including colour, texture, sponginess, taste, flavor, and overall acceptability, were evaluated across five different formulations: T0 (control with 0% chicken meat powder), T1 (5% chicken meat powder), T2 (10% chicken meat powder), T3 (15% chicken meat powder), and T4 (20% chicken meat powder) using 9 point Hedonic scale rating.The mean sensory scores of 14 panelists were plotted in spider graph and represented in Fig. 1.

Colour scores were consistent (6-6.5) across all formulations, showing minimal impact of chicken meat powder on colour. Texture improved with higher meat powder levels, peaking at T2 (7.5), but slightly declined at T3 (7) and T4 (6.5), which is due to increase in crumbliness of muffins with higher incorporation of CMP. Sponginess significantly increased with the addition of chicken meat powder, reaching the highest score of 8 in T2, T3, and T4. This shows that incorporating chicken meat powder improved the sponginess, especially at higher levels. T2 and T3 (7) were rated highest for taste, while T4 (6) was the least preferred, suggesting that excessive chicken meat powder can negatively impact taste. Flavour scores were consistent for T0-T3 (7), but slightly declined for T4 (6.5), indicating that 20% chicken meat powder affected flavour acceptability. T2 (7.2) was the most acceptable formulation, followed by T3 (7.1) and T4 (6.7), which showed a slight decline in preference but still maintained reasonable acceptance.

Based on the sensory evaluation, the incorporation of 10% chicken meat powder (T2) in kodo millet muffins resulted in the best combination of colour, texture, sponginess, taste, flavour, and overall acceptability. While further increases in chicken meat powder slightly reduced the sensory scores, moderate levels (up to 15%) still maintained good acceptability. However, 20% chicken meat powder led to a noticeable decline in the sensory appeal, particularly in terms of taste and overall acceptability. Thus, 10% chicken meat powder incorporated muffin formulation (T2) was optimized.

Proximate composition of optimized muffins:

The nutritional analysis of the control (T0) and the 10% chicken meat powder (T2) muffins revealed notable differences in their composition and represented in Fig. 2. The moisture content was slightly higher in T2 (24.21%) compared to T0 (24.01%), indicating a similar water retention capacity. Protein content significantly increased from 11.38% in T0 to 16.28% in T2, highlighting the protein-enriching effect of the chicken meat powder. Fat content decreased from 13.12% in T0 to 11.71% in T2, while fibre content showed a slight reduction (2.67% in T0 to 2.54% in T2). Ash content, reflecting the mineral presence, was slightly higher in T2 (1.51%) compared to T0 (1.37%). Carbohydrate content was lower in T2 (43.75%) than in T0 (47.46%), likely due to the replacement of carbohydrate-rich ingredients with chicken meat powder. Similar results were found in breads and baguettes enriched with CMP carried out by Cakmak *et al.* (2013) and Cakmak *et al.* (2016). These results demonstrate that adding 10% chicken meat powder improved the protein profile of the muffins while maintaining balanced levels of other macronutrients.

Physicochemical properties of optimized muffins

Water activity

The water activity of kodo millet flour (0.393±0.00) and chicken meat powder (0.552±0.00) were significantly lower than that of the muffin samples, as indicated in Table 2 by their respective t-values (186.574** and 226.155**). The addition of chicken meat powder resulted in higher water activity in the muffin formulations. T0 (0.844±0.00) and T2 (0.861±0.00) showed significantly higher water activity levels, with t-values of 1033.685** and 1127.968** respectively, indicating increased moisture retention. This suggested that chicken meat powder contributed to higher water-binding capacity in the muffins, which might influence shelf life and texture.The water activity results align with the findings of Bhaduri (2013). However, the water activity of the optimized muffins is higher compared to the kodo millet muffins enriched with bran-rich fractions developed by Barbhai *et al.* (2022).

Textural Properties

The textural properties of the muffins differed significantly between T0 and T2 (Table 3). Hardness increased from T0 (536.70±4.62 g) to T2 (738.27±4.63 g), with a highly significant F-value (946.129**), indicating that T2 muffins were firmer. Adhesiveness decreased significantly from T0 (9.44±0.02 g.sec) to T2 (4.67±0.03 g.sec), with a striking F-value (13008.105**), suggesting that T3 muffins were less sticky. Springiness showed a minor but significant increase from T0 (0.95±0.00) to T2 (0.96±0.00), while cohesiveness decreased from T0 (0.77±0.00) to T2 (0.68±0.00). Gumminess and chewiness both increased significantly in T2 (505.73±5.21 g and 483.38±5.39 g, respectively) compared to T0 (420.01±3.13 g and 404.33±5.69 g). Resilience was also significantly lower in T2 (0.40±0.00) than in T0 (0.47±0.00). These results suggested that the T2 muffins, with higher chicken meat powder content, had a firmer, less cohesive, and less resilient texture, making them harder and chewier compared to T0.The hardness and chewiness values of the optimized muffins fall significantly below those reported by Bhaduri (2013) for gluten-free muffins made with quinoa and rice flour. Similarly, the millet muffins produced by Jadhav *et al.* (2021) exhibited higher hardness values compared to our optimized muffins.

Physical properties of optimized muffins

The physical properties of the control (T0) and 10% chicken meat powder (T2) muffins revealed notable differences (Table 4).

Crumb weight was significantly lower in T2, while crust weight was higher, indicating a thicker crust in the chicken meat powder muffins. Despite these changes, height and volume remained similar between T0 and T2, with no significant differences. The specific volume of T2 was higher, suggesting an improved loaf structure. Although T2 experienced slightly higher weight loss and a minor reduction in baking yield, these differences were not highly significant. However, the crust/crumb ratio increased significantly in T2, further emphasizing the thicker crust. The addition of 10% chicken meat powder modified the crumb and crust characteristics, while maintaining acceptable volume and overall structure. Lee *et al*. (2020) reported similar specific volume results in muffins made with kamut. Additionally, the weight loss and crust-to-crumb ratio of the optimized muffins in this study are greater than those of the gluten-containing muffins developed by Ureta *et al.* (2014).

CONCLUSION

This study concludes that kodo millet muffins incorporated with 10% chicken meat powder demonstrated higher consumer acceptability, enhanced nutritional value, and increased protein content, all while maintaining desirable textural qualities. The inclusion of chicken meat powder successfully enriched the muffins without negatively affecting their sensory or physical attributes. However, further research is required to assess the product's shelf life, as this study primarily focused on developing a ready-to-eat formulation. Future studies can explore storage stability and optimize packaging to ensure product longevity without compromising quality.

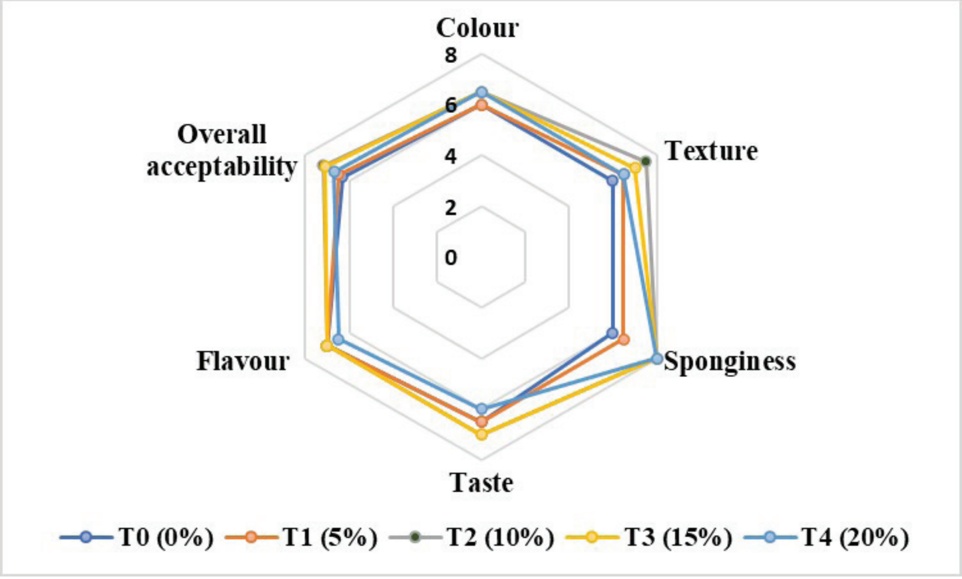

Fig. 1. Sensory Evaluation of muffin formulations with varying levels of Chicken Meat Powder (Mean)@ Average of 14 trials; T0 – Muffin without CMP, T1 – Muffin with 5% CMP, T2 – Muffin with 10% CMP, T3 – Muffin with 15% CMP, T4 – Muffin with 20% CMP.

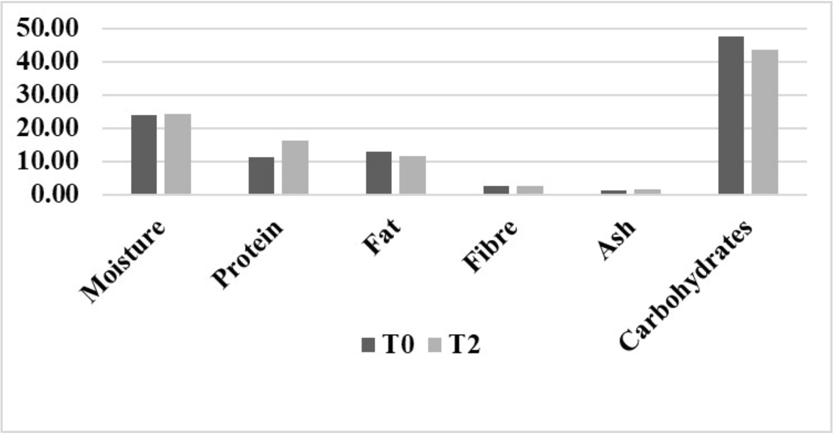

Fig. 2. Proximate composition of optimized muffin(Mean)@ Average of six trials; T0 – Muffin without CMP, T2 – Muffin with 10% CMP.

Table.1. The formulation of muffin batter with increasing Chicken meat powder

Ingredients	T0 (0%)	T1 (5%)	T2 (10%)	T3 (15%)	T4 (20%)
Kodo millet flour (g)	100	95	90	85	80
Chicken meat powder – CMP (g)	0	5	10	15	20
Sugar (g)	75	75	75	75	75
Sodium bicarbonate (g)	4	4	4	4	4
Citric acid (g)	3	3	3	3	3
Xanthan gum (g)	0.5	0.5	0.5	0.5	0.5
Water (ml)	150	150	150	150	150
Refined sunflower oil (ml)	40	40	40	40	40

Table.2. Water activity of optimized muffin(Mean±SE)@

Sample	Water activity	t value
Kodo millet flour	0.393±0.00	186.574**
Chicken Meat Powder (CMP)	0.552±0.00	226.155**
T0	0.844±0.00	1033.685**
T2	0.861±0.00	1127.968**

@Average of six trials; Non significant – P>0.05; *Significant – 0.01<P≤0.05; **Highly significant - P≤0.01; T0 – Muffin without CMP, T2 – Muffin with 10% CMP.

Table.3. Textural properties of optimized muffin(Mean±SE)@

Sample	T0	T2	F value
Hardness (g)	536.70±4.62	738.27±4.63	946.129**
Adhesiveness (g.sec)	9.44±0.02	4.67±0.03	13008.105**
Springiness	0.95±0.00	0.96±0.00	15.560**
Cohesiveness	0.77±0.00	0.68±0.00	808.265**
Gumminess	420.01±3.13	505.73±5.21	198.711**
Chewiness	404.33±5.69	483.38±5.39	101.437**
Resilience	0.47±0.00	0.40±0.00	928.336**

@Average of six trials; Non significant – P>0.05; *Significant – 0.01<P≤0.05; **Highly significant - P≤0.01; T0 – Muffin without CMP, T2 – Muffin with 10% CMP.

Table.4. Physical properties of optimized muffin(Mean±SE)

Sample	T0	T2	F value
Batter Weight(g)	30.36±0.04	30.20a±0.05	5.435*
Muffin Weight(g)	24.54±0.12	24.08±0.10	8.151*
Crumb Weight (g)	18.74±0.04	16.24±0.07	888.330**
Crust Weight (g)	5.79±0.13	7.84±0.09	151.306**
Height (cm)	2.78±0.04	2.71±0.02	1.860NS
Volume (ml)	50.41±0.15	50.75±0.21	1.600NS
Specificvolume (ml/g)	2.05±0.00	2.10±0.00	45.880**
Weight loss (%)	19.17±0.44	20.25±0.30	4.063NS
Crust/crumb ratio	0.30±0.00	0.48±0.00	296.550**
Baking yield (%)	80.82±0.44	79.74±0.30	4.063*

@Average of six trials; Non significant – P>0.05; *Significant – 0.01<P≤0.05; **Highly significant - P≤0.01; T0 – Muffin without CMP, T2 – Muffin with 10% CMP.

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