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Evaluation of Nutritional Composition of Two Fonio Ecotypes Grown in Casamance (Sénégal)

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Abstract

In order to better understand the cultural route, biochemical and nutritional composition of two ecotypes of fonio, a study was carried out in village of Tambananing located approximately 7 km from Sédhiou. The objective of studies was to determine nutritional composition of two ecotypes of fonio: the first called *momo* in short-cycle *mandinka* (75 - 90 days) and the other called medium-cycle *dibong* (90 - 110 days). For this, samples of two ecotypes were collected in an experimental field which was split into two equal parts, one sown with the *momo* ecotype and the other with the *dibong* ecotype. The nutritional composition (sugars, fats, proteins, minerals, ash, etc.) and the physicochemical properties (pH, humidity, water activity, color, etc.) of fonio's were determined by appropriate physicochemical methods. The two ecotypes exhibited quite similar physicochemical properties. The levels of biochemical compounds were relatively close with protein contents of 7.05 ± 0.06 mg/100g for the *momo* ecotype and of 8.02 ± 0.04 mg/100g for the *dibong* ecotype, in carbohydrates (76.37 ± 1.2 mg/100g for *momo* and 78.7 ± 1.5 mg/100g for *dibong*) and in fat (2.92 ± 0.05 mg/100g for *momo* and 3.14 ± 0.004 mg/100g for *dibong*). Identical mineral element contents were found except for iron, an element for which the contents were 10.80 ± 0.008 mg/100g for the *momo* ecotype and 99.59 ± 0.005 mg/100g for the *dibong* ecotype. Thus, two ecotypes of fonio present a fairly interesting nutritional composition and their consumption deserves to be popularized and could contribute effectively to fight against the problems of malnutrition of certain vulnerable groups.

Keywords

Biochemical Composition, Ecotypes, Fonio, Casamance

1. Introduction

Sénégal population is growing rapidly now estimated at. 18,032,473 million including women 8.900.614 (49.4%) and men 9.131859 (50.6%) [1]. This rapid growth poses challenges in terms of food self-sufficiency, which Senegalese agriculture is struggling to meet despite many efforts made through various agricultural development programs: the REVA plan, GOANA, PIESAN, PAIS, PRACAS, PADEN, etc. food-producing agriculture, dominated by family farms (95% of the country's farmland), includes cereal crops such as millet, sorghum, maize, fonio, and rice. Rice is a staple food in Senegal. Given the shortfall in local cereal production (2,545,494 tonnes in 2017/2018), Senegal is one of the biggest importers, with quantities estimated at 119.3 kg/head/person [2].

The population is increasing rapidly and as a result the country's food needs continue to grow. However, the performance of the agricultural sector remains mediocre and is insufficient to make up for the deficit in food (cereals) and the basic diet of a large majority of the population. Agriculture is essentially family-based, subsistence farming, and appears very vulnerable to climatic conditions (drought) but also to the volatility of world commodity prices. Ultimately, farmers' incomes continue to decline, and in fact, extreme poverty particularly affects rural people [3].

Fonio (Digitaria Exilis) is one of the traditional cereals which is one of the oldest in West Africa. It constitutes the staple food of many people, especially in the most isolated rural areas. In Senegal, fonio is a marginal cereal in agriculture. It is cultivated by ethnic minorities (Bassaris, Kognaguis, Balantes, Tenda), the Peulhs and the Mandingos of the regions of Tambacounda, Kédougou, Kolda, Sédhiou, Ziguinchor and south of Kaffrine (Koungheul). Well adapted to the climatic conditions of these regions, this cereal plays a very important role in improving nutrition, contributing to food security and increasingly in human health (diabetes). The national promotion of these crops has long been delayed on the one hand, by the arduousness of production, harvest and post-harvest work, storage, processing, on the other hand, by the lack of certified seeds, the lack of control cultural practices, lack of organization of sectors, lack of access to financing among others. For these sectors, production is not only very irregular within the country, but also its overall trend is downward. Official data show that despite the efforts made here and there, surface areas and production are in constant decline in the main producing regions [4].

Fonio is a crop that adapts to the tropical climate with a well-marked dry season at average temperatures of 25˚C to 30˚C and rainfall of 800 mm to 1000 mm. Fonio is a commodity appreciated for culinary and dietetic. A very digestible food offers several taste and savory qualities in particular.

Fonio (*Digitaria exilis* (Kippist) Stapf) is a glumaceous monocotyledon of the grass family (or poaceae) of the Digitaria genus. Among crab grasses which include more than 300 species. Today only *Digitaria exilis* or fonio is of particular importance in West Africa. Fonio is a small annual herbaceous plant 30 to 80 cm high. The spikelet includes a sterile flower and a fertile flower which will produce the fonio grain. We usually distinguish different types of varieties:

- Extra-early varieties, with a vegetative cycle of 70 to 85 days.
- Early varieties, with a vegetative cycle of 85 to 100 days.
- Semi-late varieties with a vegetative cycle of 100 to 120 days.
- Late varieties at 150 days of vegetation [5].

If the nutritional profile of Senegal is dominated by problems of undernutrition, however the country is in full transition in terms of nutrition by increasingly facing the Double Burden of Malnutrition (DFM) (The coexistence of undernutrition and over nutrition) [6].

Therefore, to better address the problem of malnutrition in peri-urban and urban or even rural areas, it would be very relevant to popularize the fonio sector. It is with the aim of contributing to the improvement and a better method of the cultivation route that these two early ecotypes cultivated in the southern region of Senegal which offer enormous potential are taken as examples. With the main objective of evaluating their nutritional composition, which will make it possible to supplement cereal crops, during the lean season in rural areas, in order to alleviate the problem of food insecurity and malnutrition.

Today, the new policy of the State of Senegal aims, within the framework of research, to promote the cultivation of cereals and boost productivity [7].

The aim of this study was to assess the nutritional composition of two fonio ecotypes grown in Casamance, Senegal. It is with the aim of contributing to the valorization of local cereals that's why this work was initiated with the objective of evaluating the nutritional composition of two ecotypes of fonio cultivated in South of Senegal, Sédhiou exactly.

2. Materials

1) Plant material

The study focused on two fonio ecotypes (*dibong* and *momo*) harvested in a

Photo 1. *Dibong* ecotype.

Photo 2. *Momo* ecotype.

half-hectare agricultural area divided into four equal plots of 1250 m^2, located in Tambananing in the Sédhiou region. For each ecotype, two samples were taken, one from control field (no organic manure applied) and another from field that had received 100 g/m^2 of organic manure. The supporting photos showing seed's samples of two ecotypes used in experimental fields (see **Photos 1 and 2** of ecotype's samples).

2) Laboratory equipment and reagents

The reagents, solvents and reference substances used for this study were of analytical quality and purchased from local suppliers (Technologies services, Fermon Labo Sénégal and Bouattour Equipements Services, Dakar, Senegal). Double-distilled water and class A laboratory glassware were also used.

SAA spectrophotometer, A300 Perkin Elmer (Agilent, California, USA).

Genesys 20 UV spectrophotometer (Thermo Fischer Scientific, Massachusetts, USA).

3. Methods

3.1. Determining Humidity Levels

It was carried out according to the AOAC method (1998) [8]. A 5 g sample of fonio was weighed (P_0) using a precision balance (Sartoruis BP 310S, Gottingen, Germany) and dried in an oven (Memert, Schwabach, Germany) set at 105˚C for 4 h. The sample was then cooled in a desiccator and weighed (P_1). On leaving the oven, the sample was cooled in a desiccator and weighed (P_1). The percentage moisture content was calculated using the formula:

$$H\% = \frac{P_1 - P_0}{P_0} \times 100 \quad (1)$$

3.2. Determining Ash Content

This determination was carried out using the AOAC (2000) method [8]. A 5 g sample (P0) was introduced into an initially tared porcelain crucible and placed in a muffle furnace (Naberterm, Gmbh LT9/11/B180, Germany) set at 550˚C for

6 h, until all the organic matter contained in the sample was destroyed (grey-white ash obtained). After cooling in a desiccator, the ash obtained was weighed (P1) to determine the ash content according to the formula:

$$\text{ash }\% = \frac{P_1 - P_0}{P_0} \times 100 \quad (2)$$

3.3. Determination Titratable Acidity

It was carried out using the AOAC (2000) method and consists of measuring the titratable acidity product with a 0.1N sodium hydroxide (NaOH) solution, in the presence of 1% phenolphthalein as a coloured indicator. To do this, 10 g of mass (Pe) finely ground product sample is diluted in 75 mL of distilled water, then left to macerate and the supernatant is filtered; 3 drops of phenolphthalein are added to a volume V_1 of 10 mL of this filtrate. The assay is carried out by pouring in the NaOH solution of normality N2 (0.1N) until a pink colour appears. If V_2 is the volume of NaOH solution poured in, the normality N1 of the filtrate taken is obtained by the following formula:

$$N_1 = \frac{N_2 \times V_2}{V_1} \quad (3)$$

$$\text{Acidité }\% = \frac{N_1 \times 0.009 \times 100}{PE}$$

N is the normality of the NaOH used.

V_1 is the volume (mL) of the NaOH solution.

PE is the mass (g) of product taken.

Depending on the food being analysed, the result may be expressed as % W/W or W/V of a particular organic acid or in ml of 0.1N NaOH per 100 g or 100 ml.

3.4. Determining PH

The pH is determined by immersing the pre-calibrated glass electrode of the pH meter (Mettler Toledo) 10 mL of supernatant obtained after macerating 10 g of sample in 75 mL of distilled water. The pH value is read on the pH meter display.

3.5. Determining Fat Content

This determination is based on the fact that fats are soluble in organic solvents such as petroleum ether and hexane. The determination was carried out using the BIPEA (1976) method, which consists of extracting the fats with hexane, which is then evaporated and the residue dried and weighed.

$$\%\text{ Lipids} = \frac{m(\text{Lipids})}{M(\text{sample})} \times 100 \quad (4)$$

3.6. Protein Determination

Proteins were determined using the BIPEA method (1976) using a Kjeldahl distiller [9]; this method is based on the determination of total nitrogen, which is then converted into protein content. The mineralisation of 1 g of sample of the products concerned is carried out in the presence of a catalyst consisting of copper sulphate ($CuSO_4$) and potassium sulphate (K_2SO_4) in a Buchi 430 type digester (Digestor Germany), for 3 hours. This was followed by distillation in a distillation unit (Buchi 320, Germany), after the addition of 10 mL of sodium hydroxide solution (NaOH) to 40% of the digest. The distillate (200 mL) was collected and determined by using 1N NaOH, at equivalence a green colour is obtained.

The levels of total nitrogen and crude protein are obtained using the following formula:

$$N = \frac{(V_1 - V_0) \times T \times 0.014 \times 100}{m} \quad (5)$$

With N = Nitrogen content

6.25 = conventional factor to be multiplied to obtain the protein content

V_0 is the volume mL of the sulphuric acid solution used for the blank test;

V_1 is the volume mL of the sulphuric acid solution used for the test sample;

0.014 is the expression, in grams, of the quantity of nitrogen equivalent to the use of 1 ml of a 1N standard sulphuric acid solution (0.5 mol/l);

m is the mass of the sample.

Protein rate = Total nitrogen rate × 6.25

3.7. Determination Reducing Sugars

The procedure consists preparing a solution of 5 g of fonio and 50 mL of distilled water, then adding 25 mL of Fehling's liqueur. The solution is then boiled for 3 minutes.

After cooling, 10 ml of KI 30% and 25 ml of sulphuric acid 25% are added. Titration is carried out with a 0.1N sodium thiosulphate solution.

$$\%\ \text{sugar reducing} = m \times \frac{100}{25} \times d \times \frac{100}{E} \quad (6)$$

P: Test sample in grams (solid sample);

m: mass of sugar, expressed in mg, corresponding to the difference in volume between blank and the sample (V_0 - V_1) as read from the Bertrand table.

V_0: Volume of 0.1N thiosulphate solution used to titrate the blank;

V_1: Volume of 0.1N thiosulphate solution used to titrate the sample;

d: dilution factor.

3.8. Determination Total Sugars

The procedure is the same as for reducing sugar except that here a few drops of hydrochloric acid are added before heating and after cooling 3 ml of NaOH is added.

The total sugar content, expressed in mg per 100 g of product, is given by the formula presented in paragraph 2.7.

3.9. Determining Energy Value

The energy value was calculated according to the Coleman (1970) formula using the coefficients of Atwater and Rosa (1899).

$$E(\text{calories}) = (4 \times \%\ \text{proteines}) + (4 \times \%\ \text{glucides totaux}) + (9 \times \%\ \text{lipides}) \quad (7)$$

1) Determining the colour

It was carried out using a Konica Minolta colorimeter. To do this, the sample is placed in a measuring chamber and the colour of the sample is read directly on the screen of the device after activating the measuring button.

2) Determination minerals by atomic absorption spectrometry

3) Mineralization

1 g of sample was weighed into a porcelain crucible and dried in an oven at 105˚C for 4 h, then mineralised by calcination in a furnace (Naberterm, Gmbh LT9/11/B180, Germany) according to the following temperature program: 150˚C for 20 min, 250˚C for 45 min and gradual increase until 550˚C was reached. The ash obtained (calcination residue) was moistened with a little water and then 4 1/2 ml of nitric acid was added. The crucibles are evaporated to dryness under a fume hood on a hot plate and then put back into the oven at 500˚C for 1 hour. Once cooled in the desiccator, the ashes were dissolved in 10 ml of 1/2 strength HCl. The solution obtained was filtered and reduced to final volume of 50 ml in a volumetric flask.

4) Calibration

For each element, range of standard solutions is prepared from a 10 ppm stock solution, which itself has been obtained from a certified 1000 ppm solution. Precise volume of the 10 ppm stock solution was introduced into a 50 ml flask and then made up to the mark with distilled water [10]. The standard and sample solutions were read at the wavelengths determined for each element: magnesium at 285.2 nm; potassium at 766.5 nm; sodium at 589.0 nm; manganese at 279.5; zinc at 213.9 nm; calcium at 422.7; iron at 248.3 nm).

A reagent blank prepared with distilled water was also used.

5) Phosphorus measurement

Phosphorus was measured using AOAC method [8].

6) Statistical analysis of results

All trials were repeated twice and the results were statistically analysed using Sigma plot stat.11 software and Excel 2010 spreadsheet software to determine the means and standard deviations, together with the standard error. The significance level was set at $p < 0.05$.

4. Results

The biochemical composition of the two fonio ecotypes (*dibong* and *momo*) is presented in **Table 1** supported by the illustration of **Figure 1**.

Acidity (milliequivalent); Nitrogen (g/100g), SR (reducing sugar; mg/100g), ST (total sugars; mg/100g), Ash in %, H% (humidity in %), Col colorimetry, The results in **Table 1** show slightly identical values for all the parameters studied, except for the ash content, where a difference of $P < 0.05$ was noted.

The results in **Table 2** show that the average lipid, carbohydrate and protein

Table 1. Biochemical composition of *dibong* and *momo* fonio ecotypes.

Variéty	pH	Ash	Acidity	H %	Nitrogen %	SR %	ST %	Col
Momo	6.21 ± 0.0212	2.49 ± 0.67	1.06 ± 0.028	10 ± 0.9	1.54 ± 0.48	0.35 ± 0.2	1.17 ± 0.59	brown
Dibong	6.12 ± 0.0354	1.49 ± 0.09	1.73 ± 0.35	7.25 ± 0.01	1.26 ± 0.118	0.45 ± 0.4	1.4 ± 0.73	brown

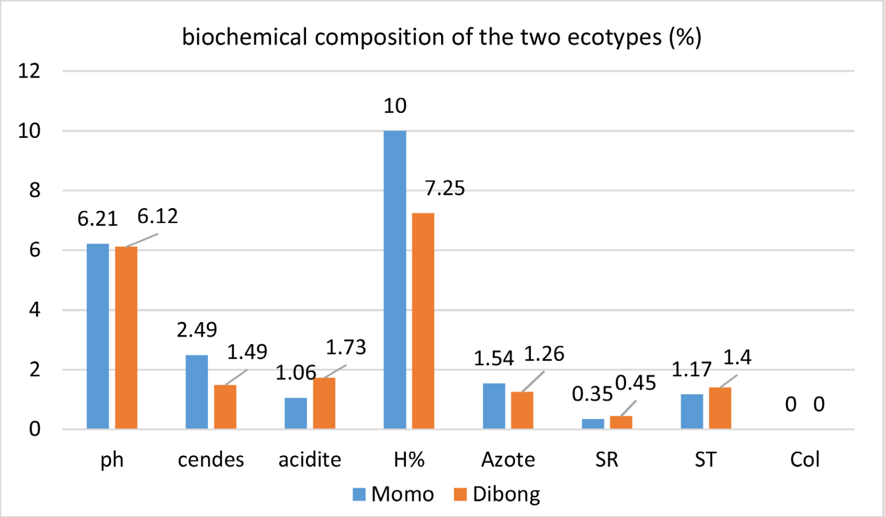

Figure 1. Biochemical composition of the two ecotypes of fonio *momo* and *dibong*.

Table 2. Lipid, carbohydrate, protein and energy content of the 02 ecotypes.

Ecotype	Lipids %	Carbohydrats %	Protiens %	Energy value in (KJ)
Momo	2.92 ± 0.15	76.37 ± 1.2	7.05 ± 0.06	1504.63
Dibong	3.14 ± 0.34	78.7 ± 1.5	8.02 ± 0.04	1568.08

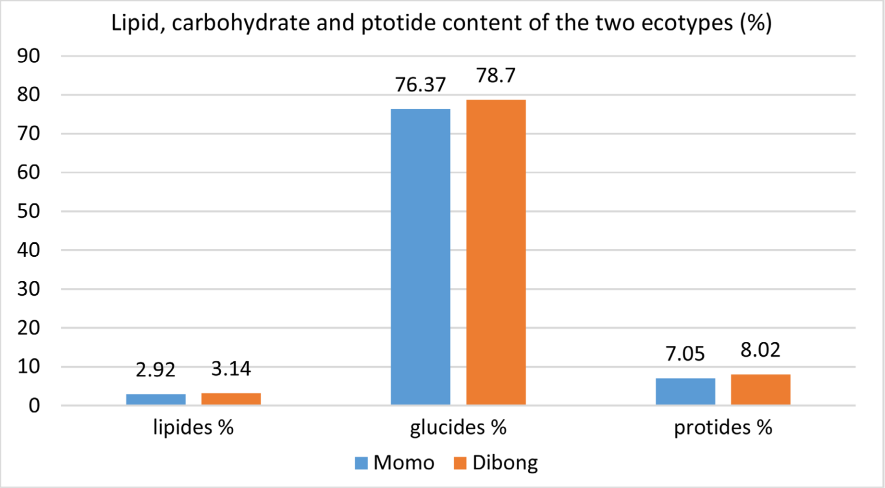

Figure 2. Lipid, carbohydrate and protein content of the two ecotypes.

contents of the two ecotypes were virtually identical. In addition, the values of 1504.63 kJ for *momo* and 1568 kJ for *dibong* were practically the same. There was no significant difference in energy content $p > 0.05$ following the **Figure 2** and Figure 3.

The levels of mineral elements are more or less identical for the two ecotypes studied, except for the two elements iron and calcium, for which higher levels were found respectively in *dibong* (99.59 ± 0.05 mg/100g) and *momo* (13.14 mg/100g). There was a significant difference with $p > 0.05$.

The table below shows the various mineral elements in local cereals consumed by the village community compared with the two ecotypes studied, supported by the Figure 4.

Figures bearing the same letter, in the same column for the same mineral elements, are not significantly different ($p \leq 0.05$).

The results in Table 3 show mineral element content of the two ecotypes before comparing with local cereals in Table 4.

Table 4 compares mineral content of the two ecotypes with that of other

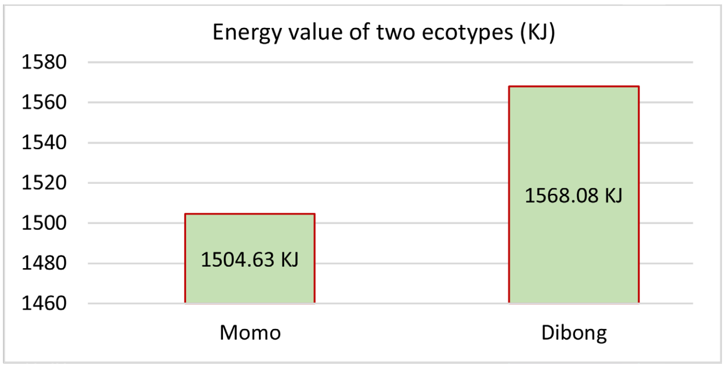

Figure 3. Energy value of the two ecotypes of fonio.

Table 3. Results of mineral element content of the two ecotypes in mg/100g.

	Zn (mg/100g)	Fer (mg/100g)	Mn (mg/100g)	Mg (mg/100g)	Ca (mg/100g)	K (mg/100g)	P (mg/100g)	N (g/100g)	Na (mg/100g)
Momo	2.97 ± 0.25	10.80 ± 0.18	1.99 ± 0.15	123.16 ± 0.9	13.14 ± 0.37	271.54 ± 0.45	215.68 ± 0.8	1.54 ± 0.1	17.81 ± 0.55
Dibong	2.17 ± 0.17	99.59 ± 0.05	2.66 ± 0.18	115.65 ± 0.7	3.87 ± 0.48	231.80 ± 0.57	199.93 ± 0.9	1.26 ± 0.2	13.96 ± 0.72

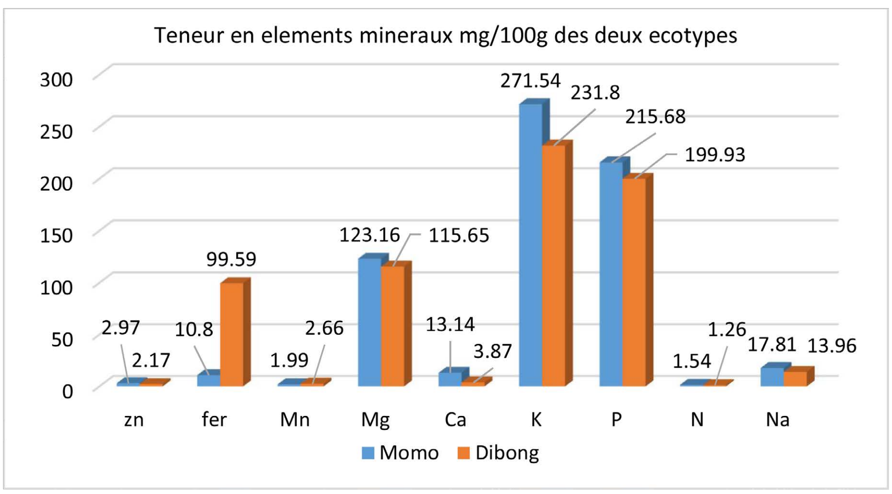

Figure 4. Mineral element content of the two fonio ecotype *momo* and *dibong*

Table 4. Mineral content of 02 fonio and local cereals.

	Eléments minéraux en mg/100g						
	Zn	Mn	Ca	Na	Mg	Fer	K
Millet	3.43 ± 0.008[b]	1.48 ± 0.006[a]	10.82 ± 0.005[a]	8.90 ± 0.008[a]	121.94 ± 0.008[a]	4.77 ± 0.005[a]	519.48 ± 0.008[c]
Sorghum	2.54 ± 0.005[a]	1.40 ± 0.008[a]	9.12 ± 0.007[a]	22.30 ± 0.009[c]	116.48 ± 0.006[a]	9.02 ± 0.008[b]	443.60 ± 0.006[b]
Maîze	2.58 ± 0.002[a]	1.12 ± 0.009[a]	11.93 ± 0.006[a]	8.06 ± 0.008[a]	78.37 ± 0.009[b]	4.07 ± 0.007[a]	391.37 ± 0.009[b]
Dibong	2.17 ± 0.005[a]	2.66 ± 0.008[b]	3.87 ± 0.008[b]	13.46 ± 0.007[b]	115.65 ± 0.007[a]	99.59 ± 0.005[c]	231.80 ± 0.007[a]
Momo	2.97 ± 0.005[a]	1.99 ± 0.005[b]	13.14 ± 0.007[a]	17.81 ± 0.005[b]	123.16 ± 0.009[a]	10.80 ± 0.008[b]	271.54 ± 0.005[a]

locally available cereals. The mineral element contents of the different cereals were more or less identical, with only manganese in *dibong* having the highest content, slightly lower than in the other cereals.

The comparative study showed a higher calcium content in *momo* (13.14 mg/100g), while iron in *dibong* was the most abundant element (99.59 mg/100g).

5. Discussion

The aim of the study was to determine the biochemical composition and mineral content of two fonio ecotypes. The parameters studied were: energy value, moisture, protein, lipids, carbohydrates, fibre and ash. The results showed that the energy values were not significantly different for the two ecotypes studied P< 0.05. These values are quite interesting with 1504.63 kJ for *momo* or 359.9 kcal and 1568.08 or 375 kcal and similar to those reported by Koudougou in 2010 (1501.87 kJ or 359.39 kcal). The lipid content (2.92% ± 0.15% for *momo* and 3.14% ± 0.34% for *dibong*), carbohydrate content (76.37% for *momo* and 78.7% for *dibong*) and protein content (7.05% for *momo* and 8.02% for *dibong*) are in line with the values reported by Fliedel *et al.* (2004) in studies conducted by CIRAD [11].

The iron content of 99.59 mg/100g obtained with the "*dibong*" variety is higher than that of the "*momo*" variety (10.80 mg/100g) with a significant difference ($p < 0.05$). This content is relatively similar to found in 2007 (107.3 mg/100g) by a CIRAD team in research carried out in collaboration with Wageningen University (Holland) [12]. However, it is higher than that found by Amouzou *et al* (2005), who obtained a level of 5.5 ± 0.28 mg/100g. The high iron content may be related to the richness of the soil in iron (ferralitic soil) and the fact fonio is a good source of iron means that it can be recommended as a treatment for iron deficiency disorders such as anaemia.

The calcium content of the *momo* variety was higher at 13.14 mg/100g compared with 3.87 mg/100g for the *dibong* variety, with a significant difference ($P > 0.05$). A comparison of the calcium levels obtained in this study with those found in the research work of Amouzou *et al* (2005) shows comparable results (13.14 versus 15 mg/100g). Compared with the other most widely consumed cereals (rice, millet, sorghum, maize) fonio is quite interesting from a nutritional point of view, even if its production remains very low in Senegal with 3757 tonnes in 2016 [13].

The results of this study have provided more information on the biochemical characteristics of these two fonio ecotypes grown in the Sédhiou region, which can be used to alleviate the problems of malnutrition and food insecurity. According to Ballogoun and al [14], fonio plays a very important socio-cultural and economic role and contributes to feeding people during the lean season. These findings are backed up by research carried out by Sekloka in Benin in 2015.

Fonio is reputed to be the tastiest cereal in terms of its finesse and flavour, and is easily digestible. It is traditionally recommended as food for children, pregnant or breast-feeding women, elderly and overweight people [11].

6. Conclusions

This study has shown that food species described as minor, rare or endangered have undeniable nutritional value. The two fonio ecotypes studied show their importance and prove that they are particularly rich in iron and can help individuals suffering from acute or severe anaemia. The high iron content of one of the ecotypes studied is evidence of its potential as a source of iron for rural populations.

There is still a need to boost cereal production, especially fonio, in order to fill the import gap in Senegal. Cultivation techniques have so far remained traditional, or very little improved despite some research efforts, and labour and yields are often low. At national and even sub-regional level, innovative research projects need to be undertaken in a concerted manner at each level fonio production chain. Mechanical assistance and improved sowing varieties will make a significant contribution to meeting the challenge of fonio cultivation and promoting it more effectively in Senegal.

Conflicts of Interest

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

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