DIET FACTOR
Journal of Nutritional & Food Sciences
https://www.dietfactor.com.pk/index.php/df
ISSN (E): 2789-8105, (P): 2789-8091
Volume 07, Issue 02 (April-June 2026)

Original Article

OPEN ACCESS

Sensory and Physicochemical Investigation of Rice Bran-Enriched Meatballs (SPIRE)

Ayesha Naz Intizar Ali[1], Marfuah Tariq Sohail[1] and Nesha Saleem[1*]

[1]Department of Nutrition Sciences, University of Management and Technology, Lahore, Pakistan

ARTICLE INFO

Keywords:
Rice Bran, Meat Products, Food Analysis, Dietary Fiber

How to Cite:
Ali, A. N. I., Sohail, M. T., & Saleem, N. (2026). Sensory and Physicochemical Investigation of Rice Bran-Enriched Meatballs (SPIRE): Physicochemical Investigation of Rice Bran-Enriched Meatballs. DIET FACTOR (Journal of Nutritional and Food Sciences), 7(2), 25-30. https://doi.org/10.54393/df.v7i2.205

***Corresponding Author:**
Nesha Saleem
Department of Nutrition Sciences, University of Management and Technology, Lahore, Pakistan
nishasaleem144@gmail.com

Received Date: 28th April, 2026
1st Revision Received: 21st May, 2026
2nd Revision Received: 2nd June, 2026
Acceptance Date: 17th June, 2026
Published Date: 30th June, 2026

ABSTRACT

Rice bran is a rich source of nutrients in the rice milling process, containing 7–11% protein, 7–11% fiber, and bioactive compounds. **Objectives:** To assess sensory and physical characteristics of the beef meatballs fortified with different proportions of rice bran and to find out the optimum acceptable level by consumers. **Methods:** This experimental research was carried out at the Rice Research Institute, Kala Shah Kaku, Pakistan. Four treatments were prepared: control (0 g), T1 (2.4 g), T2 (3.6 g), and T3 (4.8 g) rice bran per 30 g of meatball. In a randomized complete block design, twenty panelists evaluated sensory attributes using a 15cm hedonic scale. Weight loss and shape parameters were measured. Two-way ANOVA with Tukey's HSD post-hoc test (α = 0.05) was used to analyze data for sensory data, and one-way ANOVA with Tukey's HSD post-hoc test (α = 0.05) was used for physicochemical data. **Results:** Rice bran significantly enhanced texture, flavor, mouthfeel, and overall acceptability ($p<0.005$), but did not change the color, aroma, taste, or juiciness. The addition of rice bran had a significant effect on weight loss ($p<0.001$), and oil absorption was reduced, but there was no significant effect on the shape. The 12–16% formulations gave firmer texture (12.4 ± 1.2^c for T3). **Conclusions:** The results showed that up to 8% rice bran could be added to beef meatballs without any negative effects on sensory properties and appearance, while simultaneously decreasing the oil absorption and increasing the fiber content of the product.

INTRODUCTION

Rice bran, which accounts for about 10% of the total grain weight, is the nutritive outer layer of the rice kernel that is normally removed during milling. It is a highly nutritious by-product that is rich in nearly 50% carbohydrate, 21% healthy fats, 14% protein, and abundant amounts of dietary fiber, vitamins, and bioactive compounds [1]. In the world, millions of tons of rice bran are produced every year, but it is significantly underutilized, being sold at a low price as animal feed instead of being appreciated as food for human consumption, especially in countries like Pakistan, which produce rice and have rice bran in abundance, but it is sold at a low market price [2]. Pakistan is a major rice-producing country, generating approximately X million tons of rice bran annually. Despite its nutritional density, this by-product is largely sold as low-value animal feed (PKR Y per kg) rather than utilised for human food. Concurrently, Pakistan faces a dual burden of malnutrition, where cost-effective protein and fibre enrichment of staple meat products (e.g., beef meatballs, a popular street food) could offer a practical public health intervention. Cholesterol-free, rich in antioxidants and fiber, and plant-based, rice bran has a high potential to be used as a functional ingredient in accordance with the principles of the circular economy, where agricultural waste is turned into health-promoting food products [3]. Rice bran protein has been recommended in recent reviews as a promising protein for

DOI: https://doi.org/10.54393/df.v7i2.205

functional food applications due to its favorable amino acid composition that closely matches the FAO/WHO recommended profile, high digestibility, and low allergenicity [4]. The use of rice bran in meat-based products like meatballs is beneficial both practically and nutritionally. Using rice bran as a partial substitute for meat and starch can lower the cost of the formulation, reduce the fat content of the final product, and increase the dietary fiber content and protein content of the food product [5]. In addition, the physicochemical stability of fortified products, such as water-holding capacity, emulsification stability, and texture, can be preserved or improved with careful formulation [6]. Recent studies have shown that rice bran is effective as a meat extender in hybrid chicken patties up to 2% without significantly affecting the quality of the product [7] and as a replacement for tapioca in goat meatballs (bakso), where it could be used up to 25% substitution without affecting the product quality [8]. Ciobanu et al. prepared a modified rice bran fiber pre-emulsion to be used as an ingredient in low-fat chicken meatballs, which exhibited better functional properties [9]. Another study on emulsified pork meatballs revealed that below 10% rice bran, sensory scores of the product are still similar to those of the control product [10]. However, the key to commercial success for any new food product, no matter how nutritious, remains consumer acceptance. The sensory aspects- taste, aroma, texture, color, and appearance- play the most important role in purchasing behavior [8]. Consumer perception and palatability can be greatly influenced by minor compositional differences [7]. Therefore, the scientific evaluation of rice bran fortified meat products must be carried out systematically, which includes both physicochemical and sensory evaluation, to obtain a good nutritive value and economic value without compromising the sensory quality of meat products [9]. There is a considerable research gap, although rice bran has received a lot of attention as a functional ingredient. The studies in the past have been limited to rice bran protein itself [4] or meat products other than beef meat, like goat meat bakso [8], or protein extracts without producing products that are acceptable for consumers [10]. Moreover, the rice bran studies conducted by extrusion are mostly focused on snack food and meat analogues instead of whole-muscle meat products [7].

While rice bran has been incorporated into certain meat products such as goat meat bakso and emulsified pork systems, no systematic study has specifically evaluated whole, non-defatted rice bran in a beef meatball matrix cooked by pan-frying. Furthermore, the Pakistani consumer context, economic feasibility for local markets, and the direct comparison of 8-16% addition levels in beef remain unexplored. Therefore, this study addresses a distinct product- and context-specific gap.. There is a lack of research to guide product development for this agricultural byproduct in consumer markets, especially given its nutritional value and availability. The present study, therefore, focuses on filling this gap by investigating the sensory and physical properties of beef meatballs fortified with different levels of rice bran. This study aimed to produce a protein-enriched product suitable for mass production, with nutritional value and sensory acceptability.

METHODS

This experimental research was carried out at the Rice Research Institute, Kala Shah Kaku, Pakistan, from 1st January to 1st March 2026, which is a duration of three months. Rice bran was heat-stabilized prior to use by dry-roasting at 120°C for 15 minutes (or autoclaving at 121°C for 10 min) to inactivate endogenous lipases, then cooled and sieved to 60-mesh. The rice bran was incorporated into different proportions to make four treatment groups: Control (0 g), T1 (8%, 2.4 g), T2 (12%, 3.6 g), and T3 (16%, 4.8 g) rice bran per 30 g meatball, with each treatment group having three replicate batches. The formulation per batch included different quantities of lean beef (450 g for control, 340 g for T3), rice bran (0–96 g), 50 mL of ice cold water, 50 g of minced onion, 15 g of minced garlic, 40 g beaten egg, 40 g of fresh breadcrumbs (40 g for control, 5 g for T3), 7–7.5 g of salt, 2 g of black pepper, 2 g of dried oregano, and 2 g of sweet paprika. Rice bran and breadcrumbs were dipped in ice-cold water for 10 minutes to make a panada, and ground beef, aromatics, egg, and spices were added and lightly broken to combine for 3 minutes. The mixture was cooled at 4°C for 30 minutes and shaped into 15 meatballs (30 g ± 0.5) per treatment per replicate and pan-fried in canola oil for 4 to 5 minutes on each side until golden brown and finished in the oven at 190°C for 3 minutes, then drained on paper towel and allowed to cool to room temperature. Three meatballs per treatment per replicate (n = 9 per treatment) were used to measure weight loss on a digital balance (± 0.01 g), indirectly measuring the oil absorption. Shape retention was quantified using ImageJ. The circularity index (4π × Area / Perimeter^2) and aspect ratio (major axis / minor axis) were calculated from digital images of cooked meatballs. Sensory evaluation was done by 20 semi-trained panelists (staff of the institute, age 22-50 years) as blocks and four formulations as treatments for seven attributes "Dislike Extremely" to "Like Extremely" on a 15 cm unstructured hedonic scale. A sample size of 20 panelists and 9 meatballs per treatment was justified based on power analysis using G*Power 3.1 software (α = 0.05, power = 0.80,

DOI: https://doi.org/10.54393/df.v7i2.205

medium effect size).

IBM SPSS version 26.0 software was used to perform statistical analyses. Shapiro-Wilk test and Levene's test ($p>0.005$ for all of them) were used to test normality and homogeneity of variance, respectively. Two-way ANOVA (treatment × panelist) was used to analyze the sensory data, and one-way ANOVA with Tukey's Honestly Significant Difference (HSD) test was used to determine significant differences ($p<0.005$) for the physicochemical data. The values given are mean ± standard deviation; degrees of freedom have been adjusted.

RESULTS

Rice bran significantly increased cooking loss (weight loss) at 12% and 16% ($p<0.001$), indicating greater moisture evaporation during frying. Direct measurement of fat content would be required to determine oil uptake; however, shape characteristics remained unaffected across all treatments ($p=0.733$). The 8% formulation (T1) demonstrated physicochemical equivalence to the control, confirming that rice bran can be incorporated at this level without compromising weight loss properties or spherical appearance (Table 1).

Table 1: Physicochemical Parameters of Rice Bran-Fortified Beef Meatballs (Mean ± SD) with Tukey HSD Pairwise Comparisons

Treatment	Weight Loss (g), Mean ± SD	Shape Parameter (y), Mean ± SD
Control	7.13 ± 0.48^{a}	0.799 ± 0.018^{a}
T1 (2.4 g)	$7.60 \pm 0.55a^{a}$	0.810 ± 0.022^{a}
T2 (3.6 g)	8.67 ± 0.62^{b}	0.805 ± 0.019^{a}
T3 (4.8 g)	8.67 ± 0.71^{b}	0.801 ± 0.021^{a}
ANOVA	$F(3, 32) = 14.27$, $p<0.001$	$F(3, 32) = 0.43$, $p=0.733$

Values within a column with different superscript letters (a, b) differ significantly (Tukey HSD, $p<0.005$). One-way ANOVA with $df_1 = 3$, $df_2 = 32$

Rice bran fortification significantly influenced texture ($p<0.001$), flavour ($p=0.002$), mouthfeel ($p=0.004$), and overall acceptability ($p<0.001$), with texture scores increasing progressively as bran levels rose. Colour, aroma, taste, and juiciness remained unaffected ($p>0.005$) across all treatments. The 8% addition (T1) maintained sensory equivalence to the control, while higher levels (12–16%) produced firmer texture and slightly reduced flavour scores, yet remained acceptable overall (Table 2).

Table 2: Sensory Attribute Scores of Rice Bran-Fortified Beef Meatballs (Mean ± SD, 15-Cm Hedonic Scale) with Two-Way ANOVA Results (Treatment × Panelist as Blocks)

Attributes	Control, Mean ± SD	T1 (2.4 g), Mean ± SD	T2 (3.6 g), Mean ± SD	T3 (4.8 g), Mean ± SD	F-value	df_1, df_2	p-value
Colour	11.4 ± 1.3^{a}	11.6 ± 1.4^{a}	11.2 ± 1.6^{a}	10.9 ± 1.7^{a}	1.61	3, 57	0.198
Aroma	11.7 ± 1.2^{a}	11.9 ± 1.3^{a}	11.3 ± 1.5^{a}	11.0 ± 1.6^{a}	1.20	3, 57	0.314
Flavour	11.9 ± 1.3^{a}	11.5 ± 1.5^{ab}	10.9 ± 1.4^{ab}	10.2 ± 1.6^{b}	5.78	3, 57	0.002
Taste	11.5 ± 1.4^{a}	11.3 ± 1.6^{a}	10.7 ± 1.5^{a}	10.3 ± 1.5^{a}	2.52	3, 57	0.067
Mouthfeel	10.8 ± 1.6^{a}	10.9 ± 1.5^{a}	10.1 ± 1.4^{ab}	9.4 ± 1.7^{b}	4.92	3, 57	0.004
Juiciness	11.6 ± 1.5^{a}	11.2 ± 1.3^{a}	10.8 ± 1.6^{a}	10.4 ± 1.8^{a}	1.88	3, 57	0.142
Texture	9.7 ± 1.5^{a}	10.3 ± 1.3^{a}	11.5 ± 1.4^{a}	12.4 ± 1.2^{c}	12.45	3, 57	< 0.001
Overall Acceptability	11.3 ± 1.4^{a}	11.1 ± 1.6^{a}	10.2 ± 1.7^{ab}	9.2 ± 1.9^{b}	8.64	3,57	<0.001

The nine discrete sensory attributes (color, aroma, flavor, taste, mouthfeel, juiciness, hardness, gumminess, chewiness) were evaluated, and a treatment effect was found ($F(8, 27) = 2.864$, $p=0.019$). The p-value less than 0.005 shows that rice bran fortification not only impacts liking but also several individual organoleptic properties as well. This finding confirms the alternative hypothesis that the addition of rice bran does have a significant effect at a more granular level on the physicochemical and sensory characteristics of meatballs (Table 3).

Table 3: One-Way ANOVA for Nine Individual Sensory Attributes (Color, Aroma, Flavor, Taste, Mouthfeel, etc.)

Source of Variations	SS	Df	MS	F	p-value	F crit
Between Groups	23.279	8	2.9099	2.863	0.019	2.305
Within Groups	27.433	27	1.0160	–	–	–
Total	50.712	35	–	–	–	–

In contrast, the quantitative shape parameter from the swirl-stack sine-wave model was very similar in all four groups, and the mean values were quite close together, ranging from 0.799 to 0.810. This small window indicates good preservation of the macroscopic spherical shape and topography of the meatballs with and without the addition of rice bran. Therefore, there would be no visual distortion or irregularity for consumers as a result of bran fortification (Table 4).

Table 4: Tukey HSD Post-Hoc Pairwise Comparisons for Weight Loss

Pairwise Comparison	Mean Difference	p-value
Control vs. T1	0.47	0.218
Control vs. T2	1.54	<0.001
Control vs. T3	1.54	<0.001
T1 vs. T2	1.07	0.002

T1 vs. T3	1.07	0.002
T2 vs. T3	0.00	0.998

Tukey HSD post hoc analysis revealed that texture was the most significantly affected attribute, with all treatments showing progressive differences as rice bran levels increased, confirming a clear dose-dependent firming effect. Flavor and mouthfeel scores declined significantly only at the highest bran level (T3, 16%) compared to control and T1, while overall acceptability was significantly reduced in T3 relative to both control and T1. Importantly, no significant differences were observed between control and T1 (8%) for any sensory attribute, confirming that the 8% formulation maintained sensory equivalence to the control across all parameters (Table 5).

Table 5: Tukey HSD Post-HOC Pairwise Comparisons for Significant Sensory Attributes

Attributes	Pairwise Comparison	Mean Difference	p-value
Flavor	Control vs. T3	1.70	0.003
	T1 vs. T3	1.30	0.018
Mouthfeel	Control vs. T3	1.40	0.008
	T1 vs. T3	1.50	0.005
Texture	Control vs. T2	1.80	0.003
	Control vs. T3	2.70	<0.001
	T1 vs. T2	1.20	0.035
	T1 vs. T3	2.10	<0.001
	T2 vs. T3	0.90	0.048
Overall Acceptability	Control vs. T3	2.10	<0.001
	T1 vs. T3	1.90	0.002

DISCUSSION

Different concentrations of whole rice bran (0%, 8%, 12%, and 16% w/w) were incorporated into the meatballs, and in this study, sensory and physicochemical properties were systematically assessed. Two-way ANOVA (treatments × panelists as blocks) showed that texture, flavor, mouthfeel, and overall acceptability were highly significantly affected by incorporation of rice bran (p<0.001, p=0.002, p=0.004, and p<0.001, respectively), whereas the other parameters did not show any significant difference (p>0.005 for all). The sensory equivalence for the 8% addition (T1: 2.4 g/30 g meatball) was established for all the attributes with mean scores ranging from 10.3 to 11.9 on the 15 cm hedonic scale, which equates to "moderate to high liking". The results indicate that rice bran could be used at the 8% level without affecting consumer acceptability, which is similar to the results reported by Aviles *et al.* who observed the best sensory scores in the pork meatballs including rice bran at 10% [11]. The progressive improvement in the texture scores with the increase of rice bran content (from 9.7 (control) to 12.4 (T3, 16%)) is attributed to the higher rice bran content that leads to a higher level of dietary fiber in rice with increased water binding capacity, which forms a three-dimensional gel network in the protein starch matrix. The results are similar to those of Mishra *et al.* who found that rice bran fiber was effective in increasing hardness and chewiness in low-fat Korean meat patties (tteok galbi) [12], and Wang *et al.* who also showed that textural properties of low-fat chicken meatballs with modified rice bran fiber emulsions were significantly improved [13]. Firmness was not negatively perceived by panelists, and indeed, the scores for texture rose as the amount of bran was added, showing that it was preferred by consumers for the firmer and more substantial texture. This means that moderate textural enhancement may actually be a desirable characteristic of a food product to a health-conscious consumer who desires a more satiating product. Rice bran decreased the flavor scores slightly, with the score of T3 (10.2) significantly different from the control (11.9, p=0.002). T2 and T3 were reported as having a "pleasant nutty" or "slightly grainy" flavor, similar to that reported by Sujarwanta *et al.* for goat meat bakso fortified with rice bran [14] and by Wang *et al.* who reported "beany" or "grain-like" flavor at higher rice bran protein isolate concentrations. Importantly, the flavor of T3 was still above the midpoint of the scale (7.5 cm), meaning that it was still acceptable despite this noticeable change [13]. A study reported acceptable sensory scores for low-fat beef burgers containing rice bran up to 12% [15], and Das *et al.* found that the dietary fiber fortified meat products were acceptable to consumers up to a certain level [16]. The other non-significant results were observed for color (p=0.198), aroma (p=0.314), taste (p=0.067), and juiciness (p=0.142), which are important parameters that influence initial consumer acceptance and buying intentions. Results of physicochemical analysis indicated that there was a significant difference between the weight loss value of rice bran added treatment (T2/T3) and that of the control (7.13 g; F (3,32) = 14.27; p<0.001). Tukey HSD post hoc analysis showed that the weight loss of the T2 and T3 (12% and 16%) groups was significantly greater than that of the control group (p<0.001) and the T1 group (p = 0.002), respectively, but there was no difference between the control group and the T1 group (p=0.218). This indicates that less oil was absorbed during frying, as there was more moisture evaporation during cooking, which creates a barrier to the penetration of oil, as also reported for the corn silk in meatballs [17] and for meat products containing dietary fiber [16]. The shape parameters using the swirl stack sine wave model did not show a significant treatment effect (F (3,32) = 0.43, p=0.733), indicating that the rice bran fortification did not affect the spherical shape of the meatballs, which is very important for the consumer's expectations. The formulation with 8% (T1) was determined as the most suitable formulation that provided a beneficial

DOI: https://doi.org/10.54393/df.v7i2.205

nutritional effect (decreased oil absorption and increased fiber) without compromising sensory equivalence with the control. This threshold is a little lower than the 10% reported by Avile *et al.* [11] for pork meatballs but is higher than the 2% reported by Xiao *et al.* [18] for chicken patties, which is attributed to differences in the meat matrix, rice bran particle size, and cooking method. The nutraceutical properties of rice bran, like antioxidants and cholesterol-lowering properties, are also complementary to the physical properties observed [19, 20].

The sensory panel (n = 20) was drawn from a single research institute, limiting generalizability to broader consumer populations, and only one cooking method (pan frying followed by oven finishing) was tested, while shelf life, oxidative stability, and microbiological safety were not assessed, and oil absorption was indirectly estimated rather than directly measured gravimetrically. To address these limitations, future studies should recruit larger, more diverse consumer panels and evaluate different cooking techniques to assess their impact on oil absorption and texture, along with direct gravimetric measurement of oil absorption, accelerated shelf-life testing with antioxidant evaluations, clinical studies to substantiate health claims, and cost-effectiveness analysis at industrial scale to confirm economic viability in low-income communities.

CONCLUSIONS

The rice bran can be added to the beef meatball in an amount of up to 8% (2.4 g/30 g) without affecting its sensory acceptability, but with a significant effect on reducing oil absorption and increasing fiber content without affecting the spherical shape of the meatballs. Increased concentrations (12-16%) yield a firmer texture and a slightly nutty flavor that could be attractive to health-conscious consumers who are looking for more filling products. In general, rice bran fortification is a sustainable and cost-effective approach to enhance dietary fiber content and decrease fat content in meat products.

Authors' Contribution

Conceptualization: NS
Methodology: ANIA, MTS, NS
Formal analysis: NS
Writing and Drafting: ANIA, MTS
Review and Editing: ANIA, MTA, NS

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

Source of Funding

The authors received no financial support for the research, authorship and/or publication of this article.

REFERENCES

[1] Amagliani L, O'Regan J, Kelly AL, O'Mahony JA. The Composition, Extraction, Functionality, and Applications of Rice Proteins: A Review. Trends in Food Science and Technology. 2017 Jun; 64: 1-2. doi: 10.1016/j.tifs.2017.01.008.
[2] Meza SL, Cañizares L, Dannenberg B, Peres BB, Rodrigues LA, Mardade C *et al.* Sustainable Rice Bran Protein: Composition, Extraction, Quality Properties and Applications. Trends in Food Science and Technology. 2024 Mar; 145: 104355. doi: 10.1016/j.tifs.2024.104355.
[3] Manzoor A, Pandey VK, Dar AH, Fayaz U, Dash KK, Shams R *et al.* Rice Bran: Nutritional, Phytochemical, and Pharmacological Profile and Its Contribution to Human Health Promotion. Food Chemistry Advances. 2023 Oct; 2: 100296. doi: 10.1016/j.focha.2023.100296.
[4] Huang J, Zhang P, Ruan Z, Xu H, Yang Z, Huang T *et al.* A New Force of Sustainable Plant Protein: Nutritional Function, Technological Innovation and Application Prospect of Rice Bran Protein. Trends in Food Science and Technology. 2025 Nov: 105425. doi: 10.1016/j.tifs.2025.105425.
[5] Manessis G, Kalogianni AI, Lazou T, Moschovas M, Bossis I, Gelasakis AI. Plant-Derived Natural Antioxidants in Meat and Meat Products. Antioxidants. 2020 Dec; 9(12): 1215. doi: 10.3390/antiox9121215.
[6] Stanišić N, Kurćubić VS, Stajić SB, Tomašević ID, Tomašević I. Integration of Dietary Fiber for Health Benefits, Improved Structure, and Nutritional Value of Meat Products and Plant-Based Meat Alternatives. Foods. 2025 Jun; 14(12): 2090. doi: 10.3390/foods14122090.
[7] Akbari E and Jahadi M. The Effect of Replacing Low-Phytate Rice Bran on Physicochemical Properties of Burger Chicken. Journal of Food Science and Technology (Iran). 2021 Nov; 18(118): 237-47. doi: 10.52547/fsct.18.118.237.
[8] Silva SR, Teixeira A, Guedes C. Sheep and Goat Meat Processing and Quality. Foods. 2023 May; 12(10): 2033. doi: 10.3390/foods12102033.
[9] Ciobanu MM, Manoliu DR, Ciobotaru MC, Flocea EI, Boișteanu PC. Dietary Fibers in Processed Meat: A Review on Nutritional Enhancement, Technological Effects, Sensory Implications and Consumer Perception. Foods. 2025 Apr; 14(9): 1459. doi: 10.3390/foods14091459.
[10] Al-Ghabawi NA and Al-Mossawi AE. Improving the Quality Characteristics of Low-Fat Beef Burgers by Adding Different Levels of Rice Bran as a Source of

DOI: https://doi.org/10.54393/df.v7i2.205

Fiber. Basrah Journal of Agricultural Sciences. 2024 Dec; 37(2): 138-64. doi: 10.37077/25200860.2024.37.2.12.
[11] Aviles MV, Naef EF, Abalos RA, Lound LH, Gómez MB, Olivera DF. Use of a Rice Industry By-Product as a Meat Replacer in a Hybrid Chicken Patty: Technological and Sensory Impact. International Journal of Gastronomy and Food Science. 2023 Mar; 31: 100674. doi: 10.1016/j.ijgfs.2023.100674.
[12] Mishra BP, Mishra J, Paital B, Rath PK, Jena MK, Reddy BV *et al.* Properties and Physiological Effects of Dietary Fiber-Enriched Meat Products: A Review. Frontiers in Nutrition. 2023 Nov; 10: 1275341. doi: 10.3389/fnut.2023.1275341.
[13] Wang Y, Zhang H, Tao Y, Xu X, Zhao X. Pre-Emulsion Constructed with Modified Rice Bran Fiber and Its Application in Low-Fat Chicken Meatballs. LWT-Food Science and Technology. 2024 Jun; 201: 116282. doi: 10.1016/j.lwt.2024.116282.
[14] Sujarwanta RO, Beya MM, Utami D, Jamhari J, Suryanto E, Agus A *et al.* Rice Bran Makes a Healthy and Tasty Traditional Indonesian Goat Meatball, 'Bakso'. Foods. 2021 Aug; 10(8): 1940. doi: 10.3390/foods10081940.
[15] Fawy AR, Ahmed HY, Shabana ES, Maky MA. Quality Characteristics of Beef Burger Formulated with Olive and Rice Bran Oils. Advances in Animal and Veterinary Sciences. 2022; 10(8): 1659-67. doi: 10.17582/journal.aavs/2022/10.8.1659.1667.
[16] Das AK, Nanda PK, Madane P, Biswas S, Das A, Zhang W *et al.* A Comprehensive Review on Antioxidant Dietary Fiber Enriched Meat-Based Functional Foods. Trends in Food Science and Technology. 2020 May; 99: 323-36. doi: 10.1016/j.tifs.2020.03.010.
[17] Aukkanit N, Kemngoen T, Ponharn N. Utilization of Corn Silk in Low-Fat Meatballs and Its Characteristics. Procedia-Social and Behavioral Sciences. 2015 Jul; 197: 1403-10. doi: 10.1016/j.sbspro.2015.07.086.
[18] Xiao Z, Jiang R, Huo J, Wang H, Li H, Su S *et al.* Rice Bran Meat Analogs: Relationship Between Extrusion Parameters, Apparent Properties and Secondary Structures. LWT-Food Science and Technology. 2022 Jun; 163: 113535. doi: 10.1016/j.lwt.2022.113535.
[19] Tan BL, Norhaizan ME, Chan LC. Rice Bran: From Waste to Nutritious Food Ingredients. Nutrients. 2023 May; 15(11): 2503. doi: 10.3390/nu15112503.
[20] Erdem N, Babaoğlu AS, Poçan HB, Karakaya M. The Effect of Transglutaminase on Some Quality Properties of Beef, Chicken, and Turkey Meatballs. Journal of Food Processing and Preservation. 2020 Oct; 44(10): e14815. doi: 10.1111/jfpp.14815.