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Proximate Composition and Apparent Amylose Variation among Four Rice Varieties: Farro-66, Farro-67, Rok-34, Gawal-R1

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Abstract

This study evaluates the proximate composition and amylopectin content of four rice varieties (Farro-66, Farro-67, Rok-34, and Gawal-R1) relevant to Sierra Leone. Using laboratory analysis on processed paddy, the proximate analysis revealed high carbohydrate content ranging from 96.47% to 100%, protein 5.21% to 7.26%, fat 0.00% to 1.55%, ash 0.68% to 2.19%, and starch 75.73% to 100%. Our findings indicate variations in protein, fat, ash, and amylopectin. The results indicate that all varieties are high in carbohydrates, with Rok-34 showing the highest amylopectin concentration; however, there was no statistically significant difference (p-value 0.999) in amylopectin concentration among varieties, suggesting a stickier texture suitable for specific culinary uses. This study evaluates the proximate composition and amylopectin content of four rice varieties (Farro-66, Farro-67, Rok-34, and Gawal-R1) relevant to Sierra Leone. Using laboratory analysis on processed paddy, the authors report variations in protein, fat, ash, and amylopectin. The results indicate that all varieties are high in carbohydrates, with Rok-34 showing the highest amylopectin concentration, suggesting a stickier texture suitable for specific culinary uses.

Keywords

Rice Varieties, Proximate Composition, Amylopectin

1. Introduction

Rice (*Oryza sativa*) is the chief crop of the regular diet that is consumed in almost every household in Sierra Leone on a daily basis [1]. However, the consumption per capita is poorly correlated to domestic production, which means Sierra Leone depends on the importation of rice to meet its national consumption demand [2]. The annual consumption rate per capita is estimated to be 104 kg, putting the country in the sixth (6th) position in global ranking in terms of rice consumption [3]. Thus, the need to increase local productivity is necessary, and this can be achieved by adapting improved rice varieties with high yield, good physical properties, high nutritional content, etc. Cultivated rice belongs to the genus group Oryza, which includes 25 species [4]. The two cultivated species (one of African origin, *Oryza glaberrima*, and the other of Asian origin, *Oryza sativa*) are found today on all five continents [4].

The cultivation of rice is widely distributed in the tropics of the globe, and different varieties exhibit variations in their physicochemical properties, nutritional composition, and overall consumer acceptability [5] [6].

Rice, a staple food for over half of the world's population, is primarily produced in a few dominant countries [7]. According to [8], the 2024 global rice export forecast has been lowered by 3.4 million tons to 52.9 million, with India's exports reduced by 4.0 million tons to 19.0 million. This decrease for India was partly offset by increased export forecasts for Brazil, Pakistan, Russia, and Vietnam [8]. Additionally, import forecasts for several major importers in Asia and Sub-Saharan Africa have been reduced for both 2023 and 2024. China and India remain the world's leading rice producers, accounting for about 50% of global rice output [9]. However, these reductions in the global rice market are expected to influence prices negatively, with potential increases in rice prices affecting countries like Sierra Leone, which heavily depend on rice imports. As a result, the Sierra Leonean government is compelled to support local rice production to enhance self-sufficiency, stabilize prices, and protect food security amidst fluctuating international markets.

Nevertheless, the Sierra Leone government has taken several initiatives to boost rice production through the Feed Salon program, which includes:

- Farmers' Support Programs: Providing seeds, fertilizers, and tools to smallholder farmers to enhance productivity.
- National Rice Development Strategy: Implementing policies aimed at increasing domestically grown rice to achieve self-sufficiency.
- Agricultural Extension Services: Offering training and technical assistance to improve farming techniques.
- Land Reforms and Access: Promoting land reforms to ensure that farmers have access to suitable land for cultivation.
- Investment in Infrastructure: Developing irrigation systems, storage facilities, and roads to reduce post-harvest losses and improve market access.
- Public-Private Partnerships: Encouraging collaborations with private sector players to boost rice value chains.
- Promote research and innovation: provide funds to research and universities to embark on research and innovation, especially in the area of agriculture.

These efforts aim to reduce dependence on imports, stabilize prices, and ensure food security in the face of global market fluctuations [10].

The consumption of rice is not limited to just cooking with sauce, but rice can also be complementary in the preparation of other foods. However, the availability of information on the nutritional profile of these new varieties (Farro-66, Farro-67, Rok-34, and Gawal-R1) growing in different ecological regions is limited. Generally, these varieties were developed and distributed by the West Africa Rice Development Center (WARDA), now known as the Africa Rice Center (AfricaRice). These varieties are known for their high yield, disease resistance, and suitability for diverse agro-ecological zones. Sierra Leone is one of the beneficiary countries that accepted these varieties through the Africa Rice Center. Today, these varieties have shown a significant impact on food security and income generation in this nation. However, processing and preparation methods of this crop can hinder its nutritional content [11]. For example, the milling process of paddy can lower its mineral content due to the nonuniform distribution of nutrients in the different layers, especially the brown [12]. According to [13], milling processing can lower Zinc (Z) content in milled & polished rice (**Figure 1**).

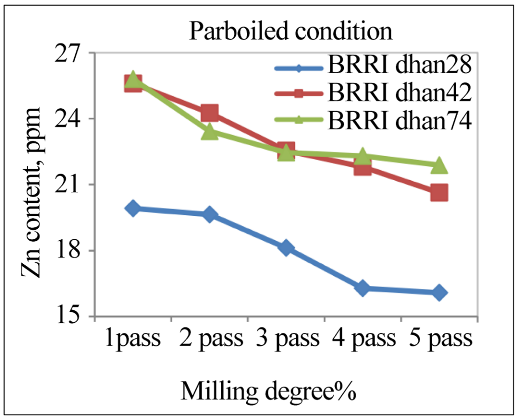

Figure 1. The image of the processing effect on Zn content in parboiled and non-parboiled rice [13].

Therefore, understanding the engineering properties and biochemical content of this crop, particularly in relation to handling, processing, storage, and nutritional content, is a key factor to consider [14].

Rice, as a staple food for many countries around the globe, especially Sierra Leone, provides a significant portion of the daily caloric intake and essential nutrients for millions of people worldwide [15]. It is a rich source of carbohydrates, with varying amounts of starch, which influence the cooking and eating qualities of different rice varieties [16]. Amylose and amylopectin are the two main components of rice starch, and their proportion significantly influences the cooking and eating quality as they affect its acceptance by consumers [17] [18]. Generally, amylose and amylopectin content in rice varies by variety, ranging from 0% to 30% for amylose and 70% to 100% for amylopectin [19]. Texture is defined as a multidimensional property, while the most commonly used parameters for cooked rice are hardness and stickiness. Several factors related to textural quality have been identified, including amylose content, unreachable amylopectin content, protein content, fat content, and the lengths of chains A and B in AP [20]. The leached amylose and short-chain AP during cooking are the main indicators of the hardness and stickiness of cooked rice [21]. The ratio of the leached amylopectin contributes to the hardness and stickiness of cooked rice [20]. The proportion of amylopectin in the leached starch significantly and positively influences overall eating quality, and it is reduced as the proportion of amylose in leached starch increases. Rice starches that are high in amylopectin are digested and absorbed more quickly than starches with a high amylose content and produce larger postprandial glucose and insulin responses.

Rice also contains essential vitamins, minerals, and bioactive compounds, such as vitamins A, B, and E, iron, zinc, and antioxidants, which contribute to human health and well-being [22]. Overall, one of the major challenges regarding improving productivity is the accessibility and availability of scientific information on the varieties of rice available in Sierra Leone. Thus, knowledge based on the chemical properties of rice varieties used across the nation, especially the improved varieties (Farro-66, Farro-67, Rok-34, and Gawal-R1), could be a key area of focus to address some of the challenges. Thus, the paper aims to understand the proximate and physicochemical properties and amylose & amylopectin of selected improved varieties of rice (Farro-66, Farro-67, Rok-34, Gawal-R1).

2. Research Materials and Methodology

The study was conducted at the Department of Agricultural Engineering, Njala University, situated on the Njala Campus, Sierra Leone. All laboratory work and data collection were performed at the Postharvest, Food and Bioprocessing Laboratory, a designated facility within the Department of Agricultural Engineering.

Materials used in this study were obtained from the departmental seed extension scheme, where tools and equipment [Rice paddy, Satake dehusking machine, Satake grain polisher, mortar and pestle, magnetic stirrer and hitting block, spectrophotometer (GENESYS 10S UV-VIS), volumetric flask, pipette, electronic weighing scale, electronic heater, Sieve (size 300 mm), measuring cylinder, test tube rack, Fourier Transform Near-Infrared and Raman spectroscopy (FT-NIR)] were obtained from the Postharvest, Food and Bioprocessing Laboratory.

Sample Collection: Five hundred grams (500 g) of each variety of rice paddy (Farro-66, Farro-67, Rok-34, and Gawal-R1) was sampled and temporarily stored in a polythene bag and properly tagged.

Sample Preparation: Upon receiving samples (rice paddy), a portion of each rice variety was cleaned to remove impurities and unfilled grains. Approximately four hundred grams (400 g) of rice paddy from each variety were dehusked using a SATAKE Dehusk Tester (Model: THU35B (3)-T, Thailand Co. Ltd), and five (5) passes were done for each sample with approximately six seconds per pass. The dehusked rice received after the fifth pass was polished using a SATAKE Grain Polisher (model: TM05c (2)-T) with a double pass for 30 seconds for each pass. A sample from the polished grains was ground to flour using a mortar and pestle; the target was to obtain 100 g of rice flour for each sample. The ground rice was sieved using Japsin Test Sieves, size 300 mm. The rice flour samples were stored in airtight containers and kept for further analysis.

Moisture Content: The moisture content of the rice paddy sample for each variety was determined according to [23].

Starch Quantification: This study quantified the starch content of rice samples using a (xxxx) spectrophotometer (GENESYS 10S UV-Vis), particularly through the formation of an iodine-starch complex, which can be measured at specific wavelengths. Sample preparation was done as described below.

Preparation of Starch for Analysis

- Step 1: Weigh 100.0 ± 2.0 mg flour.
- Step 2: Transfer into a 50 ml test tube.
- Step 3: Put a small magnetic stirrer into the tube.
- Step 4: Add 1 ml of 95% ethanol (EtOH) and disperse the contents.
- Step 5: Add 9 ml of 1N NaOH.
- Step 6: Stir at speed 5 (boil for 20 min and cool for 5 min); centrifuge at 300 RPM.
- Step 7: Transfer the entire content into a 100 ml volumetric flask (rinse the tube with 10 ml DI H_2O up to 5 times).
- Step 8: Dilute to volume with DI water and mix well.
- Step 9: Pipet a 0.5 ml aliquot into a disposable test tube.
- Step 10: Add 0.5 ml of water.
- Step 11: Add 0.1 ml 1 N acetic acid.
- Step 12: Add 0.25 ml of IKI solution (0.2% I2 in 2% KI) and 4.2 ml of DI H_2O.
- Step 13: Mix well and incubate at room temperature for 30 min.
- Step 14: Read absorbance at 620 nm.

Proximate Composition Analysis

The milled rice samples were used to determine proximate content by the Near Infrared Spectroscopy Method. The protein, crude fiber, carbohydrate, fat, and ash contents of rice flour were determined.

Data Analysis: The collected data were analyzed to identify any significant changes in the physicochemical properties of rice varieties, specifically regarding starch quantity and proximate content. The statistical analysis was conducted using Microsoft Excel 2019.

3. Results and Discussions

3.1. Result

3.1.1. Moisture Content of Rice Paddy

Figure 2 displays the moisture content of rice paddy measured on a dry basis. Moisture content represents the amount of water in a sample, which can be expressed on either a wet or dry basis (Christie *et al.*, 2014). It indicates that the moisture content (dry basis) among the rice varieties ranges from 9.7% to 7.9%. Farro-66 has the highest at 9.7%, followed by Rok-34 at 9.1%, while Gawal-R1 recorded the lowest at 7.9%.

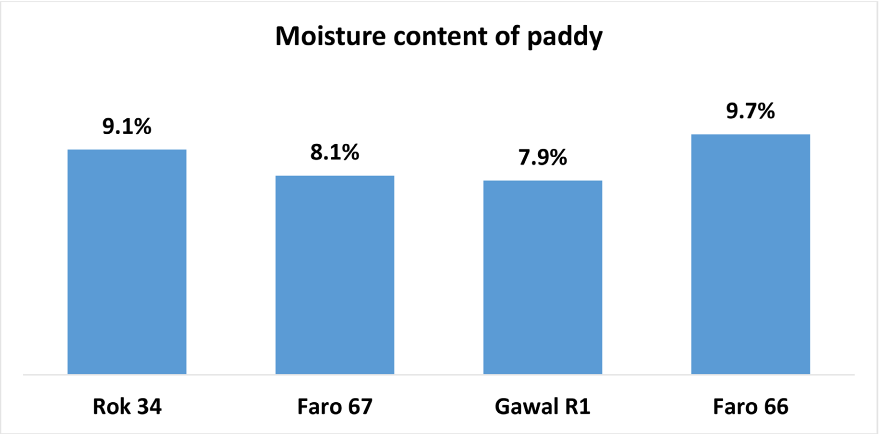

Figure 2. The result of the moisture content of rice paddy (dry basis).

3.1.2. Proximate Analysis of Rice Grains and Flour

Figure 3 shows the proximate analysis of four varieties of rice by the FT-NIRS method.

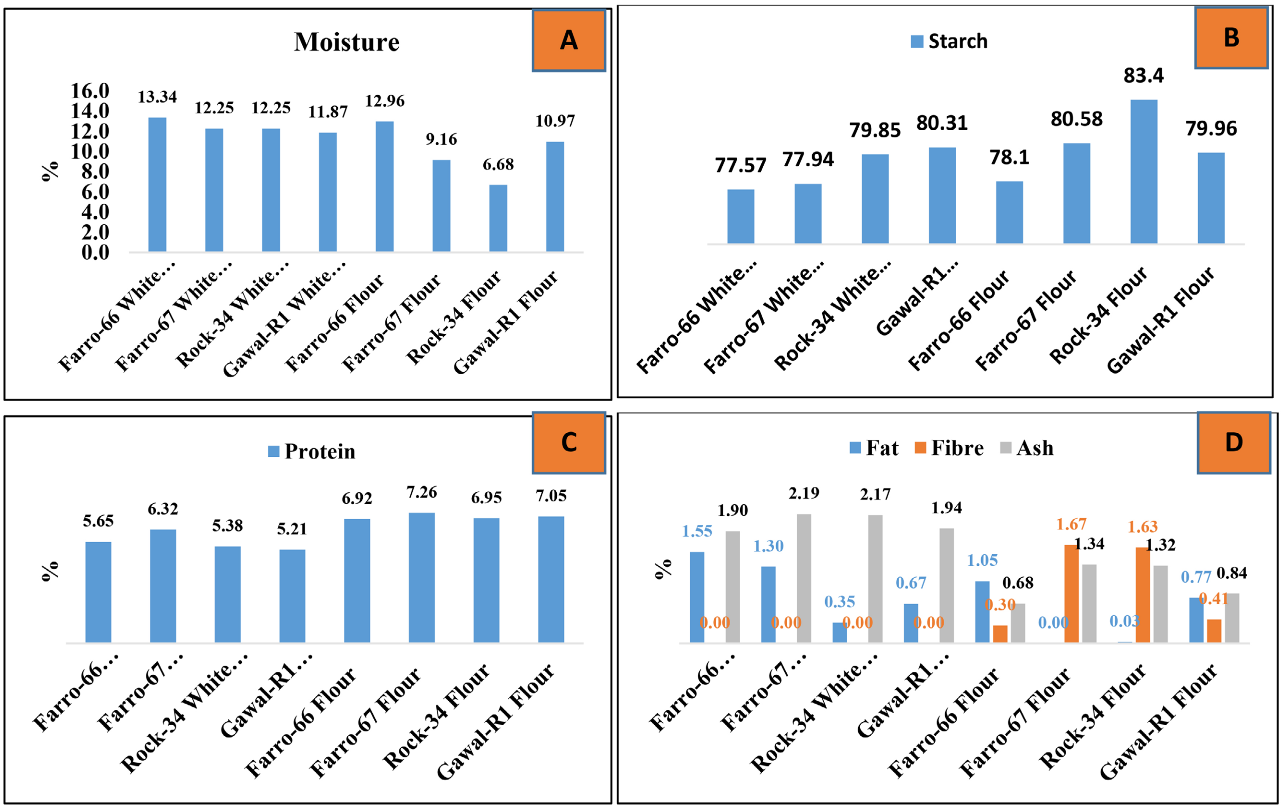

Figure 3. The proximate analysis of four varieties of rice used in this study.

The result in Figure 3 summarizes the proximate analyses of white grains and rice flour from the four rice varieties (Farro-66, Farro-67, Rok-34, and Gawal-R1), displayed in four graphs labeled A, B, C, and D.

Graph A presented Moisture Content by the FT-NIRS method: The moisture content of the white grains ranges from 11.87% (Gawal-R1) to 13.34% (Farro-66). For rice flour, moisture levels vary from 6.68% (Rok-34) to 12.96% (Farro-66).

Graph B: Starch content in the white grains is notably low compared with rice flour; however, Rok-34 recorded the highest starch content for rice flour (83.4%), and the lowest, 77.57%, was presented by Farro-66.

Graph C: Protein content in white grains ranges from 5.21% (Gawal-R1) to 6.32% (Farro-67). In rice flour, protein levels range from 6.92% (Farro-66) to 7.26% (Farro-67).

Graph D: Fat content in white grains is relatively low, with values ranging from 0.35% in Rok-34 to 1.55% in Farro-66. In rice flour, the fat content remains low, showing 0% in Farro-67 and peaking at 1.05% in Farro-66.

All four rice varieties had zero fiber content in their white grains, which underscores the need for additional fiber sources in diets relying on rice. However, rice flour shows some variation in fiber content, with values from 0.30% (Farro-66) to 1.67% (Farro-67), suggesting that processing may retain some fiber or enhance its availability in flour.

Additionally, the ash content, which reflects the mineral content of the rice, ranges from 1.90% to 2.19% in white grains and from 0.68% to 1.34% in rice flour. Farro-67 and Rock-34 obtained higher ash contents of 2.19 and 2.17, respectively.

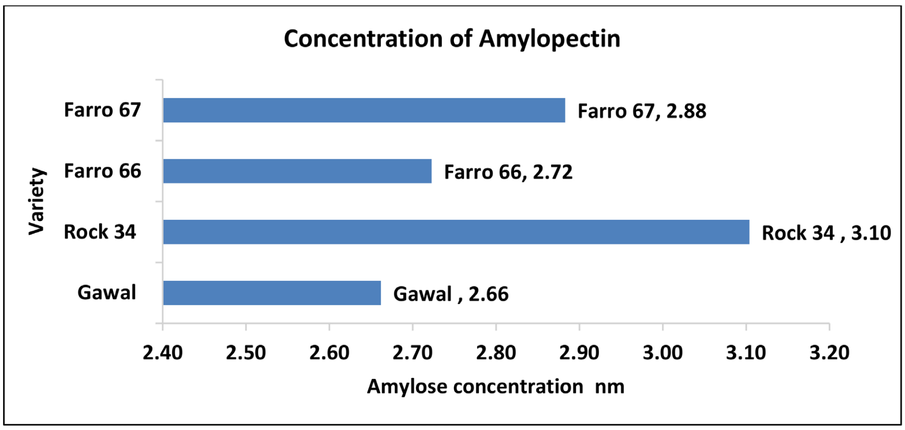

Figure 4. The concentration of amylopectin.

Results in Figure 4 show the amylopectin concentration of the rice varieties used in this study. The analysis shows that the amylopectin concentration ranged from 3.10 nm to 2.66 nm, where the highest concentration of amylopectin was obtained by Rok-34, and the lowest concentration was 2.66 nm (Gawal-R1). The value obtained for Rok-34 (3.10 nm) confirmed that Rok-34 starch may be of a higher percentage compared to the other varieties.

Figure 5 shows the standard curve of amylopectin concentration.

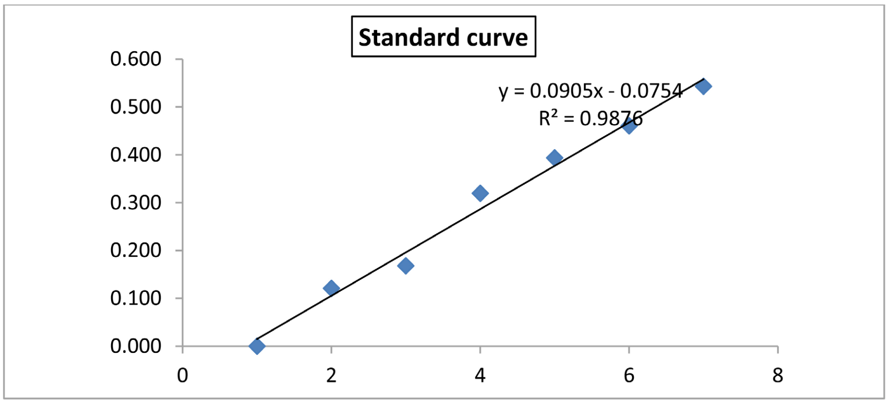

Figure 5. The standard curve of amylopectin concentration.

The result in Figure 5 presents a standard curve of amylopectin concentration computed from spectrophotometer absorbance. The linear graph displays the equation of the curve $y = 0.0905x - 0.0754$, with an R^2 value of 0.9876 for the rice variety used. From the graph in Figure 5, the linear equation function returns an R-squared value of 0.9876. This means that about 99% of the variability in amylopectin concentration is explained by spectrophotometer absorbance, suggesting that spectrophotometer absorbance is a good predictor of amylopectin concentration in the rice varieties used in this study.

3.2. Discussion

The moisture content is an important indicator of the rice's physical condition and the period for storage. Moisture content is typically expressed as a percentage of the weight of the dry seed. High moisture content can lead to spoilage during storage, increase the likelihood of mold growth, and facilitate the proliferation of pests [24]. In contrast, rice with lower moisture content is generally considered to have better storage stability [25]. It was observed that the oven moisture content of the paddy (Figure 2) was below the optimum moisture content for milling rice; however, the range provided (7.9% to 9.7%) for the varieties was good for grinding purposes. The result highlighted Farro-66 with the highest moisture content (9.7%), followed by Rok-34 at 9.1%. In comparison, Gawal-R1 has the lowest moisture content at 7.9%. This variation in moisture content among varieties can be attributed to several factors, including genetic traits, environmental conditions during storage, and post-harvest handling practices [26]. Higher moisture levels in Farro-66 and Rok-34 might indicate that these varieties are harvested or dried under less optimal conditions or that their physiological characteristics contribute to moisture retention.

Results shown in Figure 3 summarize the distribution of proximate composition for both white grains and rice flour for the varieties. The moisture content in **Figure 3(A)**, analyzed using FT-NIRS of the white grain, was absolutely within the optimum range for processing analysis, as was the rice flour.

From **Figure 3(B)**, it is observed that starch content is higher in rice flour compared with white grain for the four.

Each variety, and this may be due to the particle size distribution and homogenization of the layers of the grain, especially in fine particles. However, all the varieties' starch content is within the desired range (>70%) [27].

Hence, all the varieties can be considered to be a good source of carbohydrate. However, rice flour starch content ranged between 75.73% and 85.02% and was lower compared to white grain. Statistical analysis proved that there was a significant difference between white grain and rice flour at ($p > 0.05$).

Results of protein content (**Figure 3(C)**) for both white rice and flour ranged between 5.21% and 7.26%, with the Farro-67 variety having the highest protein value, followed by the Gawal-R1 and Rok-34 varieties. Statistical analysis shows that there is a significant difference between the means for protein content of white grain and rice flour (p-value = 0.016538) at a probability level of 0.05. The difference in protein content in the four varieties could be attributed to environmental conditions and genetic variations. The protein contents in this study are within the optimum range [27]. According to [27], higher protein content in flour will easily form bonds with greater starch content, thereby increasing the water-holding capacity of the flour.

The result of fat content implies that these rice varieties are not significant sources of fat, which is consistent with the low-fat profile characteristic of most rice. The absence of fiber content in white grains means there is a need for additional fiber sources in diets relying on rice. Farro-67 and Rock-34 presented higher ash content, indicating a richer mineral profile, which could offer additional health benefits.

Table 1. ANOVA analysis of moisture content for white grain and flour.

ANOVA: Single Factor						
SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
Moisture Content of White Grain	3	36.365	12.121 67	0.046 565		
Moisture Content of Flour	3	26.81	8.936 667	4.632 24		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F-crit**
Between Groups	15.216 34	1	15.216 34	6.504 37	0.063 281	7.708 647
Within Groups	9.357 608	4	2.339 402			
Total	24.573 95	5				

The result of amylopectin concentration, as indicated in Figure 4, shows that the Rok-34 variety has superior amylopectin concentration compared to the other varieties. This can also be explained by the fact that a high amylopectin concentration in Rok-34 means it has a low content of amylose. Generally, rice varieties with high amylopectin concentration have high starch content; therefore, cooking or branching will lead to gelatinous and sticky rice. On the other hand, Gawal-R1 and Farro-66 obtained low amylopectin concentrations (2.66 and 2.72). From the statistical analysis of amylopectin concentration at a p-value of 0.05, it was observed that there was no statistically significant difference between variations of amylopectin concentration. Also, Figure 4 clearly indicated that the method used to predict the amylopectin concentration was perfect, as the R-square obtained was 99%.

The ANOVA analysis of various factors is shown in Tables 1-4.

Table 2. ANOVA analysis of starch of grain and flour for the varieties.

ANOVA: Single Factor						
SUMMARY Starch for Grain and Flour						
Groups	**Count**	**Sum**	**Average**	**Variance**		
100	3	295.19	98.396 67	3.204 908		
85.0225	3	239.1325	79.710 83	12.63 129		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F-crit**
Between Groups	523.740 551	1	523.7406	66.144 73	0.001 243	7.708 647
Within Groups	31.672 395 83	4	7.918 099			
Total	555.412 946 9	5				

Table 3. ANOVA analysis of protein for grain and flour for the varieties.

ANOVA: Single Factor						
SUMMARY Protein for Grain and Flour						
Groups	**Count**	**Sum**	**Average**	**Variance**		
5.38	3	17.175	5.725	0.316 706		
6.9525	3	21.2225	7.074 167	0.029 765		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F-crit**
Between Groups	2.730 376	1	2.730 376	15.761 07	0.016 538	7.708 647
Within Groups	0.692 942	4	0.173 235			
Total	3.423 318	5				

Table 4. ANOVA analysis of concentration and absorbance for the varieties.

ANOVA: Single Factor						
SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
Gawal-R1	2	2.8274	1.4137	3.1160		
Rock-34	2	3.3094	1.6547	4.2003		
Farro-66	2	2.8937	1.4468	3.2555		
Farro-67	2	3.0684	1.5342	3.6379		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**p-value**	**F-crit**
Between Groups	0.0695	3	0.0232	0.0065	0.9992	6.5914
Within Groups	14.2096	4	3.5524			
Total	14.2791	7				

4. Conclusions

Overall, the analysis reveals distinct differences in the nutritional profiles of the four rice varieties investigated.

In conclusion, the study highlights that moisture content significantly influences the physical quality and storage stability of rice varieties, with values below the optimal range indicating good potential for grinding, although higher moisture in some varieties may reflect less optimal harvesting or drying conditions. The proximate composition analysis confirms that all varieties are rich sources of carbohydrates, with significant variations in protein, fat, ash, and amylopectin content influenced by genetic and environmental factors. Notably, Rok-34 exhibits the highest amylopectin concentration, indicating a sticky, gelatinous texture upon cooking, while lower amylopectin varieties like Gawal-R1 and Farro-66 may offer different culinary qualities. Overall, these findings suggest that the selected rice varieties possess diverse nutritional profiles and physicochemical characteristics, which can be leveraged for specific dietary needs or processing purposes, emphasizing the importance of appropriate post-harvest practices to optimize quality.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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