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Innovation of Batiah: The Role of Rice Varieties and Enrichment with Cassiavera-Morel Berry Extract and Pumpkin Seed Flour

Rahmayani[1], Fauzan Azima[1,*], Daimon Syukri[1], Desniarti[2]

[1]Department of Food Technology and Agricultural Product, Universitas Andalas, Indonesia
[2]Department of Agricultural Industrial Technology, Faculty of Agricultural Technology, Universitas Andalas, Indonesia

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Abstract This study aims to optimize the formulation of Batiah, a traditional Indonesian rice-based snack, as a functional food by modifying the starch source and enriching it with targeted phytochemical compounds. The innovation focuses on replacing conventional white glutinous rice with alternative rice varieties that have different amylose–amylopectin ratios, thereby influencing digestibility, texture, and glycemic characteristics. In addition, the product is fortified with pumpkin seed flour and a mixture of cassiavera–morel berry extracts, both of which are known for their antidiabetic bioactive activities, antioxidant potential, and metabolic benefits. A Completely Randomized Design (CRD) consisting of eight formulations was applied, followed by analysis of physicochemical properties, proximate composition, amylose–amylopectin profile, total energy, and sensory attributes. Unlike previous studies that focused on packaging innovation or household-scale formulations without considering the glycemic index or functional bioactive fortification, this study introduces rice starch modification combined with targeted phytochemical enrichment as a new strategy to transform Batiah into a health-oriented functional product. Results indicate that rice type significantly influences Batiah's functional quality. The formulation using a combination of white glutinous rice and red rice (P6) exhibited the most favorable characteristics, with balanced elasticity (1.67 ± 0.60%), lower oil absorption (6.95 ± 1.18%), moderate protein content (10.36 ± 1.49%), and carbohydrate availability (69.46 ± 0.36%). Sensory evaluation also confirmed P6 as the most preferred sample in terms of color, texture, aroma, taste, and aftertaste. These findings prove that strategic starch replacement combined with bioactive fortification improves nutritional and functional performance while maintaining cultural authenticity.

Keywords Batiah, Cassiavera, Functional Food, Morel Berry, Pumpkin Seed, Rice Varieties

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1. Introduction

Batiah is a traditional Indonesian food, a sweet snack made from glutinous rice: it is soaked, dried, fried, and coated with melted brown sugar. Despite its high cultural and economic potential, innovation in batiah processing is still minimal and tends not to develop [1]. The transformation of batiah into functional products offers a great opportunity not only to increase the product's added value but also to promote traditional Indonesian foods as modern, evidence-based health solutions.

Recent bibliometric findings reveal a growing research trend on Batiah, particularly over the past decade. Most existing studies have concentrated on formulation, household-scale production, and packaging. Addressing these gaps could support the development of Batiah as a competitive local food product [2].

Currently, variations of batiah are generally limited to the method of applying melted brown sugar, while the aspect of raw materials has not been widely developed. White glutinous rice as the main ingredient is also a challenge, given that white glutinous rice has a high glycemic index of 86, and adding brown sugar further increases the sugar content in the final product. With these characteristics, batiah is less ideal for consumers with special dietary needs, such as people with diabetes mellitus.

The development of batiah as a functional food can be done by changing the type of rice used. Substituting white glutinous rice with other varieties such as black glutinous rice (glycemic index 42.3), white rice (72), red rice (55), and black rice (42.3) [3] has the potential to produce batiah with a lower glycemic index. In addition, fortification with additives rich in bioactive compounds is also a promising strategy to improve the nutritional value of batiah.

One ingredient that has great potential for fortification is pumpkin seeds (*Cucurbita moschata* D). This part of the plant, although often considered waste, contains 31-34% protein, 30-33% fat (mainly polyunsaturated fatty acids/PUFAs), 9-10% fiber, 9-17% carbohydrates, as well as various vitamins, minerals, and important bioactive compounds. Several studies have shown that pumpkin seeds have antidiabetic effects, such as the ability to lower blood glucose levels and improve insulin sensitivity [4].

Furthermore, to enrich the biological activity of functional batiah, cassiavera extract (*Cinnamomum burmannii*) and morel berry extract (*Physalis angulata)* are strategic choices. Cassiavera is a dried cinnamon bark rich in cinnamaldehyde, cinnamic acid, polyphenols, and flavonoids, which are known to have hypoglycemic effects and improve insulin sensitivity [5], [6]. GC-MS analysis shows that the content of cinnamaldehyde in cassiavera is the most significant component that acts as an antidiabetic [7]. Meanwhile, morel berry contains active compounds such as physalin B, D, F, G, and gulatin A, which provides antidiabetic and anti-inflammatory effects [8]. The bioactive synergy of these two ingredients is expected to strengthen the functional impacts of batiah on controlling blood sugar levels.

Based on this background, this research aims to examine the effect of rice type variation on the characteristics of functional batiah fortified with a mixture of cassiavera-morel berry extract and pumpkin seed flour, to produce innovative, healthier, and highly competitive traditional products in the functional food market.

2. Materials and Methods

2.1. Materials

The raw materials used in this study were white glutinous rice (Helofood, Indonesia), black glutinous rice (Helofood, Indonesia), white rice (Helofood, Indonesia), red rice (Helofood, Indonesia), dry morel berry, cassiavera AA grade (Sumatra Tropical Spices, Indonesia), pumpkin seed (Hasil Bumiku, Indonesia), and stevia powder (Nutiver, Indonesia). The chemicals used in this study were ethanol 96% (Merck, Germany), DPPH (Sigma Aldrich, Germany), H_2SO_4 (Merck, Germany), hexane (Merck, Germany), and other chemicals.

The tools used were a rotary vacuum evaporator (Buchi, Switzerland), a UV-Vis spectrophotometer (Shimadzu 1800, Japan), a food dryer (Azko, Indonesia), a calorimeter (CAL3K-A, South Africa), a texture analyzer (Brookfield CT3, USA), a glucometer (Almedicus, South Korea), and other tools.

2.2. Methods

2.2.1. Preparation of Cassiavera-Morel Berry Extract Powder

The preparation of the concentrated extract mixture followed the method of [9]. The concentrated extract was then dried by adding 10% maltodextrin based on its weight. The mixture was homogenized and dried using a food dehydrator at 50 ℃ for 8 hours, then ground and sieved through a 40-mesh screen.

2.2.2. Bafubar (Functional Batiah from West Sumatra) Formulation and Production

The formulation of Bafubar was designed based on dietary recommendations for individuals with diabetes, ensuring a balanced composition of carbohydrates, proteins, and fats according to nutritional adequacy standards.

This study employed a completely randomized design (CRD) consisting of eight treatments with three replications. The formulations for each treatment are presented in Table 1. The treatments were as follows:

P1 = White rice
P2 = Red rice
P3 = White glutinous rice
P4 = Black glutinous rice
P5 = Mixture of white glutinous rice and white rice (1:1)
P6 = Mixture of white glutinous rice and red rice (1:1)
P7 = Mixture of black glutinous rice and white rice (1:1)
P8 = Mixture of black glutinous rice and red rice (1:1)

The rice was washed thoroughly under running water and soaked for 12 hours. It was then cooked using a water-to-rice ratio of 2:1. Once boiling, the rice was stirred continuously for 20 minutes over medium heat. The cooked rice was transferred to a container and mixed with pumpkin seed flour, Cassiavera–morel berry extract, stevia powder, and fine salt until homogeneous.

The mixture was molded into circular shapes (3 cm diameter × 0.5 cm height) and dried using a food dehydrator at 40 ℃ for 12 hours. The resulting raw Bafubar (unfried functional batiah) was then fried for 10 seconds over medium heat. The finished Bafubar was packed in aluminum foil standing pouches with a silica gel desiccant placed inside.

Table 1. Formulation of Bafubar

Ingredient	P1	P2	P3	P4	P5	P6	P7	P8
White glutinous rice (g)	100	-	-	-	50	50	-	-
Black glutinous rice (g)	-	100	-	-	-	-	50	50
White rice (g)	-	-	100	-	50	-	50	-
Red rice (g)	-	-	-	100	-	50	-	50
Yellow pumpkin seed flour (g)	20	20	20	20	20	20	20	20
Cassiavera–morel berry extract (mg)	300	300	300	300	300	300	300	300
Stevia powder (g)	10	10	10	10	10	10	10	10
Salt (g)	1	1	1	1	1	1	1	1

2.2.3. Analysis

2.2.3.1. Hedonic Test

A hedonic sensory evaluation was conducted with 30 panelists from the Food and Agricultural Product Technology Department, Universitas Andalas. Panelists assessed color, texture, taste, and aroma using a 5-point hedonic scale (1 = strongly dislike, 5 = strongly like). The samples tested were ready-to-eat products. Hedonic data were treated as ordinal data and analyzed using non-parametric methods. Frequency analysis was applied to determine the distribution of panelist preference. Differences among treatments were evaluated using the Friedman test at a significance level of $p < 0.05$.

2.2.3.2. Physical Analysis

2.2.3.2.1. Expansion Ratio

Expansion was determined by measuring the change in surface area before and after frying using a ruler [10], calculated as:

$$\text{Expansion (\%)} : \frac{L_1 - L_0}{L_0} \ x \ 100$$

where **L_0** and **L_1** are the surface areas of raw and fried batiah, respectively.

2.2.3.2.2. Oil Absorption

Oil absorption was analyzed by weighing samples before (W_1) and after frying (W_2) at 180 ℃ [11].

$$\text{Water absorption (\%)} : \frac{W_2 - W_1}{W_1} \ x \ 100$$

2.2.3.2.3. Water Absorption

One gram of the sample was mixed with 10 mL of distilled water, vortexed for 2 min, and centrifuged (3000 rpm, 25 min). The percentage was calculated as:

$$\text{Water absorption (\%)} : \frac{W_2 - W_1}{W_0} \ x \ 100$$

W_0 is the initial sample weight, W_1 the empty tube weight, and W_2 the weight after centrifugation [12]

2.2.3.2.4. Hardness

Hardness was measured using a Texture Analyzer by applying a single compression force. Results were expressed in N/cm^2.

$$\text{Hardness (N/cm}^2\text{)} = \frac{\frac{\text{peak load (g)}}{1000} \ x \ 9{,}8}{probe \ diameter \ (cm)}$$

2.2.3.3. Proximate Analysis

2.2.3.3.1. Moisture Content

Aluminum dishes were cleaned, dried at 105 ℃ for 30 min, cooled in a desiccator for 15 min, and weighed (W_0). A 3–5 g sample (W_1) was placed in the dish and dried at 105 ℃ for 3–4 h. The dish was cooled in a desiccator for 30 min and weighed, then reheated for 1 h and reweighed until a constant weight (W_2) was obtained [13]. Moisture content was calculated as:

$$\text{Moisture (\%)} : \frac{W_1 - (W_2 - W_0)}{W_1} \ x \ 100$$

2.2.3.3.2. Ash Content

Porcelain crucibles were dried in a muffle furnace for 15 min, cooled in a desiccator, and weighed (W_0). About 5 g of sample (W_1) was added, pre-ashed on a hot plate, and incinerated at ~500 ℃ until a grayish or white ash was obtained. The crucible was cooled in a desiccator and weighed (W_2) [13]. Ash content was calculated as:

$$\text{Ash (\%)} : \frac{W_2 - W_0}{W_1 - W_0} \ x \ 100$$

2.2.3.3.3. Fat Content

Fat flasks were dried at 100–105 ℃ for 30 min, cooled in a desiccator, and weighed. About 3 g of ground sample was wrapped in a thimble, extracted with hexane for approximately 4 h (15 cycles), and the solvent was evaporated. The flask was dried at 100 ℃ to remove residual solvent, cooled, and weighed [14]. Fat content was calculated as:

$$\text{Fat (\%)} : \frac{\text{Weight of extracted fat (g)}}{\text{Sample weight (g)}} \ x \ 100$$

2.2.3.4. Protein Content

Protein was determined through digestion, distillation, and titration [13]. About 0.5 g of the sample was digested with 1 g of selenium mix and 15 mL of concentrated H_2SO_4, distilled with 30 mL of 50% NaOH, and titrated with 0.02 N HCl. Nitrogen content was calculated as:

$$N\ (\%) : \frac{(\text{HCl sample mL} - \text{HCl blank mL}) \times \text{NHCl} \times 14.007 \times \text{Fp}}{\text{Sample weight (g)}}\ x\ 100$$

Protein content was obtained using a conversion factor of 6.25:

$$\text{Protein}\ (\%) = \%N \times 6.25$$

2.2.3.5. Carbohydrate Content

Carbohydrate was calculated by difference [14]:

$$\text{Carbohydrate}\ (\%) = 100 - (\%\text{Moisture} + \%\text{Ash} + \%\text{Protein} + \%\text{Fat})$$

2.2.3.6. Amylose and Amylopectin Content

A 100 mg starch sample was mixed with 1 mL of 96% ethanol and 9 mL of 1 N NaOH, heated at 95 ℃ for 10 min, cooled, and diluted to 100 mL. Then, 5 mL of this solution was pipetted, mixed with 1 mL of 1 N CH_3COOH and 2 mL of iodine, diluted to 100 mL, incubated for 20 min, and measured at 635 nm using a UV-Vis spectrophotometer. Amylose content (%) was calculated based on the amylose concentration (C), final sample volume (V), dilution factor (FP), and sample weight (W) using the following formula:

$$\text{Amylose content}\ (\%) = \frac{\text{C (mg/ml)}}{\text{W (mg)}}\ x\ \text{V (ml)}\ x\ \text{FP}\ x\ 100\%$$

Amylopectin content was determined by subtracting the amylose percentage from 100% [15].

2.2.3.7. Total Energy

Approximately 0.5–1 g of dried sample was placed in a nickel crucible inside the combustion vessel, connected to an ignition wire, and pressurized with oxygen (25–30 bar). The vessel was placed in the bomb calorimeter, and the combustion was initiated. Heat release was recorded as a temperature change, and total energy was automatically calculated by the instrument.

2.2.3.8. Thermal Properties

Thermal behavior was evaluated using a Differential Scanning Calorimeter (DSC 4000, Perkin Elmer). The samples and empty reference crucibles were exposed to a programmed heating profile, and the energy absorbed or released was recorded to assess thermal transitions.

2.2.4. Statistical Analysis

All data were expressed as mean ± standard deviation. The experiment was arranged in a completely randomized design (CRD) with eight treatments and three replications. Data were analyzed using one-way analysis of variance (ANOVA). Differences among treatments were determined using Duncan's Multiple Range Test (DMRT) at a significance level of $p < 0.05$.

3. Results

3.1. Hedonic Test

Based on Figure 1, the product color varied depending on the type and combination of rice used. Treatments containing black glutinous rice (P4, P7, and P8) tended to have a darker color, while formulations using white rice (P1 and P5) appeared lighter. The aroma evaluation showed slight differences among treatments, with some formulations receiving higher scores. The treatment combining white and red glutinous rice (P6) appeared to have a relatively higher aroma score compared to the others.

Based on Figure 2, the organoleptic assessment of Bafubar showed variations across the evaluated attributes: color, aroma, taste, texture, and aftertaste. For color, treatments containing black glutinous rice (P4, P7, P8) tended to receive lower scores due to their darker appearance, whereas formulations based on white rice (P1, P5) achieved higher scores.

(a) (b)

Figure 1. Raw Bafubar Product (a), Cooked Bafubar Product (b)

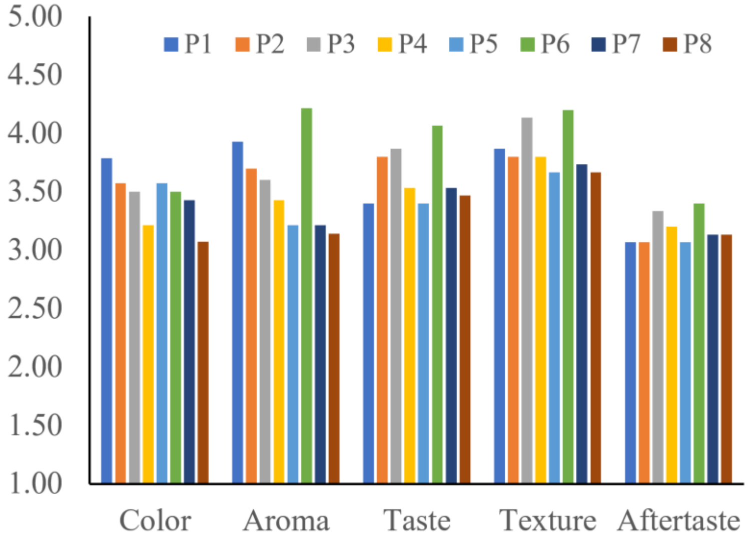

Figure 2. Histogram of Bafubar Organoleptic Assessment Results

The aroma attribute exhibited noticeable differences among treatments, with P6 (white and red glutinous rice) obtaining relatively higher scores. Similarly, taste evaluation revealed that P6 achieved the highest score, indicating better overall acceptance.

For the taste attribute, the formulation with white and red glutinous rice (P6) received the highest score. The texture attribute indicated that formulations containing glutinous rice were generally preferred, with P6 and P5 achieving higher scores. The aftertaste attribute also varied across treatments, with P6 and P5 showing better aftertaste perception.

Overall, the P6 formulation (a combination of white and red glutinous rice) exhibited the most favorable performance across most organoleptic attributes, indicating its potential for higher consumer acceptability. Frequency analysis showed that formulation P6 received the highest proportion of “like” and “strongly like” responses across most sensory attributes. Friedman test results indicated significant differences among treatments ($p < 0.05$), particularly in terms of taste and texture attributes.

3.2. Physical Analysis

Table 2 presents the physical properties of Bafubar with different rice treatments. The values of springiness ranged from 1.32% (P3) to 1.97% (P4). The lowest springiness was observed in P3 (white glutinous rice), whereas the highest was found in P4 (black glutinous rice).

The ability to absorb oil (oil absorbency) varied significantly, ranging from 4.32% (P1) to 14.78% (P3). Treatment P3 (white glutinous rice) showed the highest oil absorbency, while P1 (white rice) had the lowest value.

For water absorbency, the highest value was obtained in P6 (mixture of white glutinous rice and red rice) at 82.16%, whereas the lowest was in P8 (mixture of black glutinous rice and red rice) at 59.66%.

The texture parameter also showed variations among treatments, with the highest value in P6 (8.10%) and the lowest in P1 (4.25%). Overall, the results indicate that different rice types significantly influenced the physical properties of Bafubar.

3.3. Chemical Analysis

3.3.1. Proximate Analysis

The proximate composition of Bafubar varied significantly depending on the rice types (Table 3).

Moisture content ranged from 3.02–7.23%, with P8 showing the highest value (7.23%) and P1 the lowest (3.02%). Ash content ranged between 0.96–3.91%, with P8 having the highest ash content (3.91%) and P1 the lowest (1.60%).

Fat content showed considerable variations. P3 (black glutinous rice) contained the highest fat level (15.63%), whereas P7 recorded the lowest (9.02%). Protein content ranged from 10.91–14.84%, with the highest in P4 and the lowest in P1. Total carbohydrate content varied between 65.80–73.15%. P1 (white rice) exhibited the highest carbohydrate level (73.15%), while P8 had the lowest (65.80%). Statistical analysis revealed significant differences among treatments, particularly between P1 and P8.

3.4. Amylose, Amylopectin, and Total Energy

As shown in Table 4, white rice (P1) contained the highest amylose level (13.54 ± 1.81%) and the lowest amylopectin (86.46 ± 1.81%), resulting in the lowest total energy (463.70 ± 11.77 kcal). Red rice (P2) had a lower amylose content (9.07 ± 0.73%) and higher amylopectin (90.93 ± 0.73%), producing 500.68 ± 11.23 kcal.

Table 2. Physical Properties of Bafubar

Treatment	Springiness (%)	Oil Absorbency (%)	Water Absorbency (%)	Texture (%)
P1	1,57 ±0,33^{e}	4,32 ±1,00^{a}	60,48 ±4,23^{a}	4,25 ±1,01^{c}
P2	1,66 ±0,26^{b}	4,53 ±0,85^{c}	69,27 ±2,66^{c}	4,64 ±0,76^{d}
P3	1,32 ±0,13^{c}	14,78 ±1,57^{b}	67,51 ±2,08^{b}	7,91 ±0,89^{f}
P4	1,97 ±0,62^{d}	7,54 ±0,99^{d}	77,12 ±2,68^{d}	2,18 ±0,77^{a}
P5	1,93 ±0,60^{a}	9,63 ±0,77^{f}	83,43 ±4,90^{f}	8,74 ±0,77^{g}
P6	1,67 ±0,60^{a}	6,95 ±1,18^{e}	82,16 ±4,13^{e}	7,10 ±0,88^{f}
P7	1,86 ±0,60^{a}	5,88 ±0,94^{e}	81,09 ±1,52^{e}	3,05 ±0,54^{b}
P8	1,47 ±0,48^{a}	5,60 ±0,76^{a}	59,66 ±4,13^{a}	5,21 ±0,98^{e}

Notes: Different superscript letters in the same column indicate significant differences ($p < 0.05$).

Table 3. Proximate Analysis Data of Bafubar

Treatment	Water (%)	Ash (%)	Lipid (%)	Protein(%)	Carbohydrate (%)
P1	3,02 ±0,47^{a}	1,60 ±0,64^{ab}	11,33 ±2,12^{ab}	10,91 ±1,86^{a}	73,15 ±1,36^{c}
P2	3,95 ±0,25^{a}	1,70 ±0,55^{ab}	9,23 ±1,68^{a}	11,99 ±0,85^{a}	73,14 ±1,55^{c}
P3	4,96 ±1,63^{ab}	1,32 ±0,95^{ab}	9,02 ±2,27^{a}	12,54 ±1,06^{ab}	72,16 ±2,74^{c}
P4	5,47 ±1,93^{ab}	1,99 ±0,97^{b}	15,63 ±4,76^{b}	14,84 ±1,24^{c}	62,06 ±4,38^{a}
P5	4,55 ±1,06^{ab}	0,96 ±0,37^{a}	12,57 ±2,70^{a}	11,09 ±1,85^{a}	73,04 ±5,78^{c}
P6	4,96 ±0,90^{ab}	1,62 ±0,80^{ab}	10,36 ±1,49^{ab}	11,39 ±0,91^{a}	69,46 ±3,36^{bc}
P7	4,80 ±1,06^{ab}	2,74 ±1,06^{c}	8,52 ±2,49^{a}	12,92 ±2,13^{ab}	71,02 ±2,32^{bc}
P8	7,23 ±2,69^{b}	3,91 ±1,11^{d}	10,20 ±3,11^{a}	12,87 ±1,99^{ab}	65,80 ±5,67^{ab}

Notes: Different superscript letters in the same column indicate significant differences ($p < 0.05$).

Table 4. Amylose, Amylopectin, and Total Energy of Bafubar

Treatment	Amylose ±SD (%)	Amylopectin ±SD (%)	Total Energy (Cal)
P1	13.54 ±1.81^{e}	86.46 ±1.81^{e}	463.70 ±11,77
P2	9.07 ±0.73^{d}	90.93 ±0,73^{d}	500,68 ±11,23
P3	0,62 ±0,85^{a}	99,38 ±0,85^{a}	482,71 ±8,78
P4	0,70 ±0,60^{a}	99,30 ±0,60^{a}	475,07 ±7,29
P5	6,63 ±1,47^{c}	93,37 ±1,47^{c}	523,08 ±8,01
P6	4,87 ±1,30^{b}	95,13 ±1,30^{b}	562,60 ±3,73
P7	6,36 ±1,26^{c}	93,64 ±1,26^{c}	589,43 ±6,63
P8	5,34 ±1,49^{b}	94,66 ±1,49^{b}	585,74 ±13,03

Notes: Different superscript letters in the same column indicate significant differences ($p < 0.05$).

Glutinous white rice (P3) and glutinous black rice (P4) contained very low amylose (0.62 ± 0.85% and 0.70 ± 0.60%) and were dominated by amylopectin (>99%), yielding 482.41 ± 8.78 kcal and 475.07 ± 7.29 kcal, respectively.

The rice mixtures demonstrated intermediate values. A combination of glutinous white rice and white rice (P5) had 6.63 ±1.60% amylose, while glutinous white rice and red rice (P6) had 4.87 ±1.43%. The mixtures of glutinous black rice with white rice (P7) and red rice (P8) showed 6.36 ± 1.20% and 5.34 ± 1.49% amylose, respectively. The highest energy values were observed in P7 (589.43 ±6.63 kcal) and P8 (585.74 ±13.03 kcal).

4. Discussions

4.1. Hedonic Test

The color of the product was strongly influenced by the type of rice used. Formulations containing black glutinous rice (P4, P7, P8) tended to have a darker color due to the high anthocyanin content in the black rice pericarp. Anthocyanins are flavonoid pigments responsible for the purple to black coloration and are known for their strong antioxidant activity [16]. However, this darker color was not always preferred by panelists, who generally favored a more balanced color such as that observed in treatment P6 (a combination of white and red glutinous rice).

The aroma of the product was influenced by the presence of Cassiavera and morel berry extracts, which contain aromatic and antioxidant compounds such as physalin and characteristic volatile components. These extracts enriched the aroma profile and helped mask undesirable notes from the base ingredients. Moreover, morel berry contains chlorophyll and polyphenols, which further contributes to a more complex aroma [17].

In terms of taste, formulation P6 obtained the highest score. This may be attributed to the balance between the sticky texture provided by glutinous rice and the sweetness of stevia powder. The sticky texture creates a more pleasant mouthfeel, consistent with studies indicating that pigmented rice (red and black) combined with glutinous rice yields a more preferred texture compared to regular white rice [18]. Aftertaste was also better in P6 and P5, likely due to the herbal compounds in Cassiavera and morel berry extracts, which provide a light but distinctive residual flavor, enhancing sensory acceptance [17].

Beyond sensory quality, the combination of Cassiavera and morel berry improved the functional properties of the product. Both extracts exhibit high antioxidant activity, as demonstrated by radical scavenging assays in previous studies [19].

Bioactive compounds such as physalin in morel berry also act as potential antioxidant and anti-inflammatory agents. Thus, formulation P6 demonstrated optimal synergy between sensory quality (color, aroma, taste, texture, aftertaste) and functional benefits, making it a promising candidate for the development of Bafubar.

4.2. Physical Analysis

The physical properties of Bafubar were significantly influenced by rice type, which is consistent with starch chemistry theory. Rice starch is mainly composed of amylose and amylopectin, and their ratio determines elasticity, water/oil binding, and texture [20].

Black glutinous rice (P4) showed higher springiness, explained by its high amylopectin content. Amylopectin forms a branched structure that swells easily and provides elasticity, while high-amylose starch tends to form rigid gels [21].

White glutinous rice (P3) had the highest oil absorbency, likely due to its porous starch structure dominated by amylopectin. In contrast, white rice (P1), richer in amylose, absorbed the least because amylose molecules retrograde and form a compact gel, limiting oil penetration [22].

The greatest water absorbency occurred in P6 (white glutinous + red rice), reflecting a synergistic effect between starch and dietary fiber. Fibers in red rice enhance water-holding capacity by binding free water, while amylopectin provides porosity that facilitates hydration [20]. Conversely, P8 (black glutinous + red rice) had the lowest value, possibly because anthocyanins—abundant in pigmented rice—interfere with starch-water hydrogen bonding [23], [24].

Texture was also highest in P6, suggesting that starch–fiber interactions contribute to greater cohesiveness and elasticity. High-amylose starches, such as in white rice (P1), are known to form harder, less cohesive textures due to linear chain alignment and crystallization [21], [22].

Overall, these results confirm theoretical expectations: amylopectin promotes elasticity and water/oil binding, amylose restricts swelling and increases hardness, fiber enhances hydration, and anthocyanins may reduce starch–water interactions. Thus, blending rice types—especially P6—optimizes functional properties important for consumer acceptance.

4.3. Chemical Analysis

4.3.1. Proximate Analysis

The differences in moisture content are closely related to the ratio of amylose and amylopectin. Amylose, with its linear structure, tends to form compact gels that retain less water, whereas amylopectin, with its branched structure, more readily absorbs and retains water. During frying, starch undergoes gelatinization, and amylopectin plays a dominant role in water retention. This explains why P8 (a mixture of black glutinous and red rice) had the highest moisture content, while P1 (white rice, with higher amylose) had the lowest [25], [26], [27], [28], [29].

Ash content was highest in P8, indicating that black glutinous and red rice contain more minerals such as calcium, phosphorus, magnesium, and iron compared to white and glutinous white rice. This aligns with previous findings that pigmented rice varieties are generally richer in inorganic elements than non-pigmented ones [30], [31], [32], [33], [34].

The highest fat content was observed in P3 (black glutinous rice), which is known to have higher micro-lipid concentrations, especially in the aleurone layer and embryo. These lipids are largely composed of unsaturated fatty acids such as oleic and linoleic acids, which are beneficial for cardiovascular health. Additionally, fat content was influenced by oil absorbency during the frying process.

Protein content was highest in P4 (black glutinous rice). Rice protein mainly consists of albumin, globulin, prolamin, and glutelin, with glutelin being the major fraction. Glutelin not only contributes to the viscoelastic properties of cooked rice but also provides essential amino acids such as lysine and methionine, which enhance its nutritional quality.

Carbohydrate content was highest in P1 (white rice), reflecting its relatively higher amylose concentration. Amylose-rich rice tends to produce a drier, less sticky texture, while P8 had the lowest carbohydrate percentage because the dominance of amylopectin facilitated greater water absorption, thereby reducing carbohydrate proportion on a dry matter basis [29], [35].

Overall, these results demonstrate that the type of rice significantly affects the proximate composition of Bafubar. White rice (P1) is most suitable as a high-energy carbohydrate source, black glutinous rice (P3 and P4) contributes higher fat and protein, while the mixture of black glutinous and red rice (P8) provides higher moisture and mineral contents. These findings suggest that rice selection can be tailored to meet specific nutritional goals in the development of functional foods, highlighting the potential of pigmented and glutinous rice as alternatives to white rice in diversified diets.

4.3.2. Amylopectin, Amylose Content, and Total Energy

The variation in amylose and amylopectin content across rice types had a direct effect on both texture and energy contribution. White rice (P1), with the highest amylose level (13.54%), displayed a firmer, less sticky texture and the lowest energy value. In contrast, glutinous varieties (P3 and P4), almost entirely composed of amylopectin (>99%), were characterized by stickiness and higher energy availability. This is consistent with the role of amylopectin, whose branched structure facilitates faster enzymatic hydrolysis compared to amylose (Zhou et al., 2021).

Rice mixtures (P5–P8) showed intermediate starch compositions and energy values. Interestingly, the combinations involving glutinous black rice (P7 and P8) yielded the highest energy levels, suggesting that blending glutinous with non-glutinous rice provides a balance of texture while maximizing energy content. These results align with the biochemical properties of starch: amylose, due to its linear structure, is more resistant to enzymatic digestion, producing a slower glycemic response, whereas amylopectin is more rapidly digested, providing a quick energy source [36], [37].

From a nutritional standpoint, these findings emphasize that rice selection can be tailored to specific needs. Individuals requiring rapid energy release, such as athletes or those engaged in heavy labor, may benefit from glutinous rice or its mixtures, particularly P7 and P8. Conversely, diets requiring glycemic control may prioritize rice varieties with higher amylose content, such as white or red rice, due to their slower digestion rate and lower glycemic index [38], [39].

5. Conclusions

This study demonstrates that substituting rice varieties and fortifying them with cassiavera–morel berry extract and pumpkin seed flour can enhance the functional, chemical, and sensory quality of batiah. Rice variety has a significant impact on physical and chemical characteristics, as well as total energy, primarily through variations in amylose and amylopectin content.

The best formulation was obtained in P6 (a mixture of white glutinous rice and brown rice), which displayed a balance of organoleptic and nutritional quality, with a springiness value of 1.67 ± 0.60%, oil absorption of 6.95 ± 1.18%, ash content of 4.96 ± 0.90%, fat of 1.62 ± 0.80%, protein of 10.36 ± 1.49%, and carbohydrates of 69.46 ± 0.36%. This formulation was rated as the most preferred by the panelists and had a nutritional composition that supported health functions.

The developed Bafubar formulation demonstrates improved product quality, including enhanced nutritional composition, the incorporation of bioactive compounds, and the potential for a lower glycemic response. These modifications enhance the functional value of batiah while preserving its traditional identity, indicating that the selected formulation (P6) has strong potential as a functional snack for health-oriented consumers.

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