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Nutritive Compounds of Traditional Rainfed Rice (*Oryza glaberrima*) from Goh-Djiboua and Mountains Districts in Côte d'Ivoire

Aka Boigny Ange Aurèle [a], Biego Godi Henri [a], Konan N'Guessan Ysidor [b*] and Amadou Moustapha Beye [c]

[a] *Laboratory of Biochemistry and Food Science, Training and Research Unit of Biosciences, Felix Houphouet-Boigny University, 22 P.O. Box 582, Abidjan, Côte d'Ivoire.*
[b] *Training and Research Unit of Biological Sciences, Peleforo Gon Coulibaly University, P.O. Box 1328, Korhogo, Côte d'Ivoire.*
[c] *Africa Rice Company, P.O. Box, 4029, Abidjan, Côte d'Ivoire.*

Authors' contributions

This work was carried out in collaboration among all authors. Author ABAA designed the study, wrote the protocol, performed the laboratory analyzes and wrote the first draft of the manuscript. Authors BGH and AMB managed the study design and the literature and supervised the data recovery and interpretations. Author KNY performed the statistical analysis of the data, checked the first draft of the manuscript and worked the submission version of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The biochemical composition of rainfed rice (Oryza glaberrima) consumed in Côte d'Ivoire has not yet been revealed, whereas rice is of the main staple foods for many people. This work investigates the main biochemical traits of numerous traditional rainfed rice varieties from Ivorian environment, namely in Gôh-Djiboua and Mountains Districts, for better valorization.

**Corresponding author: E-mail: haizykonan@yahoo.fr;*

Study Design: Study performed on traditional rainfed rice varieties collected from 450 farmers in both regional Districts mentioned above. Shelled rice perceived per variety, conditioned, and total final 5.4 kg of resulted rice considered, 200g per variety, for due laboratory investigation.
Place and Duration of Study: Sampling between January and June 2017, full analysis by 2018 in Laboratory of Food Sciences, Felix Houphouët- Boigny University.
Methodology: All rice samples conveyed to laboratory, then 100g taken per variety, oven-dried at 50 °C/72 h, ground in metallic grinder, sealed into polyethylene bags, and kept into desiccator till analyses. Investigations consisted in triplicate evaluation of moisture, carbohydrates (total glucides, starch, soluble carbohydrates, reducing carbohydrates), fats, proteins, caloric energy, fibres, and ash by rice sample.
Results: Great variability (P<.001) recorded between rive samples for biochemical traits assessed. Thus, the variety Jbröko represents the most important source of glucides (84.19±0.37g/ 100 g) and caloric energy (322.17±0.37kcal/ 100 g) compared to the other varieties. Oppositely, the variety Yoroukouiagnêzê recorded the highest proteins content (7.27±0.03 g/100g), whereas Abê provides more food fibres (6.67±0.14g/ 100g). Otherwise, the variety Danané belating is richer in free soluble sugars (4.63±0.08 g/100 g), while Azi red displayed more moisture content (10.96±0.1%) and Gbêklêazi is richer in lipids with content of 1.26±0.21g/ 100g. The top ash and starch contents were respectively recovered from varieties Zonhonkloumin black (1.38±0.02 g/100 g) and Abê (71.99±0.03g/ 100g).
Conclusion: The studied rainfed rice record good nutritive traits above the widespread improved rice varieties. They remain significant caloric food resources thanks to considerable contents in glucides (varieties Abê, Akita, Jbröko, No-No-No, and Danané I), proteins, lipids, and significant amount of food fibre (varieties Boumabou, Glawlon, Dikouè, Loêgnini, and Danané fowl) and minerals. This nutritive composition could permit their quite usages for consumers and researchers, even though other investigations on the functional nutritional compounds should be performed.

Keywords: Traditional rainfed rice; nutritive components; small scale farming; Côte d’Ivoire.

1. INTRODUCTION

Rice is of important nutritive and economic interests for the food consumption in urban and rural households. It has become a staple and strategic commodity for much of the world's population [1,2]. The rice industry is one of the key sectors for the food services over Africa, with a consumption amount around 60 kg per capita.

In Côte d’Ivoire, rice is a great deal for the daily food consumption by populations. Unfortunately, this culture is still restrained by many factors as the ignorance in the quality of the local varieties and the lack of their popularization resulting from suspicious lower nutritional value [3]. Indeed, the top ratio of local rice production results from the traditional rice varieties or African rice (*Oryza glaberrima*) and is essentially intended to the home consumption. Facing the raising needs estimated to 1.3 million tons of rice in 2019, this local production remains insufficient [4]. Consequently, significant rice volume imports are yearly casted from whitened rice processed from improved varieties [5]. The traditional rice varieties are rural varieties, deriving from old cultivars and hold by farmers following local food and nutritional customs [6]. According to authors, the local traditional rice varieties are of significant resistance potentials useful for the crop improvement programs in Africa [7,8]. These varieties constitute genebank conferring various resistances against the plant diseases [9,10], the bugs [11], and the abiotic stress as climatic changes [12,13], ferrous toxicity, and soil saltiness [14]. They are often related to the history of numerous local people, dealing with their food preferences and particular needs regarding nutritional, health, cultural, and spiritual interests, especially by the production regions [15,6]. The traditional cultivars of African rice are thus important raw product for food healthy, social well-being, and sustainable growth in countries. They should be more investigated, improved, and promoted for succeeding in a large-scale production over the sub-Saharan African countries seeking for food sovereignty. The rice involvement in the global consumption is especially aheading from the food secure-less households, namely in urban surroundings [16]. However, fewer works focused the nutritional trends of the African rice except the gene aspects for developing improved varieties with better resistance and production yield [8,17,18].

Rice is generally consumed as caloric food with a predominance in glucides. The rice starch is the main energy interest and is highly digestive. So, this cereal is often ground and used as additive for infantile foods [19]. According to Frei and Becker [20] and Montecinos et al. [21], numerous local rice varieties are also great raw sources of food nutrients as vitamins (thiamine, niacin, riboflavin, vitamin D), minerals (iron and calcium), and food fibres. Besides, rice displays only minute rates in fat and food salt. In the main strategies aiming the food safety and the policies of valorization of the local products having sociocultural and nutritional importance, the traditional rainfed rice or African rice could be used as fortification product or healthy food. The spreading of this rice always requires a deepening control of its nutritional potentialities. The current study assesses the main biochemical traits of the most widespread traditional rainfed rice cultivars of Côte d'Ivoire for sustaining their valorization.

2. MATERIALS AND METHODS

2.1. Plant Material

The plant material was constituted of rainfed rice grains deriving from 27 traditional varieties (Table 1) and collected between January and June 2017 in the western Côte d'Ivoire, namely in departments of Gagnoa and Danané from respective regions of Gôh and Tonkpi.

2.2 Sampling

Samples of the 27 traditional rainfed rice varieties were collected from 450 farmers in both Districts visited and from the Africa Rice centre. Amounts of 200 g of shelled rice were perceived per variety, conditioned and labelled, leading to a total sampling of 5.4 kg of traditional rice. The full rice volume was then conveyed to laboratory for analysis. Thus, 100 g were taken per rice variety and dried at 50 °C for 72 h in an oven (Memmert, Germany). The dried rice samples were then ground using a metallic grinder (Heavy Duty), sealed into polyethylene bags and kept in desiccator till analyses.

2.3. Determination of the Nutritive Components

The biochemical assessment was about the determination of the residual moisture of the rice samples and their main contents in proteins, fat, glucides (total soluble carbohydrates, reducing carbohydrates, starch, and total glucides), fibres, total polyphenols, and the caloric energy value. The analyses were performed using standard AOAC methods [22].

The moisture was estimated from 10 g of ground rice dried into an oven (Memmert, Germany) at 105 °C till constant weight.

The ash content was assessed from incineration of 5 g of ground rice at 550 ° C for 12 h in a muffle furnace (Pyrolabo, France) allowing the full destruction of the organic matter. The ashes were then cooled into desiccator, weighed on a three digits scale, and the resulted ash contents were determined using the following formula:

Ash Content (g/100 g) = W1 * 100 / W0

W0, weight of the raw rice sample (10 g); W1, weight of the ash.

Proteins were measured by quantification of the total nitrogen in the ground rice sample using Kjeldahl device, through processing steps of mineralization, distillation and titration.

The raw fibre content was determined from 2 g (W0) of ground rice sample processed in extraction mixture using 0.25 M sulfuric acid, 0.31 M sodium hydroxide, and intermittent boiling. After filtration upon a Whatman filter paper, the insoluble residue was cleared with boiling water, dried into an oven (Memmert, Germany) at 105 ºC for 8 h, and then incinerated at 550 °C for 12 h into a muffle furnace (Pyrolabo, France). The resulting whitish product (W2) allowed the estimation of the raw fibre content according to the gravimetric method.

Fibre Content (g/100 g) = (W1 –W2 / W0) x 100

W0, weight of the raw ground rice; W1: weight of residue; W2: weight of the fibre.

Fat matter was quantified through solvent extraction using hexane reagent and Soxhlet device operated by reflux heating [23]. Ten (10) g of ground rice sample were placed in a cellulose extraction cartridge and submitted to reflux extraction with hexane solvent for 6 h. After extraction, the solvent was removed from the fat-hexane mixture using a BUCHI rotative evaporator and an oven- drying at 80 °C for 24 h. The final fat content was determined in g/100 g Dry Matter according to the formula below:

Fat Content (g/100 g DM) = (W2–W1/We) x 100

W1: weight of the empty glass flask; W2: weight of the glass flask with the fat; We: weight of the raw ground rice sample.

Table 1. List of the traditional rainfed rice varieties assessed

Districts	Local spellings of traditional rice varieties	Total
Gôh-Djiboua	*Abê, Akita, Azi red, Aziko, Biti-biti, Boumabou, Dagnon, Danané precocious, Danané belating, Dikouè, Gbêklêazi, Glawlon, Jbröko, Kôlôtchè white, Kôlôtchè red, Lepouleu, Loêgnini, Môgôssi, Nathalié, No no no, Present, Sipricri, Yoroukouiagnêzê, Zonhonkloumin white, Zonhonkloumin black*	25
Mountain	*Danané 1, Danané fowl*	2
Total		**27**

The starch content was determined with iodine method according to Walker [24]. The soluble carbohydrates were extracted from 2 g of ground rice sample using 80% ethanol (w/v), 10% zinc acetate (w/v), and 10% oxalic acid (m/v) according to the method worked by Agbo et al. [25]. The resulted carbohydrates extract was then processed by spectrophotometry methods, using phenol and 96% sulfuric acid for assessing the total soluble carbohydrates [26], whereas the reducing carbohydrates are measured from 3,5-dinitro-salicylic acid [27]. The total glucides content and the caloric energy value of the studied rice samples were estimated from standard formulas [28] according to the following equations:

$$TGC (\%) = 100 – (MOC + PRC + FAC + ASC)$$

$$CEV (kcal/100 g) = [(2.44 \times PRC) + (8.37 \times FAC) + (3.57 \times TGC)]$$

TGC, MOC, PRC, FAC, ASC: respective contents in total glucides, moisture, proteins, fat, and ash; CEV: caloric energy value

2.4 Statistical Analyses

The data recorded were analyzed using Statistica software (Statistica 7.1) at 5% significance. The statistical treatment consisted in analysis of variance (ANOVA-1) according to the traditional rice variety as divergence factor. The results were casted as means and their standard deviation, ranged with Student Newman Keuls post-hoc test. The averages were also submitted to multivariate analyses (Principal Components Analysis and Hierarchical Ascending Clustering) for correlating the rice varieties to the main discriminative biochemical parameters. These correlations were achieved with the PCA components displaying eigen- value superior to 1, according to Kaiser’s statistical rule.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Moisture content of the traditional rainfed rice varieties

The residual moisture contents statistically differentiate ($p<0.05$) the studied rainfed rice varieties. The rice of red Azi variety displays most significant moisture (10.96%) whereas the varieties Jbröko (8.68%), Akita (8.82%) and Abê (8.92%) are with the least residual moisture. The 23 other rainfed rice varieties record intermediate moisture contents included between 9.19% and 10.69% (Table 2).

3.1.2 Main nutritive traits of the studied rice samples

The mean contents of the main nutritive compounds are ranged from the Tables 2 and 3. The traditional rainfed rice varieties spellings record various contents ($p<0.001$) in their biochemical components. With contents over 80%, carbohydrates are the most important nutrients in rice samples. The spelling Jbröko is more provided in carbohydrates, with an average of 84.19 g/100 g, followed by those spelt Danané I (83.57 g/100 g), No-No-No (83.45 g/100 g), Abê (83.26 g/100 g), and Gbêklêazi (83.02 g/100 g). On the other hand, the varieties Present (80.99 g/100 g) and Yoroukouiagnêzê (80.27 g/100 g) display relatively lower carbohydrates contents. These glucides are essentially filled with starch, which contents are over 69 g/100 g of raw dried rice or more than 86% carbohydrates. The top starch content (72.14g/100 g) is for Gbêklêazi variety.

Besides, the glucides record lower amounts of free soluble carbohydrates, especially recovered in varieties Danané belating (4.63 g/100 g), Jbröko (4.48 g/100 g) and Zonhonkloumin black (4.40 g/100 g), against only 1.37 g/100 g for Nathalié. From the reducing carbohydrates, the least amounts are recovered from

Table 2. Rates (%) of moisture and other biochemical characteristics of the 27 traditional rainfed rice varieties studied

Rice varieties	Moisture	Proteins (%)	Fat (%)	Energy Value (Kcal/100g)	Ash (%)
Dikouè	9.79±0.19^{bcd}	6.23±0.40^{ghi}	1.26±0.21^{abcd}	317.19±0.59^{cdefghi}	1.08±0.08^{cdefg}
Danané precocious	10.64±0.13^{efg}	5.20±0.09^{abc}	1.03±0.03^{efgh}	314.09± 0.20^{abcd}	1.12±0.06^{cdefgh}
Aziko	10.30±0.30^{cdefg}	6.11±0.17^{fgh}	0.90±0.06^{bcdef}	313.49±1.06^{abc}	1.16±0.03^{defghi}
Lepouleu	10.26±0.07^{cdefg}	6.01±0.05^{fgh}	0.93±0.06^{cdefg}	314.47±0.67^{abcde}	1.02±0.03^{bcd}
Gbêklêazi	10.06±0.46^{cde}	4.85±0.00^{a}	0.86±0.05^{j}	315.41±2.62^{bcdefg}	1.10±0.08^{cdefg}
Present	10.70±0.00^{efg}	6.30±0.17^{ghi}	1.10±0.02^{bcdef}	313.70± 0.33^{abc}	0.91±0.05^{ab}
Loêgnini	9.23±0.20^{ab}	6.35±0.00^{hi}	1.11±0.17^{efgh}	317.73± 0.26^{defghi}	1.25±0.03^{hijk}
Dagnon	10.57±0.23^{defg}	5.03±0.06^{ab}	1.03±0.06^{hi}	314.80±0.71^{abcdef}	1.05±0.06^{bcdef}
Boumabou	9.97±0.09^{bcde}	6.05±0.09^{fgh}	1.08±0.11^{bcde}	315.93±0.59^{cdefgh}	1.07±0.04^{cdef}
Kôlôtchè white	10.85±0.11^{fg}	4.95±0.09^{a}	1.06±0.04^{gh}	314.11±0.66^{abcde}	1.02±0.06^{bcde}
Glawlon	10.19±0.12^{cdefg}	6.08±0.06^{fgh}	1.19±0.01^{bcdef}	316.10±0.69^{cdefgh}	1.00±0.01^{bc}
Jbröko	9.19±0.36^{ab}	4.94±0.09^{a}	1.10±0.02^{ij}	322.17±1.51^{hij}	1.30±0.03^{ijk}
No no no	8.68±0.37^{a}	4.98±0.03^{a}	1.13±0.03^{ij}	320.10±0.41^{ghi}	1.05±0.06^{cdef}
Akita	8.82±0.25^{a}	5.83±0.14^{ef}	1.18±0.10^{hij}	317.80±0.37 ^{i}	1.02±0.07^{bcd}
Abê	8.92±0.17^{a}	5.60±0.13^{de}	1.10±0.02^{ij}	319.07±0.30^{abcd}	1.12±0.02^{cdefgh}
Kôlôtchè red	10.12±0.05^{cdef}	6.17±0.14^{fgh}	1.00±0.08^{abc}	314.12±0.30^{abcd}	1.22±0.03^{ghij}
Sipricri	9.93±0.52^{bcde}	5.12±0.02^{abc}	0.90±0.04^{fgh}	316.29±1.88^{cdefgh}	1.06±0.02^{cdef}
Zonhonkloumin black	10.23±0.01^{cdefg}	5.03±0.03^{ab}	0.92±0.06^{efgh}	314.39±0.19^{abcde}	1.38±0.02^{k}
Azi red	10.96±0.10^{g}	5.43±0.08^{cd}	0.79±0.09^{bcdefg}	311.31± 0.27^{a}	1.17±0.02^{efghi}
Môgôssi	10.69±0.02^{efg}	5.57±0.06^{de}	1.04±0.13^{ab}	313.88±0.68^{abcd}	1.03±0.06^{bcde}
Yoroukouiagnêzê	10.42±0.02^{cdefg}	7.27±0.03^{j}	0.86±0.10^{a}	311.50±0.68^{ab}	1.19±0.01^{fghi}
Biti-biti	10.56±0.31^{defg}	6.54±0.09^{i}	0.77±0.10^{a}	311.57±0.47^{ab}	1.13±0.06^{cdefgh}
Danané belating	10.27±0.14^{cdefg}	5.39±0.07^{bcd}	1.07±0.03^{cdefgh}	314.77±0.70^{abcdef}	1.29±0.06^{ijk}
Nathalié	10.66±0.18^{efg}	5.35±0.10^{bcd}	1.12±0.08^{bcde}	313.95±0.91^{abcd}	1.19±0.01^{fghi}
Danané 1	9.70±0.55^{bc}	5.12±0.06^{abc}	0.83±0.06^{ij}	320.90±1.59^{j}	0.79±0.02^{a}
Danané fowl	9.82±0.16^{bcd}	5.97±0.03^{fg}	1.10±0.01^{efgh}	317.70±0.89^{fghi}	0.78±0.01^{a}
Zonhonkloumin white	10.42±0.03^{cdefg}	5.85±0.00^{ef}	1.06±0.05^{bcdef}	313.45± 0.34^{abc}	1.35±0.04^{jk}
F_{-value}	**19.10**	**79.3**	**6.96**	**12.00**	**30.27**
P_{-value}	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

Means ± standard deviations are compared by column using different lowercase letters at 5% significance

Table 3. Rates (%) of the carbohydrates characteristics of the 27 traditional rainfed rice varieties studied

Rice varieties	**Total carbohydrates**	**Starch**	**Free soluble glucides**	**Reducing sugars**	**Fibres (%)**
Dikouè	81.64±0.70^{bcde}	69.76±0.31^{h}	3.11±0.02^{cde}	0.15±0.01^{fghij}	3.90±0.09^{d}
Danané precocious	82.01±0.06^{cdef}	70.90±0.28^{abcdefgh}	2.54±0.61^{b}	0.10±0.02^{abcdefg}	2.96±0.06^{c}
Aziko	81.53±0.05^{bcde}	70.14±0.30^{abcde}	3.16±0.03^{cde}	0.12±0.01^{abcdefgh}	2.92±0.20^{c}
Lepouleu	81.80±0.07^{bcde}	70.35±0.29^{abcdef}	3.24±0.01^{cde}	0.14±0.02^{fghi}	1.33±0.14^{a}
Gbêklêazi	83.02±0.62^{ghi}	72.14±0.17^{abcd}	3.00±0.05^{c}	0.05±0.01^{ab}	3.67±0.03^{d}
Present	80.99±0.17^{ab}	70.10±0.28^{defgh}	2.98±0.03^{c}	0.10±0.01^{abcdefg}	5.28±0.20^{gh}
Loêgnini	82.06±0.33^{cdefg}	70.89±0.34^{defgh}	2.40±0.05^{b}	0.13±0.01^{bcdefghi}	4.94±0.08^{fg}
Dagnon	82.33±0.30^{defgh}	71.25±0.10^{abcdefgh}	3.27±0.06^{cdef}	0.20±0.01^{ijkl}	4.13±0.13^{de}
Boumabou	81.83±0.28^{bcde}	70.04±0.25^{cdefgh}	3.50±0.03^{ef}	0.15±0.01^{fghi}	5.93±0.08^{j}
Kôlôtchè white	82.12±0.05^{cdefg}	71.03±0.02^{cdefgh}	2.51±0.03^{b}	0.10±0.01^{abcdefg}	3.72±0.06^{d}
Glawlon	81.60±0.16^{bcde}	70.11±0.05^{gh}	2.32±0.03^{b}	0.19±0.01^{hijkl}	4.47±0.20^{ef}
Jbröko	84.19±0.37^{j}	71.93±0.57^{defgh}	3.40±0.02^{def}	0.06±0.01^{abcde}	5.32±0.28^{ghi}
No no no	83.45±0.43^{i}	72.01±0.11^{efgh}	4.48±0.03^{gh}	0.06±0.01^{abcd}	4.04±0.07^{de}
Akita	83.14±0.40^{hi}	71.37±0.42^{fgh}	3.24±0.01^{cde}	0.14±0.10^{efghi}	5.83±0.29^{ij}
Abê	83.26±0.32^{ij}	71.99±0.03^{defgh}	3.21±0.03^{cde}	0.30±0.00^{m}	6.67±0.14^{k}
Kôlôtchè red	81.43±0.18^{bcd}	69.69±0.13^{abcdefg}	3.65±0.07^{f}	0.23±0.06^{klm}	4.89±0.14^{fg}
Sipricri	82.99±0.51^{fghi}	70.94±0.62^{abcde}	4.22±0.09^{g}	0.14±0.01^{defghi}	2.12±0.10^{b}
Zonhonkloumin black	82.47±0.08^{efgh}	70.89±0.39^{abcdef}	4.40±0.05^{gh}	0.04±0.01^{a}	3.81±0.16^{d}
Azi red	81.64±0.18^{bcde}	70.22±0.43^{ab}	3.09±0.05^{cd}	0.09±0.00^{abcdef}	3.85±0.33^{d}
Môgôssi	81.68±0.20^{bcde}	69.44±0.14^{bcdefgh}	4.43±0.04^{gh}	0.18±0.01^{ghijk}	4.44±0.16^{ef}
Yoroukouiagnêzê	80.27±0.13^{a}	69.13±0.14^{abcd}	3.01±0.03^{cd}	0.23±0.01^{jklm}	5.90±0.09^{j}
Biti-biti	81.00±0.21^{ab}	69.01±0.19^{a}	3.07±0.03^{cd}	0.24±0.00^{klm}	4.92±0.07^{fg}
Danané belating	81.98±0.16^{cde}	70.53±0.09^{cdefgh}	4.63±0.08^{h}	0.26±0.01^{lm}	4.10±0.19^{de}
Nathalié	81.67±0.24^{bcde}	70.05±0.13^{efgh}	1.37±0.03^{a}	0.13±0.01^{cdefghi}	5.17±0.14^{g}
Danané 1	83.57±0.45^{ij}	71.92±0.06^{abc}	3.32±0.03^{cdef}	0.06±0.01^{abc}	5.72±0.18^{hij}
Danané fowl	82.33±0.13^{defgh}	70.60±0.08^{defgh}	2.95±0.04^{c}	0.25±0.01^{klm}	6.10±0.09^{j}
Zonhonkloumin white	81.32±0.04^{bc}	70.09±0.18^{cdefgh}	2.46±0.05^{b}	0.12±0.01^{abcdefgh}	3.76±0.24^{d}
F_{-value}	**24.00**	**30.00**	**102.79**	**23.88**	**167.02**
P_{-value}	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

Means ± standard deviations are compared by column using different lowercase letters at 5% significance

Table 4. Matrix of eigen- values, variances, and correlations between the components of the principal components analysis and the biochemical parameters of traditional rainfed rice samples studied

Principal components	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Eigen values	4.00	2.16	1.13	1.02	0.64	0.51	0.41	0.08	0.03	0.00
Variance (%)	40.03	21.62	11.34	10.24	6.41	5.14	4.11	0.83	0.27	0.00
Cumulated variance (%)	40.03	61.66	73.00	83.24	89.65	94.78	98.89	99.72	100	100
MOC	0.79	0.42	-0.20	-0.17	0.17	0.25	-0.17	0.02	-0.08	-0.01
ASC	0.19	0.28	0.33	0.82	-0.29	0.14	0.01	-0.02	-0.02	0.00
TCC	-0.97	0.14	0.06	-0.09	-0.03	0.06	0.06	-0.09	0.06	-0.02
PRC	0.64	-0.61	0.11	0.02	-0.14	-0.40	0.12	0.09	-0.01	-0.01
SSC	-0.29	0.20	0.85	-0.14	0.24	-0.09	-0.24	0.06	0.00	0.00
RCC	0.34	-0.66	0.37	-0.08	0.19	0.41	0.33	-0.01	0.00	0.00
FIC	-0.17	-0.76	0.02	-0.18	-0.41	0.23	-0.37	0.00	0.00	0.00
STC	-0.91	0.21	-0.13	-0.04	-0.14	0.16	0.15	0.23	-0.02	0.00
FAC	-0.31	-0.54	-0.31	0.51	0.47	0.03	-0.19	0.05	0.03	0.00
TEV	-0.91	-0.35	0.00	0.04	0.07	-0.12	0.06	-0.09	-0.13	0.00

***MOC**, moisture content; **ASC**, ash content; **TCC**, total carbohydrates content; **PRC**, proteins content; **SCC**, soluble carbohydrates content; **RCC**, reducing carbohydrates content; **FIC**, fibres content; **STC**, starch content; **FAC**, fat content; **TEV**, total caloric energy value*

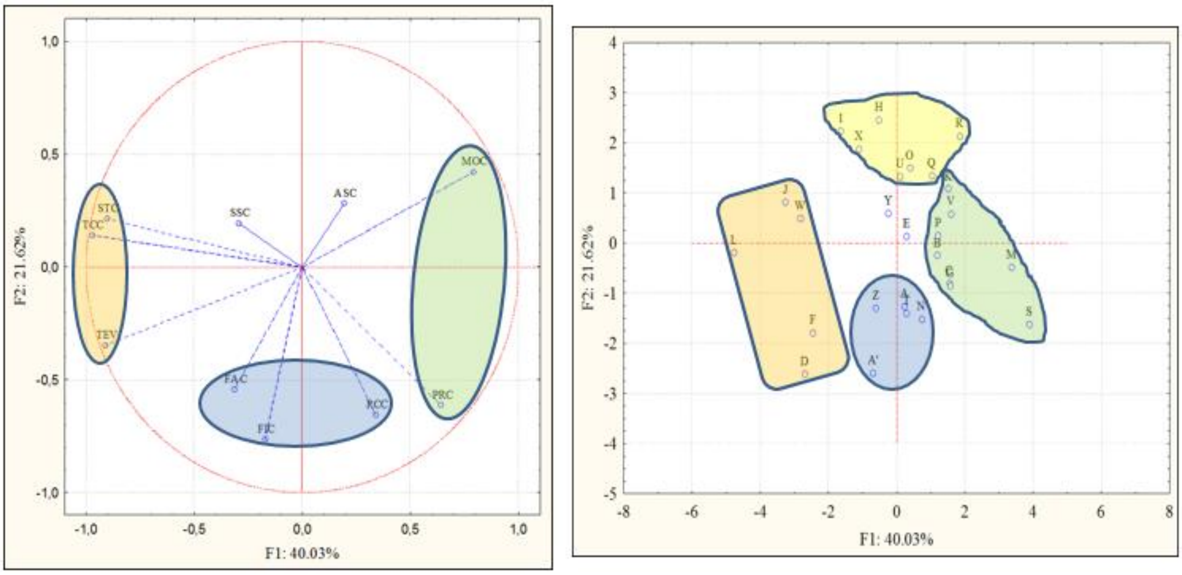

Fig. 1. Correlations of the main biochemical compounds (A) and the traditional rainfed rice varieties (B) in the F1-F2 factorial design of the principal components analysis

MOC, moisture content; ASC, ash content; TCC, total carbohydrates content; PRC, proteins content; SCC, soluble carbohydrates content; RCC, reducing carbohydrates content; FIC, fibres content; STC, starch content; FAC, fat content; TEV, total caloric energy value. A, Boumabou; B, Nathalié; C, Present; D, Abê; E, Danané belating; F, Akita; G, Kôlôtchè red; H, Zonhonkloumin black; I, Gbêklêazi; J, No No No; K, Aziko; L, Jbröko; M, Biti-biti; N, Glawlon; O, Danané Precocious; P, Môgôssi; Q, Lepouleu; R, Azi red; S, Yoroukouiagnêzê; T, Dikouè; U, Kôlôtchè white; V, Zonhonkloumin white; W, Danané I; X, Sipricri; Y, Dagnon; Z, Loêgnini; A', Danané fowl

Zonhonkloumin black (0,04 g/100 g) and Gbêklêazi (0,05 g/100 g), oppositely to the varieties Danané fowl, Biti-biti, Yoroukouiagnêzê, and Kôlôtchè Red which appeared more provided with respective contents of 0.25 g/100 g, 0.24 g/100 g, 0.24 g/100 g, and 0.23 g/100 g. Otherwise the varieties Abê, Danané fowl, Boumabou, Yoroukouiagnêzê, and Present display highest amounts of raw fibres, with averages between 6.67 and 5.28 g/100 g.

However, Danané I and Danané fowl contain lower ash content (<0.8%) compared to varieties No-No-No (1.30%), Zonhonkloumin white (1.35%), and Zonhonkloumin black (1.38%). The rice variety Yoroukouiagnêzê is richer in proteins (7.27 g/100 g), whereas the most significant fat content is from varieties Dikouè and Akita (1.26 and 1.18 g/100 g, respectively).

According to their biochemical composition, the rice varieties Jbröko, Danané I, No-No-No, and Abê show the highest caloric energy values (322.17 kcal/100 g, 320.90 kcal/100 g, 320.10 kcal/100g, and 319.07 kcal/100 g, respectively), while Azi Red is of lower energy content (311.31 kcal/100 g).

3.1.3 Rice samples gathering according to the biochemical parameters

The principal components analysis shares the investigated data over 10 factors (F1 to F10). However, both F1 and F2 factors accumulating 61.67% total variance were considered to check the gathering and correlations between the rice samples and their main characteristics.

Thus, F1 expresses 40.03% of total variance for an eigen-value of 4.03 and is especially built by the contents in moisture, proteins, total carbohydrates, starch, and the energy value. With F2 (21.62% variance and 2.16 of eigen-value), the significant correlations are filled by the contents in reducing carbohydrates, fibres, and fat (Table 4). From the F1-F2 factorial design, three groups of rice varieties reveal distinctive biochemical characteristics.

The spellings *Nathalié*, *Present*, *Kôlôtchè Red*, *Aziko*, *Biti-biti*, *Môgôssi*, *Yoroukouiagnêze*, and *Zonhonkloumin white* are with more moisture and proteins contents. The most important amounts of fibres, fat, and reducing carbohydrates are resulted from samples of rice varieties spelt *Boumabou*, *Glawlon*, *Dikouè*, *Loêgnini* and

Danané fowl. The varieties *Abê*, *Akita*, *No-No-No*, *Jbröko* and *Danané I* show the highest contents in total carbohydrates, starch, and the energy value (Fig. 1).

3.2 Discussion

The maximal average of the moisture rates of the different rice samples studied is of 10.56%, which fits the moisture reference value of 12% allowed for a good preservation of grain food products [29]. Thanks to their lower moisture contents, the rainfed rice varieties assessed could be successfully stored for lasting preservation.

The carbohydrates has been revealed as the major nutrients in the rice samples studied, with the highest contents provide from varieties Abê, Akita, Jbröko, No-No-No, and Danané I (83.14% to 84.19%). The significant carbohydrates trend of rice grains was already reported by numerous authors. Romain [30] indicated about 76% glucides in shelled rice of which the husk epidermis has been removed. Laureys and Geeroms [19] also showed the rice as a caloric energy food resource having suitable nutritional value with predominance in glucides. The works of Frei and Beckers [20] and Montecinos *et al*. [21] proved that the traditional varieties of rice are richer in nutrients and are mostly good source of healthy glucides. Those glucides mainly deal with starch and food fibres with respective maximal averages of 71.99% and 6.67%. The significant involvement of fibres in traditional rice has been reported by Frei and Becker [20], with important metabolic role for other nutrients as lipids and glucides.

Food fibres are friendly with the reduction of numerous health concerns as constipation, colon cancer, and especially glycaemia by dropping the intestinal absorption of glucose [31,32] and also the prevention regarding the excessive absorption of cholesterol [33]. Their great presence in the rice traditional varieties spelled Boumabou, Glawlon, Dikouè, Loêgnini, and Danané fowl which are also richer in fat could sustain more digestive trend for these rice types from consumers.

Regarding proteins, the greatest content is about 7.27%, beyond the average of 11.56% found by Watanabe et al. [34] from other varieties of *Oryza glaberrima*. The difference could be involved by the agronomical parameters on the nutrients elements in rice grains. Indeed, some studies revealed the nitrogen content of the cultivated soil, the sun radiance, the maturation length of the rice plant and the rice panicle, the use of manure, and the shortening of the maturation periods as great involvements on the final protein content of the rice grains [35,36]. Once harvested, the main practices for storing, treatments and culinary can also have influence on the global nutritional quality of rice [37]. According to Grist [38] and Juliano and Villareal [39], the rice proteins are mostly fitted in aspartic and glutamic aminoacids. Although proteins are not the major rice nutrients, they are really advantageous for its consumption by the populations, especially those facing concerns regarding proteins food resources. Proteins are essential for building and repairing body tissues, production of antibody molecules, and the due functioning of the full organism [40].

About lipids, the content is maximal (1.26%) from the rice variety spelt Dikouè, as value comparable to the result (1.6%) reported by Favier [41]. So, the traditional rice grains contain obvious lower lipids than other cereals as wheat (1.8%), sorghum (3.2%), millet (4.1%), and corn (4%). Thus, rice doesn't record enough fat content. But, this lipid fraction is of significant nutritional interest since lipids molecules are involved in the formation and biological function of tissues, achievement of cerebral functions, vitamins absorption, etc. [42].

From the main nutrients, the global caloric energy value of the traditional rice varieties studied oscillates between 311.11 and 322.17 Kcal/100 g. So, the consumption of the traditional rice varieties could fit the energy needs of active populations, even during muscular efforts, in accordance with Gina et al. [37] who mentioned 27% energy needs filled by rice.

The maximal ash content was settled at 1.38%, forecasting significant presence of mineral micronutrients in rice. According to Leung et al. [43], iron, calcium, sodium, magnesium, potassium, phosphorous, and zinc are the essential minerals of the shelled rice grains. These minerals are of fluctuating contents according to the rice varieties. Some authors showed traditional rice varieties as very richer in iron and zinc, compared to the high yielding improved varieties fluently cultivated [37].

4. CONCLUSION

The current work aimed to reveal the nutrients potentials of the traditional rainfed rice varieties cultivated from the districts of Gôh-Djiboua and Mountains in Côte d'Ivoire. In spite of their obvious weak yields, these rice varieties record good nutritive traits above the widespread improved rice varieties. They remain significant caloric resources thanks to their considerable contents in glucides (for varieties Abê, Akita, Jbröko, No-No-No, Jbröko, and Danané I), proteins, lipids, and significant amount of food fibre (for varieties Boumabou, Glawlon, Dikouè, Loêgnini, and Danané fowl) and minerals. Other investigations on the functional nutritional compounds (minerals, secondary metabolites, bioactive compounds) could sustain the spreading of the traditional rainfed rice varieties in agro-food industry with advantage in ensuring food safety for populations, fighting against rural poverty, and preserving the rice biodiversity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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