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Enriching the Quality and Flavor of Rice Porridge with Plant Modifications

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ABSTRACT

The limited sensory appeal of traditional rice porridge encourages the development of enriched formulations with improved consumer properties. This study evaluated the effects of Asparagus officinalis, Laminaria spp., and Stevia rebaudiana powders on the culinary and sensory characteristics of porridges prepared from rice varieties differing in grain processing and pericarp pigmentation. Sensory quality was assessed using a 9-point hedonic scale, together with measurements of cooking yield and water absorption capacity. Rice variety strongly influenced the response to enrichment, and formulation significantly affected all sensory attributes ($p < 0.05$). The white glutinous cultivar Dieta showed the greatest technological stability, a neutral baseline sensory profile, and the highest adaptability to plant additives. In contrast, the pigmented Redut and Yuzhnaya Noch cultivars were more sensitive, frequently developing bitterness, intense aroma, and unstable texture. The most acceptable Dieta-based formulations contained 0.5–1.0% asparagus powder, 0.25–0.75% kelp powder, and 0.20% stevia powder. At these levels, the porridge retained the characteristic structure of glutinous rice while acquiring mild sweetness and a weak plant aroma. Cooking yield and water absorption remained within the typical range for glutinous rice, indicating preservation of the starch matrix. Higher additive concentrations caused excessive dryness or mucilaginous texture, undissolved particles, bitterness, and strong off-aromas. Thus, functional enrichment is most suitable for the Dieta cultivar under strictly controlled additive dosages and may support the development of dietary and health-oriented rice products.

Keywords: *Glutinous sticky rice, Culinary properties, Flavor, Rice porridge, Asparagus, Kelp*

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INTRODUCTION

In recent years, there has been an increase in consumer interest in food products that combine natural origin, affordability, and enhanced health benefits without compromising taste and consumer properties. Products that adapt to the modern pace of life and require minimal preparation time are becoming popular. One such product is porridge, an easily digestible and nutritious dish. Its soft, semi-liquid consistency facilitates chewing, swallowing, and digestion, making it suitable for children, elderly people, and recovering patients. However, traditional porridge, consisting mainly of starch, has limited nutritional value. Its nutritional and functional value can be increased by incorporating whole grains, legumes, vegetables, and other functional components (Mahgoub *et al*., 2020; Noor *et al*., 2023).

Rice occupies a special place among cereal crops due to its rich chemical composition. It contains significant amounts of starch, proteins, vitamins, and minerals. The absence of gluten makes rice a hypoallergenic raw material suitable for specialized and gluten-free foods. Its protein fraction is characterized by high digestibility and biological value compared with wheat, barley, and maize proteins. For much of the global population, rice remains a primary source of energy and essential nutrients (Koo & Lasekan, 2007; Shozib *et al*., 2018).

Rice (*Oryza sativa* L.) is used in infant, clinical, and dietary nutrition. Rice porridge is a liquid or semi-solid product with a soft texture, making it convenient for individuals with specific physiological needs. However, it typically contains a high proportion of easily digestible carbohydrates and a limited amount of functional ingredients. Food technology therefore aims to develop products that combine convenient preparation with improved nutritional value and functional properties. In this context, enriching rice porridge with plant and marine components capable of modifying its composition, texture, and organoleptic characteristics is relevant (Goyat *et al*., 2019; Ishfaq *et al*., 2023).

Glutinous rice represents a promising raw material for porridge production. Rice grain consists mainly of starch formed by amylose and amylopectin, whose ratio determines the culinary and technological characteristics of rice-based products. Glutinous rice has an extremely low amylose content (0–2%) and a high amylopectin level, providing a sticky, viscous, and homogeneous consistency after cooking. Rice varieties with pigmented pericarp, including red and black rice, are of interest because they retain the aleurone layer and germ and contain higher levels of vitamins, lipids, minerals, phenolic compounds, and anthocyanins than polished white rice (Tuman'jan *et al*., 2016; Ali & Hashim, 2024).

The quality of rice-based products depends on consistency, texture, aroma, taste, and color. Rice varieties differ in grain shape, size, and the consistency of cooked porridge, which largely determine consumer preferences. Rice porridge may also exhibit insufficient grain structural integrity and a relatively neutral taste, limiting its consumer attractiveness. Therefore, additives capable of influencing starch gelatinization, water absorption, moisture distribution, and sensory characteristics represent a promising approach (Fitzgerald, 2010; Pakanun Charoensri *et al*., 2025).

Modern research confirms the effectiveness of non-starch polysaccharides and plant powders in modifying texture and enhancing the nutritional value of starch-based products. Asparagus (*Asparagus officinalis*) is a source of dietary fiber, saponins, and phenolic compounds with antioxidant and prebiotic properties. Its addition to cereal products can increase dietary fiber and mineral content while improving sensory properties. Kelp (*Laminaria* spp.) is rich in alginates, fucoidans, trace elements, and iodine. Its polysaccharides can increase viscosity, slow starch hydrolysis, and reduce the glycemic load of foods, making kelp a promising additive for functional porridges (Smolyar & Petrashenko, 2014; Garcia-Segovia *et al*., 2017).

Stevia (*Stevia rebaudiana* (Bertoni) Hemsley) is widely used as a natural non-caloric sweetener. Steviol glycosides provide high sweetness without caloric contribution and do not significantly affect blood glucose levels, allowing stevia to improve taste without increasing caloric content. Stevia leaf powder can provide sweetness to glutinous rice porridge while maintaining a low glycemic load. It also contains biologically active compounds with immunostimulatory and anti-inflammatory properties, which may enhance the functional value of the product when combined with asparagus and kelp (Boonkaewwan & Burodom, 2013; Rizzo *et al*., 2013; Orellana-Paucar, 2023; Ferdous *et al*., 2025).

The present study aims to develop porridge formulations based on different glutinous rice varieties and to evaluate the effects of plant-based additives on their culinary and sensory properties.

MATERIALS AND METHODS

Materials

The objects of the study were porridges prepared from four glutinous rice varieties differing in botanical and technological characteristics, as well as in the degree of grain processing. The following rice varieties were used: white amylose rice cultivar "Regul" (control sample), white glutinous rice variety "Dieta," red rice type "Redut," and black rice cultivar "Yuzhnaya Noch," bred at the Federal Scientific Rice Centre in Krasnodar, Russia.

The study investigated the effect of plant modifications on the formation of consumer and technological properties of rice porridges. The porridges were prepared using rice with different degrees of grain processing—polished and dehulled—providing additional variability in formulations and enabling assessment of the effect of the bran layer retention on the structural, mechanical, and sensory properties of the final product. The control for all experimental variants was porridge made from polished white amylose rice (Regul) without the addition of plant ingredients.

Thus, the set of research objects included multicomponent rice porridges differing in rice variety, type of grain processing (white, red, and black rice), and the proportion of added functional plant ingredients, such as asparagus (*Asparagus officinalis*), kelp (*Laminaria* spp.), and stevia (*Stevia rebaudiana*). These characteristics allowed for a comprehensive evaluation of the influence of these components on product quality and consumer properties (appearance and color, consistency, taste, and aroma).

Rice grain quality assessment

This present research also included the determination of key physical characteristics and quality indicators of rice grains, including 1,000-grain weight, husk content, grain moisture, linear grain dimensions (length, width, length-to-width ratio), and the proportion of whole grains **(Table 1)**.

Table 1. Technological quality characteristics of glutinous rice grains.

Trait \ Variety	Dieta	Redut	Yuzhnaya Noch
1000 -grain weight (g)	24,5	25,8	20,40
Husk Content, %	19,8	16,07	20,22
Grain Moisture, %	11,7	16,4	13,3
Linear Grain Dimensions, Cm	5,35x3,45x2,20	6,75x3,5x1,85	5,95x3,69x1,93
L/B²	1,55	1,92	1,16
Total Milling Yield,%	69,6	73,26	70,06
Proportion of Whole Grains,%	65,19	88,01	99,45

Note: **l/b²- grain length to width ratio**

Rice grain quality assessment showed that all three studied varieties belong to the short-grain type (length-to-width ratio ≤ 2.0) and are characterized by medium grain weight (20-26 g per 1000 grains). The analysis was conducted using a flatbed scanning method based on processing two-dimensional scanned images of rice grains placed on a grid matrix against a black background. The resulting images were used to determine grain dimensions, geometric ratios, and the proportion of whole grains. A technological evaluation of three glutinous rice varieties grown under the irrigation system of the Federal Scientific Rice Centre in 2024 was conducted. The highest milling yield was observed for the red rice variety Redut (73.26%). High proportions of whole kernels were also recorded for colored glutinous varieties—Redut (88.01%) and Yuzhnaya Noch (99.45%). The assessment of 1000-grain weight revealed relatively high values for the white-grain cultivar Dieta (24.5 g) and the red-grain cultivar Redut (25.8 g).

Preparation of rice porridge

Rice samples (25 g each) were prepared for six control variants and nineteen experimental rice porridge samples with plant-based additives, according to the formulations presented in **Table 2**.

Table 2. Formulations of glutinous rice porridges

Rice porridge samples	Processing type	Asparagus content, %	Kelp content, %	Stevia content, %
Regul (control, no additives), polished white rice	polished	-	-	-
Diet, white glutinous rice Control	polished	-	-	-
Test samples		0,50	0,25	0,20
		1,00	0,75	0,20
		1,50	1,50	0,20
		2,00	0,50	0,05
		2,00	2,00	0,50
		3,00	-	-
		3,00	4,00	1,00
		4,00	-	-
		4,00	8,00	1,50
Redut, red rice Control	hulled	-	-	-
Test samples		2,00	0,50	0,05
		5,00	1,00	0,10
Redut, red rice Control	polished	-	-	-
Test samples		1,50	1,00	0,10
		2,00	0,50	0,05
		5,00	1,00	0,10
Yuzhnaya Noch, black rice Control	hulled	-	-	-
Test samples		2,00	0,50	0,05
		5,00	1,00	0,10
Yuzhnaya Noch, black rice Control	polished	-	-	-
Test samples		1,50	1,00	0,10
		2,00	0,50	0,05
		5,00	1,00	0,10

Note: "-" - no additive

As modifying components, asparagus *(Asparagus officinalis*), kelp (*Laminaria* spp.), and stevia *(Stevia rebaudiana*) were incorporated into the formulations at varying concentrations. The mass fractions of the additives ranged as follows: asparagus 0.00–5.00%, kelp 0.00–8.00%, and stevia 0.00–1.50%. These ranges enabled the evaluation of both minimal and elevated levels of their impact on the properties of the final product **(Table 2)**.

Cooking properties of rice grains

Rice porridge can be prepared using various technological approaches, including boiling in excess water, steaming, slow simmering at low heat, and the use of electric rice cookers. The most common traditional method in East and Southeast Asian countries, such as China, Japan, Korea, Thailand, Malaysia, and Indonesia, is prolonged simmering under moderate heating conditions. In this method is cooked in excess water, typically at a ratio of 1:10 to 1:20 for 30–60 minutes, ensuring complete gelatinization and disintegration of the grains (Lee & Ferreira, 2024). An alternative approach is steam cooking, also known as the double-boiling method. This method produces a product with lower viscosity, as it prevents drying and sticking of the rice to the cooking vessel. In addition, steaming is considered a milder processing method that helps preserve nutrients due to the absence of direct exposure to high temperatures (Negreiros & Ory, 2024). In modern practice, the most convenient and widely used method for preparing rice porridge is the use of electric rice cookers, which have become standard household appliances in many Asian countries. Using a rice cooker significantly reduces the labor intensity and eliminates the need for continuous stirring. Differences in temperature regimes and processing time associated with various cooking methods result in variations in the physicochemical composition and textural properties of the final product (Karatas, 2024).

For the experimental procedure, 25 g of rice was weighed and placed into a 100 mL graduated cylinder, followed by triple washing until the rinse water became clear. The washed rice was drained and air-dried. Subsequently, plant-based components were added, and the mixture was thoroughly homogenized. Then, 47 mL of distilled water was added to the cylinder containing the mixture, which was covered and placed in an electric rice cooker for 20 min. After cooking, the porridge was allowed to stand for an additional 10 min. The rice broth was then decanted, after which the mass of the container with porridge and the height of the sample in the cylinder were recorded. Calculations were performed using Eqs. (1) and (2).

$$\text{Weight of porridge} = \text{Weight of glass with porridge} - \text{Weight of empty glass} \tag{1}$$

$$V_{\text{porridge}} = 310.86 - 28.26 * 7.9 * (\text{height from porridge to top}) \tag{2}$$

The cooking coefficient (volume expansion) was determined using a volumetric swelling procedure. Approximately 20 g of dried rice porridge was placed in a graduated cylinder and gently tapped on a flat surface until a constant initial volume was achieved and recorded. Hot water was then added, and the sample was allowed to swell for 10 min. The final volume of the swollen sample was measured, and the cooking coefficient was calculated as the ratio of the final volume to the initial volume.

$$К_{pw} = \frac{V_{porridge}}{V_{cereal}} \tag{3}$$

A pre-dried rice porridge (IRC and IFRC) weighing approximately 2.5 g was placed into a centrifuge tube and hydrated by adding 30 ml of distilled water. The suspension was incubated at room temperature for 30 min, stirring every 5 min to ensure uniform hydration. After incubation, the samples were centrifuged at 2200 rpm for 15 min. The supernatant was decanted, and the sediment was weighed. The WAI value was calculated as the ratio of the mass of the hydrated sediment to the mass of the dry sample.

$$К_{в} = \frac{М_{porridge}}{25} \tag{4}$$

Sensory evaluation of the porridge samples

Sensory (organoleptic) evaluation of the porridge samples was performed using a 9-point hedonic scale ranging from 1 to 9 (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). A panel of six semi-trained participants took part in the sensory evaluation by tasting the prepared samples. The participants were informed about the aims, procedures, and methodology of the study and provided their consent to participate. The porridge samples were evaluated according to the following sensory attributes: appearance (external and crumb structure), texture (consistency), color, taste, and aroma. The evaluation results were expressed as the average score for each characteristic, calculated based on the panelists' assessments.

Statistical analysis

All experiments were replicated at least three times, and the data were expressed as "mean ± standard deviation". Two-way ANOVA analysis of variance was used to identify differences between samples, with $p < 0.05$ considered statistically significant.

RESULTS AND DISCUSSION

Results of the evaluation of culinary and organoleptic properties of porridge

The assessment of culinary properties, including the cooking coefficient (volume expansion ratio) and water absorption index, made it possible to characterize the ability of rice grains to absorb water and increase in volume during cooking. Generally, a cooking coefficient below 5.0 is considered relatively low, while water absorption values for most rice varieties typically range from 4.15 to 4.99.

The cooking coefficient (volume expansion ratio) reflects the increase in grain volume during cooking, which occurs due to water uptake and the swelling of starch granules and proteins. In contrast, the water absorption index characterizes the increase in mass of the grain as a result of water absorption during thermal processing. These parameters are not indicative of quality per se but describe the extent of physical changes occurring during cooking. For example, a sample with a cooking coefficient of 5.0 will yield a greater final volume compared to a sample with a value of 4.7; similarly, higher water absorption corresponds to a greater increase in mass.

The results showed that cooking coefficient values exceeding 5.0 (5.15–5.32) were observed for the Regul and Dieta varieties with 2% Asparagus officinalis addition. The lowest cooking coefficients (2.7–2.9) were recorded for porridges prepared from Redut and Yuzhnaya Noch varieties without additives. The water absorption indices of the studied samples ranged from 2.3 to 3.3, while the Redut variety exhibited a lower value of approximately 2.1.

The data on culinary properties (cooking coefficient and water absorption index) of the studied rice varieties are presented in **Table 3**.

Table 3. Culinary properties of rice varieties (cooking coefficient and water absorption index)

Rice porridge samples (controls and samples with additives: asparagus, kelp, stevia)	Cooking coefficient	Water absorption index Texture (grain separation)
White rice		
Regul (control, no additives), polished white rice	5,15	2,81
Dieta, (control, no additives), white polished rice	4,6	3,3
Dieta, 0,50:0,25:0,20	4,87	2,95
Dieta, 1,00:0,75:0,20	4,71	2,93
Dieta, 1,50:1,50:0,20	4,71	2,93
Dieta, 2,00:0,50:0,05	5,32	2,95
Dieta, 2,00:2,0:0,50	5,15	2,87
Dieta, 3,00:0,00:0,00	4,87	2,87
Dieta, 3,00:4,00:1,00	4,99	2,93

Dieta, 4,00:0,00:0,00	4,87	2,92
Dieta, 4,00:8,00:1,50	4,84	3,03
Red rice		
Redut (control, no additives), husked	2,7	2,1
Redut, 2,00:0,50:0,05	4,15	2,47
Redut, 5,00:1,00:0,10	4,31	2,49
Redut (control, no additives), polished	4,3	3,3
Redut, 1,50:1,00:0,10	4,87	2,96
Redut, 2,00:0,50:0,05	4,71	2,90
Redut, 5,00:1,00:0,10	4,71	2,91
Black rice		
Uzhnaya noch., (control, no additives), husked	2,9	2,3
Uzhnaya noch., 2,00:0,50:0,05	4,31	2,36
Uzhnaya noch., 5,00:1,00:0,10	4,31	2,49
Uzhnaya noch., (control, no additives), polished	4,2	3,2
Uzhnaya noch., 1,50:1,00:0,10	4,71	3,03
Uzhnaya noch., 2,00:0,50:0,05	4,71	2,91
Uzhnaya noch., 5,00:1,00:0,10	4,71	2,47

Sensory evaluation of rice porridges

Sensory analysis demonstrated that the taste, aroma, and consistency of the final product were strongly influenced by both the rice variety and the type and dosage of plant additives. Control samples without plant-based modifications exhibited the most balanced sensory properties. The Regul variety was characterized by a distinct rice flavor and aroma, as well as a loose, non-mucilaginous structure. The control sample of the Dieta variety showed a neutral taste, absence of bitterness, and a satisfactory texture, confirming its high technological suitability for further modifications. The control samples of the Redut and Yuzhnaya Noch varieties retained their characteristic varietal sensory attributes. However, they more frequently exhibited denser or mucilaginous textures, which is consistent with their previously observed water absorption behavior. Modifying the porridge by incorporation of plant components at low and moderate doses (up to 0.5–1.0%) in the initial formulations had a positive effect on the flavor and aroma profile. In particular, porridges prepared from the glutinous Dieta variety with the addition of stevia (*Stevia rebaudiana*) exhibited a mild sweet aftertaste and a moderately pronounced plant-derived, herbal aroma without significant distortion of the base flavor. The most favorable sensory profile was observed in samples No. 1 and No. 2, which contained all three plant additives (*Asparagus officinalis, Laminaria spp., and Stevia rebaudiana*) in the following percentage ratios: 0.5:0.25:0.2 and 1.0:0.75:0.2, respectively. In sample No. 1 (0.5:0.25:0.2), the porridge shows a drier and more crumbly texture compared to the control (porridge from Dieta variety without additives), along with a more pronounced, slightly spicy taste, a sweet aftertaste, and a weak plant, herbal aroma **(Table 4)**.

Table 4. Sensory scores of white rice porridge Dieta variety samples with statistical groupings (mean±SD, Tukey's HSD test)

	Appearance & Color	Consistency	Flavour & Taste	Overall acceptability
C+	7.80±0.26 a	8.50±0.41 a	8.70±0.26 a	8.70±0.26 a
C-	7.70±0.35 a	8.50±0.33 a	8.50±0.41 a	8.70±0.35 a
1	7.70±0.26 a	8.05±0.28 a	8.35±0.41 ab	8.20±0.26 b
2	7.55±0.44 a	7.55±0.50 b	7.95±0.60 b	7.90±0.39 b
3	7.05±0.69 b	7.20±0.54 bc	7.15±0.58 c	7.40±0.39 c
4	6.30±0.59 c	7.35±0.67 b	7.05±0.50 c	6.70±0.59 d
5	5.95±0.50 c	6.80±0.54 c	6.50±0.47 d	6.05±0.64 e
6	5.25±0.59 d	5.85±0.47 d	5.35±0.67 e	5.50±0.91 f
7	4.70±0.54 e	4.70±0.35 e	4.95±0.69 e	5.05±0.60 f
8	4.05±0.69 f	3.65±0.58 f	5.00±0.67 e	4.25±0.86 g
9	3.00±0.97 g	2.35±0.75 g	3.95±0.60 f	3.15±0.58 h

Sensory evaluation of the white rice porridge samples revealed significant differences ($p < 0.05$) between the formulations across all assessed parameters, including appearance and color, texture, aroma and flavor, and overall acceptability. The control samples (C+ and C−) scored high on all parameters and did not differ statistically from each other ($p \geq 0.05$), indicating stable baseline sensory quality. Sample 1 demonstrated comparable sensory characteristics to the control group, particularly for appearance, texture, and flavor, as indicated by the letters denoting the overall characteristics (a–ab). However, its overall acceptability was slightly lower ($p < 0.05$). A gradual decrease in sensory scores was observed from samples 2 to 9. Samples 2 and 3 showed moderate acceptability, while samples 4–6 demonstrated significantly lower scores ($p < 0.05$), particularly for flavor and overall acceptability. The lowest sensory ratings were recorded for samples 7–9, which differed significantly from the control group across all assessed parameters ($p < 0.05$), indicating a decrease in consumer acceptability. Overall, the results show that increasing the level of modification negatively impacts sensory properties, with optimal acceptability observed in samples closest to the control formulation. Values in the table are presented as mean ± standard deviation (SD). Different superscript letters in the same column indicate statistically significant differences between samples at $p < 0.05$ according to Tukey's HSD test. Mean values that share at least one superscript letter are statistically insignificant.

In version No.2 (1.0:0.75:0.2), prepared from white glutinous rice (Dieta), the texture was slightly dry, and the taste became saltier. Due to the increased kelp content, the aroma became more characteristic of seaweed. These two formulations can be recommended as functional food products with potential health benefits. With increasing concentrations of plant powders (1.5–3.0% and higher), the sensory properties of most samples deteriorated. Typical adverse effects included increased bitterness, the development of a sharp and specific aroma (particularly with kelp and asparagus), and undesirable textural changes such as excessive dryness or, conversely, mucilaginous consistency.

Overall, the results of the sensory evaluation showed that porridges prepared from the glutinous rice variety Dieta with low and moderate levels of plant additives were the most acceptable in terms of taste, aroma, and consistency. Increasing the concentration of plant components, especially kelp (*Laminaria spp.*) and asparagus (*Asparagus officinalis*), led to a significant deterioration in organoleptic properties despite potential improvements in functional and technological characteristics.

Thus, the optimal concentrations of plant additives for enriching rice porridge based on white glutinous rice are as follows: 0.5-1.0% *Asparagus officinalis*, 0.25-0.75% *Laminaria spp.*, and 0.20% *Stevia rebaudiana*. These formulations are recommended for use in functional foods, including dietary and pediatric nutrition.

For rice varieties with pigmented pericarp (Redut and Yuzhnaya Noch), a higher sensitivity to plant additives was observed. Even at moderate doses, undesirable attributes such as bitterness, a harsh aroma, and unstable texture (mucilage formation, grain deformation, and structural heterogeneity) were detected. Samples with high concentrations of plant components were particularly deemed unsuitable for consumption due to pronounced off-flavors, distinctive odor, and unsatisfactory texture **(Table 5)**.

Table 5. Sensory scores of red rice porridge Redut variety samples with statistical groupings (mean±SD, Tukey's HSD test)

	Appearance & Color	Consistency	Flavour & Taste	Overall acceptability
C+	7.80±0.26 c	8.60±0.39 a	8.70±0.26 a	8.70±0.26 a
C-	8.50±0.41 a	8.45±0.37 a	8.50±0.41 ab	8.40±0.32 ab
1	7.35±0.47 d	7.30±0.42 c	7.60±0.52 c	7.55±0.50 c
2	6.35±0.58 e	6.05±0.55 e	6.25±0.35 e	6.55±0.60 d
3	8.25±0.54 ab	7.80±0.42 b	8.20±0.26 b	8.30±0.35 b
4	8.00±0.33 bc	7.05±0.50 cd	7.00±0.41 d	7.30±0.35 c
5	7.10±0.32 d	6.75±0.54 d	5.95±0.50 e	6.55±0.37 d
6	5.85±0.47 f	5.70±0.48 e	4.75±0.49 f	5.00±0.41 e

Sensory evaluation of the Redut red rice porridge revealed significant differences between the samples for all assessed parameters ($p < 0.05$). ьThe control samples demonstrated high sensory scores, and no differences were observed between the control samples ($p \geq 0.05$), indicating stable sensory quality. ьAmong the experimental samples, sample 3 showed the best sensory characteristics, receiving high scores for all parameters (appearance: 8.25, taste: 8.20, overall acceptability: 8.30) and did not differ from the control group for several parameters ($p \geq 0.05$). This indicates good maintenance of sensory quality. Samples 1 and 4 demonstrated moderate acceptability, with slightly reduced scores for consistency and taste. In contrast, samples 2 and 5 showed a more pronounced decrease in sensory characteristics, especially taste and overall acceptability ($p < 0.05$). The lowest scores were recorded for sample 6, which differed significantly from all other samples across all assessed parameters ($p < 0.05$), indicating low sensory quality. Overall, the results indicate that moderate modification levels maintain acceptable sensory properties, while further increases negatively impact product quality. Values in the table are presented as mean ± standard deviation (SD). Different superscript letters in the same column indicate statistically significant differences between samples at $p < 0.05$ according to Tukey's HSD test. Mean values that share at least one superscript letter are statistically insignificant **(Table 6)** (Agrawal *et al*., 2024; Bona & Lozano, 2024; Ghiga *et al*., 2024; Khan *et al*., 2024; Qiao *et al*., 2024; Musa *et al*., 2025; Raza *et al*., 2025).

Table 6. Sensory scores of black rice porridge Yuzhnaya Noch variety samples with statistical groupings (mean±SD, Tukey's HSD test)

	Appearance & Color	Consistency	Flavour & Taste	Overall acceptability
C+	7.95±0.37 c	8.60±0.39 a	8.70±0.26 a	8.75±0.26 a
C-	8.45±0.55 ab	8.15±0.24 b	8.60±0.39 a	8.65±0.41 a
1	8.10±0.52 bc	7.60±0.39 c	8.05±0.37 b	7.95±0.50 b
2	6.95±0.50 d	6.80±0.48 d	6.90±0.61 c	6.75±0.59 d

3	8.55±0.44 a	8.20±0.26 b	8.50±0.33 a	8.15±0.41 b
4	7.90±0.52 c	7.55±0.50 c	7.80±0.42 b	7.60±0.46 c
5	6.70±0.59 d	6.75±0.54 d	6.70±0.48 c	6.85±0.47 d
6	5.65±0.63 e	5.50±0.67 e	5.65±0.53 d	5.70±0.48 e

The sensory analysis of the Yuzhnaya Noch black rice porridge also demonstrated statistically significant differences between the samples for all assessed parameters ($p < 0.05$). Both control samples (C+ and C−) showed high sensory scores and did not differ significantly in taste and overall acceptability ($p \geq 0.05$), indicating high basic product quality. Among the experimental samples, sample 3 again showed the best results, receiving the highest appearance score (8.55) and high values for consistency, taste, and overall acceptability (Kęska & Suchy, 2024; Kounatidis *et al*., 2024; Lee & Ferreira, 2024; Noor *et al*., 2024; Jagsi *et al*., 2025; Petronis *et al*., 2025; Wong *et al*., 2025; Yu *et al*., 2025). These results were comparable with the control group, indicating an optimal formulation. Sample 1 also demonstrated high sensory scores, although slightly lower than sample 3, especially for consistency and taste. Samples 2, 4, and 5 showed moderate sensory acceptability with statistically lower scores compared to the control group ($p < 0.05$), especially for taste and overall acceptability. The lowest sensory scores were observed for sample 6, which differed significantly from all other samples ($p < 0.05$), indicating a decrease in consumer acceptability. Overall, the "Yuzhnaya Noch" variety showed a similar trend to "Redut," with optimal sensory characteristics observed at moderate levels of recipe modification and a decrease in quality at higher levels of modification. Values in the table are presented as mean ± standard deviation (SD). Different superscript letters in the same column indicate statistically significant differences between samples at $p < 0.05$ according to Tukey's HSD test. Mean values that share at least one superscript letter are statistically insignificant.

Both varieties (Redut and Yuzhnaya Noch) demonstrated similar sensory trends. However, Yuzhnaya Noch demonstrated slightly greater consistency in flavor and overall acceptability across samples, indicating better suitability for product development. Statistical analysis of sensory evaluation data for the three rice varieties (Diet, Redut, and Yuzhnaya Noch) revealed a significant effect of sample formulation on all assessed attributes, including appearance and color, texture, aroma and flavor, and overall acceptability ($p < 0.05$). One-way ANOVA followed by Tukey's post hoc test (HSD) revealed that sensory scores significantly decreased with increasing modification level for all varieties. In all cases, the control samples (C+ and C−) demonstrated high acceptability and did not differ statistically from each other ($p \geq 0.05$). Among the experimental samples, recipes corresponding to moderate modification levels (typically samples 1–3) demonstrated the most favorable sensory characteristics, while higher levels (samples 5–9) resulted in statistically significant decreases in all parameters ($p < 0.05$). Despite similar overall trends, notable differences were observed between rice varieties. The "Diet" variety demonstrated the most stable sensory profile, with minimal decreases in scores at low and moderate modification levels. Sample 1 of the "Diet" variety remained close to the control group for most parameters, indicating high tolerance to recipe changes. In contrast, the "Redut" variety showed greater variability in sensory scores. Although sample 3 achieved high acceptability comparable to the control samples, other recipes demonstrated more pronounced decreases, particularly in flavor and texture. The "Yuzhnaya Noch" variety demonstrated intermediate behavior. Although sample 3 again demonstrated high sensory scores, a more noticeable decline in quality was observed in samples with increasing levels of modification compared to the "Dieta" variety.

Overall, the "Dieta" variety can be considered the most suitable for product modification, as it retained higher organoleptic acceptability across a wider range of formulations compared to the "Redut" and "Yuzhnaya Noch" varieties. This suggests that "Dieta" has excellent technological and organoleptic adaptability, making it a promising raw material for the development of rice-based functional foods.

It should also be noted that the combination of multiple plant additives at elevated concentrations resulted in a cumulative negative effect, manifested as excessive intensity of taste and aroma, technological instability of texture, and loss of product homogeneity. These findings highlight the necessity of strictly controlling the total content of plant additives in the development of functional rice porridges.

Overall, the results of the sensory evaluation confirm that the most acceptable products are porridges made from white glutinous rice (Dieta) with low to moderate levels of plant additives **(Table 7)**.

Table 7. Analyses of sensory evaluation of rice porridge by Two-way ANOVA

Sensory evaluation						
White rice						
Appearance						
	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Samples	21.20	5	4.30	72.33	0.00	2.71
Respondents	0.09	4	0.02	0.38	0.82	2.87
Consistency						
Samples	12.25	5	2.45	13.46	0.00	2.71
Respondents	4.42	4	1.10	6.07	0.00	2.87
Scent						
Samples	9.95	5	1.99	23.53	0.00	2.71
Respondents	0.37	4	0.09	1.10	0.38	2.87
Color						

Samples	19.23	5	3.85	58.60	0.00	2.71
Respondents	0.10	4	0.02	0.36	0.83	2.87
			Taste			
Samples	17.13	5	3.43	137.01	0.00	2.71
Respondents	0.31	4	0.08	3.12	0.04	2.87
			Brown rice			
			Appearance			
	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Samples	20.39	5	4.08	98.82	0.00	2.71
Respondents	0.47	4	0.12	2.95	0.05	2.87
			Consistency			
Samples	12.22	5	2.44	14.56	0.00	2.71
Respondents	4.77	4	1.19	7.11	0.00	2.87
			Scent			
Samples	15.11	5	3.02	94.66	0.00	2.71
Respondents	0.19	4	0.05	1.51	0.24	2.87
			Color			
Samples	29.81	5	5.96	118.53	0.00	2.71
Respondents	0.05	4	0.01	0.25	0.91	2.87
			Taste			
Samples	16.56	5	3.31	118.53	0.00	2.71
Respondents	1.28	4	0.32	0.25	0.05	2.87
			Black rice			
			Appearance			
	SS	*df*	*MS*	*F*	*P-value*	*F crit*
Samples	11.72	5	2.34	68.61	0.00	2.71
Respondents	1.15	4	0.29	8.40	0.00	2.87
			Consistency			
Samples	12.22	5	2.44	14.56	0.00	2.71
Respondents	4.77	4	1.19	7.11	0.00	2.87
			Scent			
Samples	10.51	5	2.10	24.08	0.00	2.71
Respondents	0.40	4	0.10	1.14	0.36	2.87
			Color			
Samples	19.43	5	3.89	90.57	0.00	2.71
Respondents	0.42	4	0.11	2.46	0.08	2.87
			Taste			
Samples	22.51	5	4.50	51.10	0.00	2.71
Respondents	0.40	4	0.10	1.14	0.37	2.87

df: Degrees of Freedom. *MS* = Mean Square. Significance at $^*p < 0.05$. F crit - α level

CONCLUSION

It was established that the varietal characteristics of glutinous rice play a decisive role in swelling capacity, water retention, and the formation of a stable structure. Among the studied varieties, the "Diet" cultivar exhibited the highest technological stability and organoleptic balance. In control samples, it demonstrated satisfactory cooking yield and water absorption capacity, along with a neutral taste and aroma, making it the most promising base for functional modifications. The incorporation of plant additives at low to moderate levels (up to 0.5–1.0% of the rice mass) resulted in a moderate increase in cooking yield and water-holding capacity due to the presence of hydrophilic components in the plant materials, without disrupting the integrity of the starch matrix. Under these conditions, sensory evaluation revealed acceptable or mildly expressed plant aroma, absence of pronounced bitterness, and formation of a satisfactory consistency.

Further increases in the concentration of plant components (1.5–3.0% and higher), particularly when multiple modifications were combined, led to deterioration in both technological and organoleptic properties. The main negative effects included excessive dryness or sliminess, phase separation, the presence of undissolved plant particles, increased bitterness, and the development of a sharp, specific aroma. In several cases, such samples were deemed unsuitable for consumption. The Redut and Yuzhnaya Noch varieties demonstrated higher sensitivity to plant modifications. Even at moderate additive levels, these varieties more frequently exhibited undesirable sensory attributes (bitterness, sharp aroma, structural instability), which limit their application in functional porridge formulations without additional technological adjustments.

Based on the obtained data, the most optimal formulations are those based on the glutinous rice variety Dieta with low to moderate levels of plant additives, ensuring a balance between functional value and consumer acceptability. These include formulations containing: *Asparagus officinalis* powder at up to 0.5–1.0%; *Laminaria* spp. powder at up to 0.2–0.5%; and *Stevia rebaudiana* powder at minimal amounts that do not have a dominant effect on taste. These variants are characterized by satisfactory values of cooking yield and water absorption capacity, absence of pronounced bitterness or specific odor, and the formation of a homogeneous, technologically stable consistency.

Patents

Based on the results described in this article, a patent for invention No. 11924, "Enriched mixture of glutinous rice with the addition of Asparagus officinalis for the production of bakery products and instant porridge" was filed on 20.03.2026.

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REFERENCES

Agrawal, M., Shrivastava, S., Khare, R. L., Jaiswal, S., Singh, P., & Hishikar, R. (2024). Comparative analysis of nephrotoxicity in patients on tenofovir-containing and non-tenofovir antiretroviral therapy. *Annals of Pharmacy Practice and Pharmacotherapy, 4*(1), 24–33. doi:10.51847/ZTJxzvNZt4

Ali, M. M., & Hashim, N. (2024). Exploring nutritional composition, volatile compounds, health benefits, emerging processing technologies, and potential food products of glutinous rice: A review. *Rice Science, 31*(3), 251–268.

Bona, C., & Lozano, R. (2024). Delayed hematologic toxicities following axicabtagene ciloleucel and tisagenlecleucel CAR-T cell therapy: A retrospective analysis of lymphocytopenia, neutropenia, and thrombocytopenia. *Asian Journal of Current Research in Clinical Cancer, 4*(2), 1–4. doi:10.51847/13fIAq9Er0

Boonkaewwan, C., & Burodom, A. (2013). Anti-inflammatory and immunomodulatory activities of stevioside and steviol on colonic epithelial cells. *Journal of the Science of Food and Agriculture, 93*(15), 3820–3825. doi:10.1002/jsfa.6287

Ferdous, J., Bhuia, M. S., Chowdhury, R., Sheikh, S., & Islam, M. T. (2025). Therapeutic effects of natural food additives steviol glycosides from *Stevia rebaudiana*: A comprehensive review with mechanisms. *Journal of Food Biochemistry*, 7772203. doi:10.1155/jfbc/7772203

Fitzgerald, M. A. (2010). Rice: Characteristics and quality requirements. In *Cereal grains: Assessing and managing quality* (pp. 212–236). doi:10.1533/9781845699529.2.212

Garcia-Segovia, P., Pagán-Moreno, M. J., Lara, I. F., & Martínez-Monzó, J. (2017). Effect of microalgae incorporation on physicochemical and textural properties in wheat bread formulation. *Food Science and Technology International, 23*(5), 437–447. doi:10.1177/1082013217700259

Ghiga, I., Pitchforth, E., Lundborg, C. S., & Machowska, A. (2024). Bacterial infections and antibiotic resistance in Romanian children: Insights from a hospital-based study. *Interdisciplinary Research in Medical Sciences Special, 4*(2), 1–8. doi:10.51847/pISlxaQJVu

Goyat, J., Rudra, S. G., Suri, S., Passi, S. J., & Dutta, H. (2019). Nutritional, functional, and sensory properties of ready-to-eat chia and quinoa mix enriched low amylose rice-based porridge mixes. *Current Research in Nutrition and Food Science Journal, 7*(2), 399–414.

Ishfaq, J., Soomar, A. M., Khalid, F., & Abbasi, Y. (2023). Assessing rice (*Oryza sativa* L.) quality: A comprehensive review of current techniques and future directions. *Journal of Agriculture and Food Research, 14*, 100843. doi:10.1016/j.jafr.2023.100843

Jagsi, R., Lee, J., Roselin, D., Ira, K., & Williams, J. (2025). Do U.S. medical schools follow medical associations' recommendations on paid parental leave for faculty? *Annals of Pharmacy Education, Safety and Public Health Advocacy, 5*(1), 1–11. doi:10.51847/r117In8wdi

Karatas, K. S. (2024). First episode psychotic disorder and COVID-19: A case study. *Bulletin of Pioneer Research in Medical and Clinical Sciences, 4*(1), 19–23. doi:10.51847/VP5xOKglSX

Kęska, M., & Suchy, W. (2024). Cardiovascular risk and systemic inflammation in rheumatoid arthritis: A comparative analysis with psoriatic arthritis. *Journal of Medical Sciences and Interdisciplinary Research, 4*(2), 30–40. doi:10.51847/PvcqitKMgB

Khan, T. M., Tahir, H., Adil, Q., Baig, M. R., Jaber, A. A. S., Khaliel, A. M., & Mohammed, Z. M. (2024). A three-decade overview of female-specific cancers in Malaysia: A thorough examination. *Asian Journal of Current Research in Clinical Cancer, 4*(2), 5–18. doi:10.51847/LIdazW7afN

Koo, W. W., & Lasekan, J. B. (2007). Rice protein-based infant formula: Current status and future development. *Minerva Pediatrica, 59*(1), 35–41.

Kounatidis, D., Dalamaga, M., Grivakou, E., Karampela, I., Koufopoulos, P., Dalopoulos, V., Adamidis, N., Mylona, E., Kaziani, A., & Vallianou, N. G. (2024). Evaluation of blood-aqueous barrier permeability in response to tetracycline antibiotics under normal and pathological conditions. *Interdisciplinary Research in Medical Sciences Special, 4*(2), 9–17. doi:10.51847/wu4fOEjgDv

Lee, M. J., & Ferreira, J. (2024). COVID-19 and children as an afterthought: Establishing an ethical framework for pandemic policy that includes children. *Asian Journal of Ethics, Health and Medicine, 4*, 1–19. doi:10.51847/haLKYCQorD

Mahgoub, S. A., Mohammed, A. T., & Mobarak, E. A. (2020). Physiochemical, nutritional, and technological properties of instant porridge supplemented with mung bean. *Food and Nutrition Sciences, 11*(12), 1078–1095. doi:10.4236/fns.2020.1112076

Musa, K., Noor, O., Ibrahim, M., & Saleh, A. (2025). A validated whole-body PBPK model of dextromethorphan and its metabolites for genotype-based prediction of CYP2D6 phenotype and urinary metabolic ratio. *Special Journal of Pharmacognosy, Phytochemistry and Biotechnology, 5*(1), 50–76. doi:10.51847/xbESBJHHcx

Negreiros, A. B., & Ory, M. G. (2024). Navigating uncertain outcomes: Returning genomic results in children with developmental delays. *Asian Journal of Ethics, Health and Medicine, 4*, 20–27. doi:10.51847/grOfZd8oyo

Noor, F. M. S., Lay, J. S., Anida, Y., & Seow, E. K. (2023). Unravelling the potential of rice congee: A review of its physicochemical properties, processing methods, functional food opportunities, and current hurdles. *Journal of Food Technology Research, 10*(3), 75–92. doi:10.18488/jftr.v10i3.3493

Noor, H., Sabău, D., Coțe, A., Mihetiu, A. F., Pirvut, V., Mălinescu, B., & Bratu, D. G. (2024). Advancements in Esophageal Stricture Treatment: The Role of Stents in Benign and Malignant Conditions. *Journal of Medical Sciences and Interdisciplinary Research, 4*(2), 47-52. doi:10.51847/LtuxAzRl0M

Orellana-Paucar, A. M. (2023). Steviol glycosides from *Stevia rebaudiana*: An updated overview of their sweetening activity, pharmacological properties, and safety aspects. *Molecules, 28*(3), 1258. doi:10.3390/molecules28031258

Pakanun Charoensri, P., Kijroongrojana, K., Sukkwai, S., Nilsuwan, K., & Benjakul, S. (2025). Physical, sensory, antioxidant and nutritional properties on Riceberry rice porridge fortified with bio-calcium and protein hydrolysate from salmon (*Salmo salar*) frame for elderly. *Journal of Agriculture and Food Research, 19*, 101679. doi:10.1016/j.jafr.2025.101679

Petronis, Z., Golubevas, R., Rokicki, J. P., Guzeviciene, V., Sakavicius, D., & Lukosiunas, A. (2025). A systematic review and meta-analysis on trigeminal neuralgia linked to neurovascular compression using MRI analysis. *Journal of Current Research in Oral Surgery, 5*(1), 17–24. doi:10.51847/sptZWIrWeo

Qiao, J., Luo, B., Ming, J., Zhou, S., Chen, Y., & Zhang, X. (2024). Prevalence and implications of non-prescription antibiotic dispensing in Baghdad community pharmacies. *Annals of Pharmacy Practice and Pharmacotherapy, 4*(1), 34–41. doi:10.51847/5SuGTfpren

Raza, S., Khan, A., Mehmood, F., & Farooq, U. (2025). Nationwide implementation of essential pharmacogenomic testing in the Netherlands: A decision-analytic model of lives saved and cost-effectiveness. *Special Journal of Pharmacognosy, Phytochemistry and Biotechnology, 5*(1), 39–49. doi:10.51847/PUWEymkYkk

Rizzo, B., Zambonin, L., Angeloni, C., Leoncini, E., Vieceli Dalla Sega, F., Prata, C., Fiorentini, D., & Hrelia, S. (2013). Steviol glycosides modulate glucose transport in different cell types. *Oxidative Medicine and Cellular Longevity, 2013*, 348169. doi:10.1155/2013/348169

Shozib, H. B., Jahan, S., Sultan, M. Z., Alam, S., Das, S. C., Amin, R. B., Hasan, M., & Siddiquee, M. A. (2018). Nutritional properties of some BRRI HYV rice in Bangladesh. *Vitamins & Minerals, 7*(1), 174. doi:10.4172/2376-1318.1000174

Smolyar, V. I., Petrashenko, A. I., & Golohova, E. V. (2014). Food fortification. *Problemy Kharchuvannia, 1*, 29–32. http://pronut.medved.kiev.ua/index.php/ua/categories/original-researches/item/406-food-fortification

Tuman'jan, N. G., Papulova, E. Yu., Kumejko, T. B., Esaulova, L. V., Zelenskij, G. L., & Ostapenko, N. V. (2016). Classification of colored rice varieties (with red and black grain pericarp) as objects of a genetic collection based on the analysis of quantitative quality traits. *Achievements of Science and Technology of AIC, 30*(3), 57–61.

Wong, Y.-F., Lin, S.-J., Cheng, H.-C., Hsieh, T.-H., Hsiue, T.-R., Chung, H.-S., Tsai, M.-Y., & Wang, M.-R. (2025). Understanding the impact of medical humanities on internship training and performance. *Annals of Pharmacy Education, Safety and Public Health Advocacy, 5*(1), 12–21. doi:10.51847/Z1fogzPksy

Yu, M., Ma, Y., Han, F., & Gao, X. (2025). Effectiveness of mandibular advancement splint in treating obstructive sleep apnea: A systematic review. *Journal of Current Research in Oral Surgery, 5*(1), 25–32. doi:10.51847/AInSXrD9rc