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Physicochemical and Biochemical Characteristics of Local Rice Variety (Sahel 108) Samples Grown in the Senegal River Valley

Bou Ndiaye[1,2,3,*], Oumar Ibn Khatab Cissé[1,2,4], Papa Guedel Faye[1,2], Abdou Diouf[5,6], El Hadji Moussa Diop[1,3], Samba Diop[8], Seyni Ndiaye[1,2], Alioune Sow[7], Nicolas C. M. Ayessou[1,2]

[1]Laboratory of Water Energy Environment and Industrial Processes (LE3PI), Higher Polytechnic, Cheikh Anta Diop University of Dakar (ESP-UCAD), Dakar 10700, Senegal.
[2]Center for Studies on Food Security and Functional Molecules (CESAM), ESP-UCAD, Dakar 10700, Senegal.
[3]Higher School of Industrial and Biological Engineering (ESGIB), Dakar 11000, Senegal.
[4]National School of Agriculture, Iba Der THIAM University, Thies, Senegal.
[5]Faculty of Science and Technology, Cheikh Anta Diop University of Dakar, Fann, Dakar 10700, Senegal.
[6]Institute of Food Technology (ITA), Hann, Dakar 10700, Senegal.
[7]Department of Agrifood Technologies, UFR of Agronomic Sciences, Aquaculture and Food Technologies (S2ATA), Saint-Louis 32000, Senegal.
[8]Professionnal Technical Education College (LTP-MXN), Mgr François Xavier Ndione, Thies, Senegal.

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Corresponding author: Bou Ndiaye, Laboratory of Water Energy Environment and Industrial Processes (LE3PI), Higher Polytechnic, Cheikh Anta Diop University of Dakar (ESP-UCAD), Dakar 10700, Senegal; Center for Studies on Food Security and Functional Molecules (CESAM), ESP-UCAD, Dakar 10700, Senegal; Higher School of Industrial and Biological Engineering (ESGIB), Dakar 11000, Senegal.

Abstract

Rice (*Oryza sativa* L.) is one of the most important cereals in the Senegalese diet. The Senegal River valley is a privileged area of rice cultivation where several varieties are grown, but their physicochemical and biochemical characteristics are very little known. The aim of this work is to encourage the consumption of the Sahel 108 variety grown in northern Senegal. The results show a moisture content between 10.28 and 11.85%, crude ash from 0.15 to 0.50%, lipids from 0.28 to 0.57%, and carbohydrates from 90.05 to 91.36% of dry matter. The starch content varies between 61.83 and 98.13% with a proportion of amylose ranging from 19.04 to 35.57% and cellulose content ranging from 0.37 to 0.67% of dry matter and an energy value that varies from 397.47 to 400.21 Kcal/100g. The evaluation of minerals in the dry sample reveals contents of iron, calcium, phosphorus, and magnesium varying respectively from 2.69 to 21.15 mg/100g; from 3.54 to 12.26 mg/100g; from 26.85 to 84.96 mg/100g, and from 14.12 to 25.39 mg/100g. The analysis of the granulometry made it possible to classify the studied samples of average breakage type with 80,78% retained by the sieve of mesh 1,70 mm. This study on the physicochemical and biochemical properties of the rice (Sahel 108) variety showed that it has a good nutrient composition, and its popularization in domestic trade would be important for the population.

Keywords

Rice (*Oryza sativa* L.) (Sahel 108); physicochemical and biochemical characteristics; Senegal River valley

1. Introduction

Agriculture is the backbone of the economy of developing countries. It contributes to feeding the population and occupies the major part of the working population, of which it employs 70% [1]. Food production is one of the most popular options for ensuring the food security of the population. Thus, cereals occupy an important place in the food habits of Africa, particularly in Senegal [2]. Rice is one of the most consumed cereals in the world [3]. In Asia, Africa, and South America, rice is the main source of energy, vitamins, and minerals [4, 5]. It has become a very strategic and priority product for food security in Africa. Its consumption is increasing faster than any other major commodity on the continent due to high population growth, rapid urbanization, and changing dietary habits [6]. Its annual consumption was estimated at 90kg per person [7, 8]. Nowadays, rice farming plays a dual role in Senegal's development. On the one hand, it generates significant farm income, and on the other hand, rice has become a staple food for both urban and rural households. It is an important part of the government's strategy to overcome food shortages and improve food self-sufficiency for local consumption and export. The rice crisis in 2008 and continuing demand have given visibility to the rice sector and increased investment in it. Thus, Senegal launched a National Rice Self-Sufficiency Program, which aimed to increase production from 215,000 tons in 2007 to 1.5 million tons of paddy rice in 2015. According to the National Agency of Statistics and Demography (ANSD) of Senegal, national rice production is estimated at 1,206,587 tons (735,518 tons for irrigated and 420,789 tons for rainfed) in 2018. A growth of 19% compared to 2017 (1,011,269 tons) and 56%, compared to the average of the last five (05) years [9]. Nevertheless, it was found that consumers give some preference to imported rice over locally produced rice [10]. Local rice is still slow to make a place for itself in the household basket despite numerous initiatives. Indeed, several varieties are grown in Senegal and have good yields per hectare. However, very few studies have focused on their physicochemical properties. The Sahel 108 variety is one of the most popular varieties. Several properties determine consumer choice of rice for food and non-food applications. It is with this in mind that this study is undertaken to investigate the physicochemical and biochemical characteristics of the local variety (Sahel 108) grown in the river valley to characterize the rice.

2. Materials and methods

2.1 Vegetable material

Ten sample of a local rice variety namely Sahel 108 were provided free of charge by rice farmer in the river valley located in different zones. These samples were de-hulled and then cleaned to remove the bran.

2.2 Methods

2.2.1 Granulometric analysis

The size of rice analysis is performed by measuring the mass in each sieve after passing a precise mass of sample through a series of superposed sieves of decreasing mesh. These sieves of mesh size 2mm; 1.7mm; 1mm; 0.85mm; and 0.5mm were superposed respectively. A test sample of 500g of rice was poured onto the top sieve. The clamping lid was adapted and the whole set was put under mechanical agitation for 5 min. Finally, the different fractions representing the refusals of each sieve are weighed as well as the contents of the collection bottom. This analysis will allow us to characterize the particle size of the grains. Grain with a diameter inferior to 2mm is whole rice, those whose diameter is between 2mm and 1.7mm are medium broken grain. Fine chipped grain and very fine chipped grain have diameter between 1.7mm and 1mm, and 1mm and 0 mm respectively.

2.2.2 Alkali test

This test gives an idea of the gelatinization temperature or starch birefringence disappearance temperature (TDBA) of rice varieties. It consists of assessing the resistance of the grain of rice placed in a dilute potash solution. Indeed, the rices with a low TDBA are completely dispersed, those with an intermediate TDBA are a little disintegrated, and finally those with a high TDBA are only swollen.

Six whole milled rice grains, free of chalky stains, are dispersed in a transparent kneading box and soaked with 10 ml of 1.7% potash. The covered box is placed in an oven at 30°C for 23 hours. According to the state in which the rice seed is presented, at the exit of the oven, a note is given from 1 to 7 in accordance with a data sheet that shows the image of the grains corresponding to each note. Par rapport aux notes les appréciations:1 (Grain intact), 2 (Swollen grain), 3 (Swollen grain with a beginning halo), 4 (Swollen grain with formed halo), 5 (Split or broken grain + large halo), 6 (Scattered grain without transition to the halo), 7 (Grain totally dispersed).

The gelatinization temperature is classified according to the grade given to the behavior of the seed when it leaves the oven (high, intermediate, and low gelatinization temperature). Elle est noté de 1 à 6. Elle est dite high pour la note comprise entre 1et 2, high/intermediate pour 3, intermediate pour 4-5 et low pour 6.

2.2.3 Determination of major components

A mass of 5g of previously ground sample was weighed and put in the oven at 105°C for 4 hours. Then the capsule was cooled in a desiccator and weighed.

The ash is determined by incinerating 3 g of the sample placed in a crucible using a furnace at 550°C following the AOAC method (1995). The mineral elements were evaluated using an atomic absorption spectrophotometer (AAS).

The protein content was determined by the Kjeldahl method. Fat content is evaluated by the soxhlet extraction method. The carbohydrate content is obtained by the difference between the dry matter content and the sum of the protein, fat and crude ash contents. The energy value is calculated using the ATWATER coefficients assigned to proteins, carbohydrates, and fats, which are 4Kcal, 4Kcal, and 9Kcal respectively.

Starch is determined by the luff-school method. A mass of 1g was weighed into an Erlenmeyer flask with 50 mL of distilled water. The solution was chilled for 20 min and then filtered with a filter paper. The residue obtained was hydrolyzed for 2 hours in the presence of glass beads. The cooled solution was neutralized with sodium hydroxide solution in the presence of phenolphthalein and then decolorized with a few drops of acid. A volume of 5ml of Luff Shoorl reagent is added to the hydrolysate in the balon adapted to the refrigerator for 5mn then cooled, then 3mL of KI (30%), 3ml of H_2SO_4 (6N) are poured. The obtained solution is titrated with 0.1N thiosulfate in the presence of starch starch. The blank is made under the same conditions (5mL of distilled water)

Calculations

% Starch = $\frac{n\,x250x100x0{,}95}{W\,x\,5x\,1000}$

n =Vb - Vsample and reads the value of n on the table that corresponds to this difference .

Vb is the volume of blank poured and Vsample is the volume of sample poured.

W: weight of sample

Amylose principe determination consists in grinding the rice into fine particles to destroy the crystallinity of the starch, in order to have a complete dispersion. A weight of 20 mg delipided ground sample is placed in a 100 ml volumetric flask. Then 1 ml of ethanol is added to the sample. Then a volume of 9 ml of sodium hydroxide is added and left to stand at room temperature for 24 h. After this step, the solution is made up to the mark with distilled water and homogenized vigorously. A blank test is carried out in parallel following the same procedure. A calibration curve is made by using standard solutions of amylose. From this aliquot, a solution of acetic acid and iodine solution is added and the absorbance of the colored complex formed is measured with a spectrophotometer at 620nm.

Crude cellulose was obtained by calcination of the dry residue from digestion of the sample with an acidic solution and a basic solution under special conditions. A mass of 0.2 g of previously powder sample was digested in 50 mL H_2SO_4 (0.30N) in the presence of a drop of defoamer. The whole is heated until boiling for 30 min and gently stirred every 5 min avoiding that the material adheres to the flask wall. A volume of 25ml of NaOH (1.5N) was added and the whole is heated again for 25 min, a pinch of lye was added to the fire for 5mn before filtering in a filter crucible with pore size 2. The residue is washed respectively with 25ml H_2SO_4 (0.30N), then with 3 portions of 50ml distilled water then washed respectively with 25ml ethanol and finally 25ml acetone. After washing the residue is dried in an oven at 130°C for two hours then cooled in a desiccator and finally incinerated at 400°C for two hours. The cellulose content is determined according to the following formula:

Cellulose content (%)= $\frac{M_1-M_2}{M}x100$

M_1: mass of the crucible plus material after drying

M_2: mass of the crucible plus material after incineration

M: mass of the sample

2.2.4 Statistical data processing

The analysis of variance (ANOVA) was performed using XLSTAT 6.1.9. The level of significance of the results is taken at the probability $p<0.05$.

3. Results and discussion

3.1 Physicochemical characterization

The commercial values of milled rice also depend on its physical characteristics. These are of fundamental importance for the design, sizing, manufacture, and operation of the various equipment used in post-harvest processing.

3.1.1 Particle size analysis

Rice quality can be influenced by the macroscopic characteristics of the raw grains. The results obtained on grain size measurement are presented in Table 1.

The particle size analysis shows some heterogeneity in the rice grains in each sample. For the 2mm diameter sieve, the percentages of rice retained by mass vary between 3.47 and 58.58% with an average of 30.6%. For the 1.70mm mesh sieve, the percentages of rice retained ranged from 21.44 to 76.52% with an average of 50.12. For the 1mm diameter sieves, the percentages vary between 5.93 and 21.94% with an average of 14.90%. The sieves of diameter 0.85 and 0.5mm retain between 0.06 and 0.98% and between and 0.1 and 0.85% respectively. Their averages are respectively between 0.41 and 0.23%. However, a very small amount of dust was noted in the bottom. These results make it possible to classify into different types of breakage. Thus, Sahel 108 sample rice is predominantly composed of large and medium-sized particles.

Table 1. Particle size characterization of rice samples

Samples	Diameter size 2mm	1.70mm	1mm	0.850mm	0.5mm	Fond
	%					
Samples 1	5	72.7	20.56	0.86	0.85	0.016
Samples 2	52.49	40.16	7.14	0.044	0.01	0.01
Samples 3	57.70	38.15	5.93	0.076	0.08	0.016
Samples 4	56.58	34.28	8.96	0.06	0.012	0.001
Samples 5	21.44	58.2	19.42	0.42	0.28	0.001
Samples 6	21.45	21.44	19.42	0.42	0.28	0.026
Samples 5	44.27	43.48	14.77	0.18	0.13	0.0024
Samples 8	3.47	76.52	19.53	0.99	0.11	0.02
Samples 9	44.25	43.48	11.99	0.15	0.074	0.001
Samples 10	4.13	72.83	21.94	0.98	0.53	0.054
Mean value	30.66	50.12	14.90	0.41	0.23	0.015
Results	Large chips	Medium chips	Fine chips	Very fine chips	Fragments	Dust

3.1.2 Alkali test

The aspects of the grains are defined using the alkali test according to the gelatinization temperature. Based on the temperature of gelatinization, rice can be classified into three types: low-temperature gelatinization (55-69ºC), medium-temperature gelatinization (70-74ºC), and high-temperature gelatinization (>74ºC). Alkali test results showed low 55, high, and intermediate starch birefringence disappearance temperatures (TDBA). The TDBA is 69ºC, the average for which 90% of the grains are gelatinized. Indeed, this is the temperature range in which the starch grains start to swell irreversibly in hot water while losing their birefringence in polarized light. The results show overall a high gelatinization temperature and thus a better resistance in their grains but we have intermediate temperatures that show a slight disintegration (Table 2). The gelatinization temperature associated with the cooking time of the rice showed that higher gelatinization temperatures increase the cooking time of the rice. Rice with a low gelatinization temperature absorbs water and expands at a lower temperature than rice with a high gelatinization temperature. The gelatinization temperature is influenced by the characteristics of the granules and the presence of protein, fat, and sugar. High-protein rice will require more water and more cooking time.

Table 2. Results of the alcali test

Samples	Score	Description	Gelatinization temperature characteristics
Samples 1	3	Swollen grains and the beginning of aureole	High/intermediate
Samples 2	4	Swollen grains and well-formed halo	intermediate
Samples 3	3	Swollen grains and the beginning of the halo	High/ intermediate
Samples 4	5	Fen or broken grains and large halo	intermediate
Samples 5	6	Scattered grains without transition with the halo	Low
Samples 6	2	Swollen grains	High
Samples 5	2	Swollen grains	High
Samples 8	1	Intact grains	High
Samples 9	5	Split or broken grains and large halo	Intermediate
Samples 10	1	Intact grains	High

3.2 Biochemical characteristics

Rice contains a number of nutrients, the levels of which differ according to variety and the different fractions after milling. The contents of the major components are given in Table 3.

Table 3. Biochemical characteristics of the selected sample

Samples	Moisture %	Proteins %DM	Total sugar %DM	Cellulose %DM	Lipids %DM	Starch %DM	Amylose %DM	Energetic value (Kcal)
S1	11.43 ^{a}	8.21^{a}	90.63 ^{a}	0.56 ^{a}	0.385^{ab}	61.83^{ab}	ND	398.785^{bc}
S2	11.05 ^{a}	7.81 ^{a}	90.89 ^{a}	0.52 ^{a}	0.371^{ab}	98.13^{e}	19.88^{b}	398.125^{b}
S3	10.47	7.92 ^{a}	91.11 ^{a}	0.39 ^{a}	0.30^{ab}	65.06^{bc}	26.62^{f}	398.815^{bc}
S4	11.64 ^{a}	8.05 ^{a}	90.05 ^{a}	0.67 ^{a}	0.30^{ab}	72.43^{d}	21.20^{cd}	396.145^{a}
S5	10.63 ^{a}	7.91 ^{a}	90.69 ^{a}	0.41 ^{a}	0.44^{ab}	65.0^{bc}	35.57^{g}	398.345^{b}
S6	10.66 ^{a}	8.03 ^{a}	90.97 ^{a}	0.38 ^{a}	0.31^{ab}	70.28^{cd}	20.07^{bc}	398.79^{bc}
S7	10.28 ^{a}	8.32 ^{a}	90,4 ^{a}	0.49 ^{a}	0.39^{ab}	65.86^{bc}	19.04^{b}	398.305^{b}
S8	11.37 ^{a}	7.67 ^{a}	91.31 ^{a}	0.37^{a}	0.28^{a}	68.16^{cd}	27.67^{f}	397.47^{ab}
S9	11.85 ^{a}	8.48 ^{a}	90.23^{a}	0.51 ^{a}	0.57^{b}	67.20^{bcd}	21.71^{d}	400.21^{c}
S10	11.01 ^{a}	7.81 ^{a}	91.05 ^{a}	0.4 ^{a}	0.31^{ab}	58.25^{a}	24.45^{e}	398.14^{b}
Mean value	11.04±043	8.02±0,20	90.74±0,33	0.47±0.08	0.36±0.06	62,295±0.06	24,022±4.047	398.31±0.68

Note. *Different letters or groups of letters on the same line are statistically different (P<0,05).

3.2.1 Moisture content

Moisture content affects the quality and palatability of rice grains. It plays an important role in determining the shelf life and also the market value of the rice. Analyses reveal a moisture content varying between 10.28 and 11.85% (Table 3), values observed respectively for samples Ech5 and Ech9. The average value was estimated at 11.04%. The analysis of variance shows that there is no significant difference (P>0.05) between the samples. These contents are lower than those observed by Olalekan et al. [11] where contents obtained varied between 13.04 and 13.94%. The moisture content is below the acceptable limit for long-term storage of rice [12]. This moisture condition is a favorable asset for storage.

3.2.2 Lipid content

Rice is known for its low-fat content. It varies between 0.28 and 0.57% (Table 3). These contents are observed in samples S8 and S9 respectively. The average fat value is 0.36%. These results are close to the lipid contents observed in the Thai and local rice varieties studied by Ogbuonye Edith (2017), [13], which have contents ranging respectively from 0.22 to 0.32%. Similar results were found by Cornejo and Rosell (2015) [14]. However, they are lower than those obtained in the work of Oko et al. (2012) [15], where the average was 1.90%, and in the unparboiled pady rice studied by Sadji et al., (2016) [12] where the content was 1.6%. The analysis of variance reveals that only the contents of samples S8 and S9 are statistically different (p<0.5) between them and between the other samples. These low levels could be due to the degree of milling during post-harvest operations. Most of the fat in rice is concentrated in the aleurone layer of the grain.

3.2.3 Protein content

The protein content of the samples varies between 7.67 and 8.48% (S8 and S9) with an average of 8.021% (Table 3). The obtained contents are higher than those observed by Oko and Ugwu (2011) [15], in their study on five Nigerian varieties where contents varied between 1.58 and 4.84%. The protein contents are also higher than those of Chinese varieties studied by He et al. (2021) and ranging from 4.03% to 6.99% [16]. However, these results are similar to those of Fabiola and Cristina (2021) [14] and of germplasm rice varieties studied by Masniawati et al. [17], ranging from 7.4 to 8.5%. Analysis of variance shows that protein contents are statistically identical (P>0.05) in all samples. Proteins are naturally found in all parts of the seed. They are mainly found in the bran and germ, but a small proportion is also found in the albumen. The study reveals that soil and climatic factors are not influential on the protein content of the samples studied. It could be deduced from these results that the growing sites seem to have the same environment. Nevertheless, it is known in advance that environmental factors are determinants in the composition of rice. The protein content of milled rice is strongly influenced by the degree of rice milling and the soil conditions in which the rice is grown [17].

3.2.4 Total carbohydrate, starch, cellulose, and energy content

Total carbohydrates in rice are mainly composed of starch. The samples analyzed had high carbohydrate contents ranging from 90.05 to 91.31% (S4 and S8) of dry matter with an average of 90.74% (Table 3). These contents are higher than those of local Ghanaian varieties found in the work of Fautina et *al*, (2017) [18], which vary from 74.27 and 79.41% and those found in the work of Adékola et al. [3]. The analysis of variance shows no significant difference (P>0.05). The energy value of the analyzed samples ranged from 398.35 to 400.21 kcal/100g. These values are slightly higher than those obtained in Ethiopian varieties, ranging from 365.35 to 376.92 kcal/100g [19].

The cellulose content is between 0.37 and 0.67% respectively in samples S8 and S4 (Table 3). The analysis of variance shows a non-significant difference (P>0.05) between samples. Starch is the major component of rice that mainly determines its physicochemical and culinary properties. Its content may depend on certain soil and climatic factors, but also on genetic factors. Analysis of starch content shows a variation between 58.25 and 98.13% of the total carbohydrate mass. The average value is 62.92 ±6.63%. These contents are in the order of variation on the samples Only samples S3, S5, and S7 show statistically identical contents (P>0.05). The same is observed for samples S6 and S8.

The amylose content ranges from 19.04 to 35.57% (Table 3). The maximum value is observed in sample S5). The analysis of variance shows a statistically significant difference between samples. These values are higher than those obtained by Masniawati et al. [17], which range from 2 to 18%. The average amylose content is close to that observed in the work of Anugrahati et al. [20] and corroborates the results of Mbodj et al. [8]. Sensory characteristics, such as texture, color, and volume increase depend on the amylose content. Rice is classified according to amylose content: very low (2-12%), low (12-20%), medium (20-25%), and high (25-33%) rice [21]. According to this classification, the samples belong to the medium and high rice classes.

3.2.5 Ash and mineral element content

The crude ash content of the rice samples studied varied from 0.15 to 0.55%. Its average value is 0.35% (Table 4). The analysis of variance shows that samples S2, S4, S8, and S10 have statistically identical ash contents (P>0.05). The ash contents in samples are lower than those obtained in Ethiopian varieties, varying between 0.62 and 1.63% [19]. This average ash value is lower than those observed in the work of Oko and Ugwu [15] and Olalekan et al. [11] which ranged from 1.40 to 1.69%. However, these results corroborate those reported by Ogbuonye Edith [13]. This difference could be explained by the effect of abrasion which removes the outermost layer of the rice.

The mineral element contents are established in Table 4. They vary from 2.69 (S2) to 21.15 mg/100g (S5) for iron; from 3.54 (S7) to 12.26 mg/100g (S2) for calcium; from 26.85 (S2) to 84.96 mg/100g (S4) for potassium and from 14.12 (S7) to 25.39 mg/100g (S1) for magnesium (Table 4). Potassium remains the most important mineral element followed by magnesium. The average contents are respectively 8.01; 7.92; 43.78 and 21.3 mg/100g for iron, calcium, potassium, and magnesium. The analysis of variance shows that the calcium contents are statistically no significant (P>0.05) between samples 1, 2, and 4; between samples 8 and 10, and samples 6 and 9. The difference is statistically insignificant (P>0.05) between samples 3 and 6; 5 and 10 for the potassium content. A comparison of the nutritional value of the 10 local rice samples (Sahel 108) showed variability in mineral content.

Table 4. Mineral concentration of rice sample

Samples	Ash content %	Fe	Ca	K	Mg
		mg/100g			
S1	0.24^{ab}	3.42^{a}	11.35^{e}	56.23^{f}	25.39^{fg}
S2	0.41^{bc}	2.69^{a}	12.26^{e}	26.85^{a}	22.39^{de}
S3	0.28^{ab}	3.34^{a}	7.91^{c}	36.42^{c}	22.26^{de}
S4	0.48^{bc}	6.64^{c}	11.67^{e}	84.96^{g}	17.81^{bc}
S5	0.55^{c}	21.15^{f}	5.04^{b}	39.98^{d}	20.05^{cd}
S6	0.31^{abc}	2.75^{a}	4.185^{ab}	36.40^{c}	16.39^{ab}
S7	0.41^{bc}	11.72^{de}	3.54^{a}	48.31^{e}	14.12^{a}
S8	0.24^{ab}	12.63^{e}	9.15^{d}	30.13^{b}	22.35^{de}
S9	0.15^{a}	11.38^{d}	4.45^{ab}	38.36^{cd}	28.30^{g}
S10	0.44^{bc}	4.83^{b}	9.28^{d}	40.24^{d}	24.09^{ef}
Mean value	0.35±0.11	8.06±4.93	7.88±2.86	43.79±11.63	21.32±3.38

Note. Different letters or groups of letters on the same line are statistically different (P<0.05).

Indeed, the variation in biochemical constituents of the studied rice samples could be related to several factors such as the nature of the variety, the degree of milling, and the storage condition [22, 23]. The degree of milling and the nature of the soil could have a considerable influence on the mineral content of rice grains. The degree of milling is involved because minerals are concentrated in the outer layers of the cargo rice or in the bran fraction. Ash and cellulose content correlate with the degree of milling. The location of mineral elements in the aleurone layer leads to a loss of these elements during milling. The technological transformation then influences the contents of mineral elements. Also, the difference in milling methods and equipment could explain this variation in nutrient composition in these different rice samples.

4. Conclusion

This study on the characterization of local Sahel 108 rice shows that it has interesting physicochemical and biochemical characteristics. Its popularization in the national market could allow the population to benefit from its nutritional properties. The sampling carried out shows that the samples do not differ significantly in their biochemical composition. The pedoclimatic conditions would seem identical. In the future, it would be interesting to study the techno-functional properties of Sahel 108 rice.

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