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Production of Highly Nutritious Enriched Infant Flours from a Traditional Ready-to-Eat Dish: the Plantain *Dockounou*

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Abstract

This study aims to verify the nutritional potential of three enriched flours that could be used to fight child malnutrition. To do this, it relies on a traditional dish prepared from senescent plantain called *dockounou*. Indeed, *dockounou* is a ready-to-eat dish that is popular in Côte d'Ivoire, accessible to get, and beneficial to people of all socioeconomic backgrounds. It is, however, deficient in some macronutrients and difficult to conserve after cooking. The enrichment and conversion of this dish into available and accessible infant flours can allow many women with reduced financial conditions to have simple and effective food for their children from 6 to 59 months. Also, from senescente plantain, three types of *dockounou* incorporated with maize, soybeans and fish were made according to the optimized method of Kra et al. (2014). After drying in an oven, the *dockounou* were turned into flours, and their biochemical and functional properties were assessed. The results obtained showed that enriched *dockounou* flours had fat and protein contents ranging from 9.73 ± 0.11 % to 10.00 ± 00 % and from 11.30 ± 00 % to 14.13 ± 1.29 % respectively. The energy value of these flours varied from 375.06 ± 1.1 Kcal to 375.89 ± 0.51 Kcal. All these values are in line with FAO/WHO standards and are able to meet daily requirements of children under 10 years age. After statistical analyses, it emerged that Ms2 flour was the best maize enriched *dockounou* flours.

Keywords: senescent plantain, *dockounou* flour, infant flour, soybean, fish, malnutrition

1. Introduction

In the context of climate change, human nutrition is becoming increasingly difficult. The resurgence of politico-religious-ideological tensions, as well as the coronavirus epidemic, have aggravated the problem. Sub-Saharan Africa is the world's most food-insecure area, with more than a quarter of its 856 million residents malnourished and 21.4 % suffering from moderate or severe malnutrition. Despite this, food crop post-harvest losses are still being documented on a regular basis. This is true of plantain (*Musa paradisiaca* L.), a critical food resource in underdeveloped nations. It has a substantial socioeconomic impact and notably contributes to food security (Frison & Sharrock 1998; Bonnet-Bruno, 2012). Its global yearly production in 2019 was 41.58 million tons (FAOSTAT, 2019).

This very perishable vegetable, however, suffers from severe post-harvest losses, which are estimated to be between 30 and 40% of yearly harvests (Atanda, Pessu, Agoda, Isong & Ikotun, 2011). To close this gap, many preserving and processing technologies have been designed (FIRCA, 2010).

In rural area of Côte d'Ivoire, the senescent plantain is turned into a meal called *dockounou* during seasons of high output. It's a classic meal made with senescent plantain pulp (90:10) and grain flour like rice or maize (Akoa, Kra, Mégnanou, Akpa & Ahonzo, 2012); (Akoa, Kra, Mégnanou, Kouadio & Niamké, 2014). People from many walks of life value and consume it (adults, adolescents and children). It is a meal with a high mineral content as well as a high energy value. It is, however, a food with little nutritional value due to its low fat and protein content (Kra, Akoa, Megnanou, Yeboue, Akpa & Niamke, 2013). Furthermore, this meal may only be kept at room temperature (37 ℃) for 3 to 5 days and in the refrigerated for 10 to 12 days (Akoa, 2014).

To make *dockounou* a complete food that meets FAO/WHO (1991) standards and is suitable for infant nutrition, it has been enriched with high nutritional potential foods such as soybean and fish, which are high in protein and trace elements. It was also processed into flour to extend its shelf life and availability. The goal of this study was to confirm the nutritional potential of flour made from enriched *dockounou* for children under the age of ten years.

2. Materials

The senescent plantain (*Musa paradisiaca*), soybean (*Glycine max*), maize (*Zea mays*), and fish (*Trachurus trachurus*) were purchased at the Socofrais supermarket in Abidjan, Côte d'Ivoire, during the second quarter of 2020. *Thaumatococcus daniellii* leaves were acquired from the Gouro market in Adjamé (Abidjan, Côte d'Ivoire) to package the fortified *dockounou*.

3. Methods

3.1 Preparation of the Flours Used to Make Dockounou

3.1.1 Preparation of Maize Flour

Maize grains were sorted, rinsed in tap water, and steeped at room temperature (25 ±2 ℃) for 18 hours. The kernels were allowed to germinate for 48 hours after soaking. The germinated grains were subsequently dried in an oven at 50 ℃ (venticell, MMM Medcenter, Germany) and pulverized in a moulinex (Moulinex, Groupe SEB, France). The flour was sieved through a fine mesh sieve (200 µm) before being roasted at 70 ℃ for 30 minutes on a hot plate with a probe.

3.1.2 Preparation of Soybean Flour

Two (02) kg of soybeans were sorted, washed with tap water until the dust was removed and soaked in tap water for 24 h at room temperature (37 ± 2 ℃) in a clean basin covered with a cloth. After 24 h, the soaked grains were washed again with tap water and drained with a sieve and dried at 50 ℃ for 24 h in an oven (venticell, MMM Medcenter, Germany). The dried grains were then lightly crushed in a mortar and winnowed to remove the gemmules and the film before being ground using an electric mill (Moulinex, Groupe SEB, France). The resulting flour was also sieved using a fine mesh sieve (200 µm), then roasted on a hot plate at 70 ℃ for 30 minutes and stored after cooling under the same conditions.

3.1.3 Preparation of Fish Flour

Fresh fish, after being eviscerated and washed with tap water, were dried over charcoal embers before being steamed for drying at 50 ℃ for 19 h in a venticell brand oven. After drying, the samples were finely ground in a moulinex brand electric mill. The powder obtained was then sieved with a fine mesh sieve (200 µm).

3.2 Preparation of Maize Dockounou Enriched with Soybean and Fish

The *dockounou* preparation process was revised from the reported optimal approach (Akoa et al., 2014). To prevent enzymatic browning, 0.2 % of ascorbic acid was added to the paste. Three formulations, Ms1, Ms2, and Ms3, were formulated, each with a different proportion of maize. Each composition included 75% of senescent plantain paste and 25% of flour-based component combination. The paste was mixed with the remaining ingredients, and the resulting homogenous mixture was fermented at room temperature (37 ±2 ℃) for 3 hours. After fermentation, 150 g portions of the fermented pastes were wrapped in *Thaumatococcus danieilii* leaves and baked at 150 ℃ for 1 hour in an electric oven.

3.3 Processing of Enriched Dockounou into Flour

After being cut, the cooked *dockounou* was processed into flours, dried in an oven at 50 ℃ for 24 hours, and ground with an electric mill. The flours were sieved with a fine mesh sieve (200 m) and stored at room temperature (37 ±2 ℃) in clean glass jars for various analyses.

3.4 Physicochemical and Biochemical Analyses

The dry matter and moisture contents were determined using (AOAC, 1990) method, the ash content using the AOAC (1980) method, the pH and titratable acidity using (AOAC, 1990) method, the fiber content using the Wolf (1968) method, the fat content by using BIPEA (1976) method, the total protein content using (AOAC, 1990) method, and the reducing and total sugar content through using (Bernfeld, 1955) and (Dubois, Gilles, Hamilton, Rebers & Smith, 1956). The total carbohydrate and starch contents were calculated using (FAO, 1947) recommended method, and the energy value of enriched *dockounou* flours was calculated using (FAO, 2002) energy coefficients.

3.5 Statistical Analysis

All analyses were carried out in triplicate. The analysis of variance (ANOVA) was used with the SPSS software version 20.0.0 to compare the flours from the dependent variables using the "Duncan" test. The XLSTAT software version 2014.5.03 was used to perform the principal component analysis (PCA) for the identification of the discriminating parameters. These statistical tests determined the variability within the various samples analyzed, as well as the statistical significance at $P \leqslant 0.05$.

4. Results

4.1 Result of Physicochemical and Biochemical Evaluations of Enhanced Maize Dockounou Flours

Table 1 displays the results of physicochemical and biological tests of improved *dockounou* flours. Statistical research demonstrates a significant variation in pH, titratable acidity, proteins, reducing sugars, total sugars, carbs, starch, and fiber content of the various maize *dockounou* flours enhanced with soybean and fish at the 5% level. The pH values found range from 6.43 ±00 to 6.7 ±00 for Ms2 maize *dockounou* flour and Ms3 maize *dockounou* flour, respectively. The titratable acidity varies from 15.33 ±1.15 meq to 18 ±00 meq per 100 g DM for Ms2 maize *dockounou* flour and Ms3 maize *dockounou* flour, respectively. Protein content ranges from 11.30 ±00 % to 14.13 ±1.29 % per 100g DM for Ms2 maize *dockounou* flour and Ms3 maize *dockounou* flour, respectively. Reducing sugar amount ranges from 5.54 ±0.22 g to 9.28 ±0.57 g per 100 g DM for Ms3 and Ms2 maize *dockounou* flour, respectively, whereas total sugar content ranges from 12.72 ±0.09 g to 13.75 ±0.03 g for Ms2 and Ms3 maize *dockounou* flour. Total carbohydrate content is between 57.74 ±1.44 g and 60.43 ±0.44 g per 100 g DM for Ms3 maize *dockounou* flour and Ms2 maize *dockounou* flour, while starch content ranges between 39.59 ±1.3 and 42.94 ±0.38 g/100 g DM for Ms3 maize *dockounou* flour and Ms2 maize *dockounou* flour. Fat content varies from 9.73 ±0.11 % to 10.00 ±00 % per 100 g DM for Ms3 maize *dockounou* flour and Ms1 maize *dockounou* flour, with statistically significant variations. The fiber content of the samples ranges from 2.83 ±0.29% for *dockounou* flour Ms3 to 4.33 ±0.29% for *dockounou* flour Ms2. There was also no significant change in ash content, moisture content, dry matter content, or energy value between *dockounou* flours Ms1, Ms2, and Ms3. The ash concentration ranges from 5.20% (for Ms2 and Ms3 maize *dockounou* flour) to 5.270.11%. (for Ms1 maize *dockounou* flour). Ms3 and Ms1 flours have energy values of 375.06 1.1 Kcal and 375.89 0.51 Kcal per 100 g DM, respectively. These two values are statistically comparable.

Table 1. Physicochemical and biochemical composition of enriched *dockounou* flours

Enriched dockounou flour / *Nutritional parameters*	*Ms1*	*Ms2*	*Ms3*	*Standards*
Ash (%)	5.27 ± 0.11^a	5.2 ± 00^a	5.2 ± 00^a	3
pH	6.43 ± 0.05^a	6.5 ± 00^b	6.7 ± 00^c	-
Titratable acidity (meq/100g)	18 ± 00^c	15.33 ± 1.15^a	16 ± 00^b	-
Moisture (%)	13.26 ± 0.13^a	13.2 ± 0.2^a	13.2 ± 0.17^a	5
Dry matter (%)	86.74 ± 0.13^a	86.8 ± 0.2^a	86.8 ± 0.17^a	95
Fats (%)	10 ± 00^b	9.87 ± 0.23^a	9.73 ± 0.11^a	10 - 25
Proteins (%)	13.02 ± 00^b	11.30 ± 00^a	14.13 ± 1.29^c	15
Reducing sugars (g)	7.51 ± 0.45^b	9.28 ± 0.57^c	5.54 ± 0.22^a	-
Total sugars (g)	13.29 ± 0.19^b	12.72 ± 0.09^a	13.75 ± 0.03^c	-
Carbohydrates (g)	58.46 ± 0.13^b	60.43 ± 0.44^c	57.74 ± 1.44^a	64
Starch (g)	40.65 ± 0.1^b	42.94 ± 0.38^c	39.59 ± 1.3^a	-
Fibers (%)	4 ± 00^b	4.33 ± 0.29^c	2.83 ± 0.29^a	5
Energetic value (kcal)	375.89 ± 0.51^a	375.73 ± 0.32^a	375.06 ± 1.1^a	400

Each value is the average of the analysis of three trials. Different letters (a, b and c) on the same line indicate a statistical difference ($p < 0.05$).

4.2 Result of Mineral Content of Enriched Dockounou Flours

Table 2 displays the mineral composition of enhanced *dockounou* flours. Statistical study showed a substantial difference in 5 % of enhanced *dockounou* flours. The phosphorus content of Ms1 and Ms3 maize *dockounou* flour varies from 31.88 ±01 mg to 34.09 ±00 mg. Ms1 maize *dockounou* flour has a potassium level of 97,00 mg, whereas Ms3 maize *dockounou* flour has a potassium content of 140,00 mg. The calcium content of Ms1, Ms2, and Ms3 maize *dockounou* flours is 128.88 ±00 mg, 131.78 ±00 mg, and 174.09 ±00 mg, respectively. The magnesium content of Ms1, Ms2, and Ms3 maize *dockounou* flour is 19.25 ±00 mg, 19 ±00 mg, and 19 ±00 mg, respectively. The iron values of the enhanced *dockounou* flours range from 4.17 ±00 mg to 4.69 ±0.1 mg for Ms3 and Ms1 maize *dockounou* flour, respectively. The sodium concentrations of Ms1 and Ms2 maize *dockounou* flour range from 27.03 ±0.59 to 43.29 ±00 mg, respectively. Zinc concentration ranges from 10.14 ±0.22 mg to 14.27 ±00 mg for Ms1 and Ms2 maize *dockounou* flour.

Table 2. Mineral content of maize enriched *dockounou* flours

Enriched dockounou flour / *Minerals content*	*Ms1*	*Ms2*	*Ms3*
Phosphorus (mg)	31.88 ±00a	33.78 ±00b	34.09 ±00c
Potassium (mg)	97 ±00a	98 ±00b	140 ±00c
Calcium (mg)	128.88 ±00a	131.78 ±00b	174.09 ±00c
Magnesium (mg)	19.25 ±00b	19 ±00a	19 ±00a
Iron (mg)	4.69 ±0.1c	4.34 ±00b	4.17 ±00a
Sodium (mg)	27.03 ±0.59a	43.29 ±00c	40.76 ±00b
Zinc (mg)	10.14 ±0.22a	12.84 ±00b	14.27 ±00c
Calcium/phosphorus ratio	4.04 ±00b	3.90 ±00a	5.11 ±00c
Sodium/potassium ratio	0.29 ±00a	0.44 ±00b	0.29 ±00 a

Each value is the average of the analysis of three trials. Different letters (a, b and c) on the same line indicate a statistical difference ($p < 0.05$).

5. Discussion

According to Soro, Konan, Elleingand, N'guessan, & Koffi, (2013), the somewhat acidic pH of maize *dockounou* flours enhanced with soybean and fish might be a strategy of resisting microbial assault. The enhanced *dockounou* flours can thus be kept for an extended length of time without concern of microbiological degradation (aerobic mesophilic germs, yeasts etc.). The high quantity of organic acids in the flours, such as acetic acid, lactic acid, and butyric acid, may result in a high degree of acidity, which may be an essential element in the food's stability and safety (Caplice & Fitzgerald, 1999). The presence of these organic acids would aid in the prevention of diarrhea in young infants (Lorri & Svanberg, 1994).

The protein levels reported in the Ms3 diet (13.2 %) are comparable to the FAO/WHO (1991) protein in baby meals standard of 15 g/100 g DM. The obtained protein levels are greater than the 3.9 ±1.7 g/100 g DM reported by (Tshite, Mulamba & Ndianabo, 2015). The mix of cereals, legumes, and animal protein sources in our flours produces proteins with great biological value, containing vital amino acids, minerals and vitamins. WHO/UNIICEF (2003) recommends combining cereals and legumes as an alternative to animal protein shortage in the diet. Proteins are vital macromolecules for the efficient functioning of the body, and include them in the diet encourages appropriate growth in children of weaning age. The reducing sugar levels are lower than those reported by Aboubakar (2009) on taro flours (13.5 % to 26.7 %), but greater than those reported on sweet potato flours (1.2 % to 2.8 %) of Ndangui, (2015). According to studies of Jangchud K, Phimolsiripol, & Haruthaithanasan, (2003), reducing sugars content is proportional to starch content, and so the greater the starch level, the lower the reducing sugars content. Sugars, in addition to playing a key part in dietary energy content, may also assist meals to last longer.

The carbohydrate contents of enriched *dockounou* flours are high and comparable to those obtained by (Songre-ouattara, Gorga, Bationo, Savadogo & Diawara, 2016) (53.2 ±2.2 g DM to 68.5 ±0.5 g/100 g DM) in sorghum cookies enriched with moringa, spirulina, sweet potato, mineral and vitamin complex. The contents obtained by Kouassi et al. (2015), which range between 60 % and 70 % are comparable to those obtained in *dockounou* flours enriched with soybean and fish. Carbohydrates are one of most important products of starch hydrolysis. The starch content obtained is less than the FAO/WHO (2006) standard which is 64 g/100 g DM and less than the plantain standard of 56 g/100 g. This explain the fact that senescing plantain main food matrix is deficient in starch, which is essentially converted into reducing sugars. The starch content obtained is the same as that of maize flour use for *dockounou* formulation. Carbohydrate content of enriched *dockounou* flour has a higher energy value. Their abundance promotes proper body functioning.

The fiber content obtained in this study is greater than that obtained by Fogny et al. (2017) (2.16 ±0.08 g/100 g DM) and Soro et al. (2014) (2.95 ±0.18 g/100 g DM). This level, however, is within the FAO/WHO (1991) standard, which recommends a fiber content of less than 5 g/100 g DM. The high fiber content of enriched *dockounou* flours is beneficial because it makes the flours more digestible and facilitates intestinal transit. Fiber is essential in the diet because it helps to maintain an acidic digestive environment by lowering pH. It lowers cholesterol and blood sugar levels, boosts microbial activity in the colon, and speeds up the absorption of certain micronutrients like calcium (Spiller, Woods & Gorbach, 2001; Anderson et al., 2009; Sika et al., 2019; Songré et al., 2016; & FAO/WHO, 1991) standard of 3 mg/100 g all obtained ash higher values than those of this study. The mineral content of a food is indicated by its ash content (Sika et al., 2019). As a result, these flours may be good sources of minerals for the growth of children who will consume them. In studies by Ijarotimi and Oluwalana (2013), the moisture contents are higher than those of soybean and moringa enriched with maize flour (8.02 ±0.24 g/100 g DM) and comparable to those of cerelac (5 %) (2013). The moisture content of *dockounou* flours is lower than the moisture content of maize (12.38g/100g) and millet (19.71g/100g) flours determined by Sall (1998) in Senegal.

The energy values of the *dockounou* flours are in agreement with the values reported by Kouassi et al. (2015) for fermented compound cereal flour (361.39 ±1.52 Kcal/100 g DM) and Ijarotimi and Oluwalana (2013) for popcorn and bleached moringa flours (389.69 ±1.40 Kcal/100 g DM). These values are slightly lower than those obtained by (Sika et al., 2019), which range from 397.27 ±0.90 to 400.86 ±0.49 Kcal/100 g DM, and the 400 Kcal/100 g DM recommended by FAO/WHO (1991). As a food supplement for children who receive daily family food rations, these energy values could cover the daily requirements of weaning age children. Foods with high energy values would allow children to better assimilate the nutrients they require for development (Ponka, Nankap, Tambe & Fokou, 2016).

Lipids are one of the potential sources of energy, a high lipid content contributes to an increase in the energy value of a food (Henry, 1974). The results of this study are comparable to the FAO/WHO (2006) recommendation of 10%. These results are higher than those obtained by Kouassi et al. (2015), who obtained 4.5 ±0.5 g and 7.5 ±0.5 g of fermented and sprouted composite flours, respectively. This high lipid content in *dockounou* flours could be explained by the inclusion of soybean and fish in the feed, both of which are good sources of lipids.

Calcium and potassium were found to be the most abundant minerals in fortified *dockounou* flours based on mineral content analysis. The high potassium content of *dockounou* flours is thought to be due to the high potassium content of the plantains and cereals used to make enriched *dockounou* flours (Assemand, Camara, Kouamé, Konan V. & Kouamé, 2012 ; Adeyeye and Ajewole, 1992). Potassium is a hypotensive agent that also plays a role in muscle contraction (Dedehou et al., 2015). It is also involved in electrolyte maintenance, osmotic pressure regulation, nerve impulse conduction, and the reduction of kidney stones in the body. Thus, fortified *dockounou* flours may be a good source of potassium for consumers' bodies, particularly for children after weaning.

Sodium is an essential mineral for the body which contributes to the maintenance of water balance, the improvement of cerebral functions, in the regulation of acid-base balance and the stabilization of blood pressure. Its daily consumption is recommended for the proper functioning of the body. The sodium/potassium ratio of all *dockounou* flours is less than 1. This ratio is in conformity with the FAO/WHO standard (1991). The conformity of the sodium/potassium ratio shows that the absorption of these two minerals could be optimal.

The calcium contents observed in this study are higher than those obtained by (Gnagne, Akely, Petit, Scher & Amani, 2017) in flours used for the production of instant foufou and foutou (4.60 to 7.08 mg/100g). Calcium helps maintain acid-base balance and promotes the control of energy metabolism in the body. It is a constituent of teeth and bones, thus allowing good bone development and growth in children who consume it regularly. Phosphorus, is essential mineral to life. It is involved in maintaining of blood pH, and the formation of bones and teeth. It is essential in the process of producing ATP (Adenosine triphosphate), which is the main source of energy for metabolism (D'Elia, 1977). Thus, its regular consumption is essential for the proper development of the human body. According to (Appiah, Oduro & Ellis, 2011), a Ca/P ratio must be higher than 1 to prevent mineral and osmotic imbalance that could lead to inflammation. According to these authors, any good food should have a Ca/P ratio greater than 1. Magnesium is one of the most abundant minerals in human body. It acts on various organs of the neuromuscular and cardiovascular systems. It is an essential mineral that is involved in the synthesis of proteins, amino acids, lipids and carbohydrates. Its deficiency is the cause of many disorders that can be fatal for the body. It is therefore necessary to have it in a satisfactory quantity in the daily diet for the proper functioning of the body. Zinc is an integral part of many enzymes and is important for the human body (Challem, 2003). It is a mineral that participates in the strengthening of the immune system and is also essential for the synthesis of nucleic acids. According to FAO/WHO (2001), a zinc-rich food can be used in the treatment of stunted growth and skin lesions. It is also involved in the storage and regulation of insulin which regulates blood sugar levels. The presence of zinc in *dockounou* flour could help to overcome deficiencies in children. Iron plays an important role in the body. As a constituent of hemoglobin, it enables the transport of oxygen in the body. Iron is also involved in numerous metabolic and enzymatic reactions and in the proper functioning of the brain. The presence of iron in food could help prevent iron deficiency anemia.

Relationship between physicochemical and biochemical parameters and the different flours of dockounou enriched with fish and soybean

PCA (Principal Component Analysis) was used to relate physicochemical and biochemical parameters to the three (3) *dockounou* flours with enriched soybean and fish. The PCA determined that all of the parameters are discriminant (cosine squared greater than 0.5) and are represented by two principal component axes, F1 and F2 (Table 3). At an Eigen level of one, the two components F1 and F2 explain the variability of each parameter, according to this table.

The F1 component explains the pH, fat, protein, reducing sugars, total sugars, total carbohydrates, starch, fiber, and energy value, whereas the F2 component explains the variability of the parameter's ash, titratable acidity, moisture, and dry matter. Figure 1 shows that the two axes F1 and F2 explain 100% of the variability for each parameter: the F1 axis explains 58.66% of the variability and the F2 axis explains 41.34% of the variability. As a result, these two axes were taken into account for the principal component analysis.

The biplot in Figure 1 not only confirms the correlations expressed by the Pearson indices in the correlation matrix but also provides insight into the parameters that determine each of the three formulations. Thus, the parameters are grouped in the plane around each of the formulations. The Ms1 formulation groups the parameters titratable acidity, ash, moisture, protein and total sugars which are strongly correlated by the F1 axis. Fiber, reducing sugars, starch, total carbohydrates, fat and energy content are correlated with the Ms2 formulation. On the other hand, pH and dry matter better express the Ms3 formulation.

According to this analysis (PCA), the two formulations Ms2 and Ms3 appear to be the best in terms of the factors that describe them. We were able to find the optimal formulation by comparing the two flours to the standard values. Thus, Ms3 flour has the characteristics of a protein-energy diet that is commonly recommended for children, with ash, fat, protein, and energy values that are near to those of the standard. According to this analysis, the best flour is Ms3 since it is closest to the nutritional guidelines for children under the age of ten.

Table 3. Discriminating physico-chemical and biochemical parameters of *dockounou* maize flours enriched with soybean and fish

Axis / *Nutritional parameters*	F1	F2
Ash (%)	0.1934	0.8066
pH	0.9007	0.0993
Titratable acidity (meq/100g)	0.0442	0.9558
Moisture (%)	0.1934	0.8066
Dry matter (%)	0.1934	0.8066
Fats (%)	0.7084	0.2916
Proteins (%)	0.7004	0.2996
Reducing sugars (g)	0.8303	0.1697
Total sugars (g)	0.7557	0.2443
Carbohydrates (g)	0.5677	0.4323
Starch (g)	0.6199	0.3801
Fibers (%)	0.9798	0.0202
Energetic value (kcal)	0.9384	0.0616

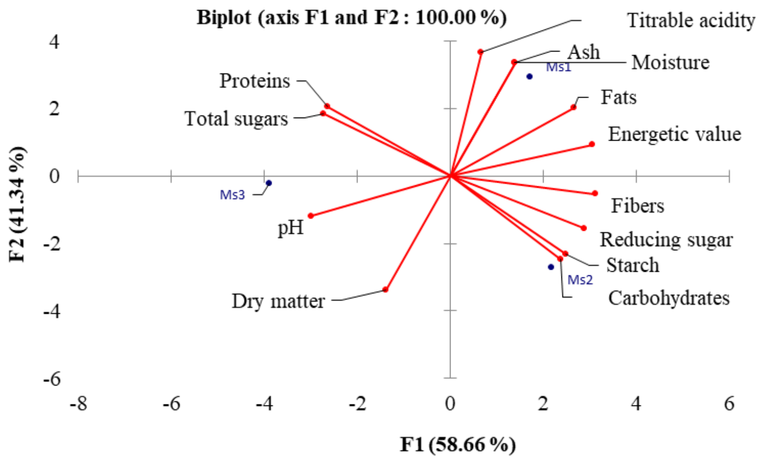

Figure 1. Biplot of physico-chemical and biochemical parameters of maize *dockounou* flours enriched with soybean and fish

6. Conclusion

The research enabled for the creation of flours made from plantain dockounou and enhanced maize. These flours have the nutritional ability to satisfy the protein-energy demands of children under the age of ten (10) years old, and their compositions are usually in accordance with WHO approved supplemental food criteria. These flours included high amounts of protein, fat, titratable acidity, total carbs, and energy values sufficient to fulfill the energy requirements of children under the age of ten for optimal growth. However, because the moisture level of the flours was high and slightly over the required limit for infant flours, it would be prudent to assess the shelf life of these meals, as a high water content would promote the growth of bacteria. The statistical analysis allowed us to classify the different flours in order to highlight the best one, which is the Ms3 flour.

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