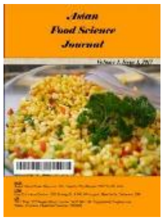

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# Physicochemical and Functional Properties of Flours from Three Purple Maize Varieties Named "Violet de Katiola" in Côte d'Ivoire

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author SLN designed the study. Authors FAA did all laboratory work, wrote the protocol and the first draft of the manuscript. Authors DMK and MC performed the statistical analysis, managed the analysis of the study. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aims:** The study examined the proximate composition and functional properties of flours from three purple maize varieties from Côte d'Ivoire with a view to exploring their potential uses in food and non-food applications.

**Study Design:** Three different purple maize varieties were grown on different experimental plots and the harvested dry maize kernels were processed into flours to determine their physicochemical and functional characteristics.

**Place and Duration of Study:** The study took place at the Biotechnology Laboratory of Felix Houphouët-Boigny University. May to December 2017.

**Methodology:** After collecting dry maize kernels from experimental plots they were processed into maize flour. Physicochemical composition and functional properties were investigated using standard methods. The yellow corn variety was used as a control in this study.

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**Results:** The results reveal that purple corn flours had highest in protein (ranging from 9.72 to 10.09 g/100 g) and fat (ranging from 5.87 to 6.21 g/100 g) contents as well as energy value (ranging from 380.66 to 384.04 kcal/100 g) while carbohydrate and starch contents were found to be highest in yellow corn flour with values of 77.85 and 67.27 g/100 g, respectively. Mineral composition showed that the consumption of 100 g of flours from purple corn would provide about 32% of the Recommended Dietary Allowances of iron. Also, purple corn samples contain higher total phenolic compounds (232.14 – 253.80 mg/ 100 g) compared to yellow corn variety (116.51 mg/ 100 g). These total polyphenols were mainly constituted of anthocyanins (135.87 – 178.54 mg/ 100 g). Therefore, they exhibited a good antioxidant activity (69.22%) Concerning the functional properties of flours from purple and yellow maize, there was no significant difference. These flours recorded high bulk density, dispersibility and oil absorption capacity as well as good wettability and foam stability.

**Conclusion:** purple maize varieties recorded a good antioxidant activity related to their content of polyphenolic compounds. This suggests their potential health benefits like in prevention of many metabolic and neurodegenerative diseases. These corn varieties have also exhibited interesting functional properties, therefore, would be suitable for use as a functional ingredient in many food formulations.

*Keywords: Flours; purple corn varieties; "violet de Katiola"; physicochemical composition; functional properties.*

## ABBREVIATIONS

*YC : Yellow Corn*
*DPC : Dark Purple Corn*
*LPRC : Light Purple Red Corn*
*LPC : Light Purple Corn*

## 1. INTRODUCTION

Cereals are the most widely cultivated and consumed crops globally. In developing countries, cereal-based diets are the main source of energy and nutrients [1]. Among these crops, maize or corn (*Zea mays* L.) is the first one as regard production. Global production of corn exceeded 1 billion metric tons in 2013, and about 35% was produced in the United States of America. But, it ranks as the third most important cereal grain in the world, after wheat and rice, as staple food [2]. Although, worldwide, 60–70% of maize production is used as livestock feed, it remains an important cereal crop, serving as the major staple in the diet to a large population of Africa, Asia and Central and South America. Maize is mainly a basic source of carbohydrates (about 70 - 74%, mostly in the form of starch) and also constitutes a convenient source of minerals, vitamins and antioxidant compounds with number of health benefits [3]. It contains approximately 9% protein, and nearly 5% lipid mainly consists of unsaturated fatty acids [4].

Maize kernel is the edible and nutritive part of the plant. These kernels can be eaten raw, cooked, grilled, in a salad or soup, dry (popcorn, etc.), or used in a feed mill or as fresh feed or silage. Maize products and processing methods are as diverse as the maize crop itself [2]. Thus, processing maize can produce a wide range of products such as corn flour and corn meal. Corn flour is one of the most common ingredients in food preparation and is used as an alternative to wheat flour because of similar calorie content. For example, in some countries such in Spain, Portugal or Bangladesh bread is made from whole maize flour. Maize is also used in livestock feed (poultry, pigs, cattle) in the form of grains, feed milling or as fodder [1]. Moreover, it is used as raw material in a range of bioindustrial products such as biodegradable plastics, biofuel and even alcohol [5].

In many part of the world, maize colour is important to specific consumer groups. Thus, white maize is preferred for food consumption in Central and South America as well as in Africa. However, in other areas of the world, the desired colour could depend on the region or the food use. Then, although most consumers prefer white maize, other varieties are also used for making bread, like yellow and purple maize [6].

Concerning purple corn, it has been reported for its substantial amounts of phenolic compounds especially anthocyanins, among other phytochemicals, which give the corn its vibrant colour. Indeed, anthocyanins are water soluble pigments responsible for the purple, blue and red colours in vegetal tissues, belonging to the class of flavonoids [7]. Interest in anthocyanins has increased due to their colour properties and potential health benefits as an alternative to the use of synthetic dyes. Due to their high antioxidant and bioactive properties, anthocyanin-rich foods and anthocyanin pigments have been suggested as potential agents to reduce the risk of colon cancer. Many authors have shown that an anthocyanin-based food colorant from purple corn was able to inhibit cell mutation, reduce chemically induced colorectal carcinogenesis, and may aid in the prevention of some chronic diseases like obesity, diabetes and cardio pathology [8].

In Côte d'Ivoire, there are different maize varieties including the purple corn whose culture is confined to Katiola (Central-North) and in surrounding areas. In this part of the country, the purple maize locally called "Violet de Katiola" is the most widely grown and prized maize variety because of its important socio-cultural character, its good organoleptic quality, its market value and its therapeutic virtues. Based on the intensity of the colour of kernels, three local cultivars of purple corn were identified: the light purple, light purple red and dark purple cultivars [9,10]. To our knowledge, there are no reports concerning the biochemical characteristics of flours from these three different purple corn varieties cultivated in Côte d'Ivoire. This paper focuses on the physicochemical and the functional properties of flour from these purple corns harvested in Côte d'Ivoire to explore their potential uses in food and non-food applications.

## 2. MATERIALS AND METHODS

### 2.1 Raw Material

Dry kernels of three different varieties of Ivorian purple maize and the ordinary yellow maize (taken as control) were employed as raw material. Ordinary yellow maize kernels were purchased from local market in Abidjan. Purple maize seeds were grown during its appropriate cropping season (raining season from May to July) in 2017 on experimental plots of the National Center of Floristic of the University Felix Houphouet Boigny and Bingerville (5°21′ N and 3°54′ W). After harvesting and drying, 30 kg of each sample were collected and transported to the Biotechnology Laboratory of Felix Houphouët-Boigny University for analysis.

### 2.2 Flour Production

Maize flours were produced according to the process described by Moreira et al. [6], slightly modified. Dry kernels were sorted and free from any kind of waste, and then 5 kg of each sample was ground using an electric crusher to obtain the crude flours. These crude flours were sieved with a mesh screen of 250 µm. The final products obtained were placed in a closed vessel (desiccator) with constant temperature (25°C) and relative humidity of air (54%) employing blue silica gel, until equilibrium between samples and surrounding air was reached in order to reach constant moisture content in flours (7–10%).

### 2.3 Proximate Analysis

The moisture content was determined by drying in an oven at 105°C during 24 h to constant weight AOAC [11]. The crude protein content was calculated from nitrogen contents (N×6.25) obtained using the Kjeldahl method by AOAC [11]. The crude fat content was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent AOAC, [11]. The total ash content was determined by incinerating in a furnace at 550°C AOAC, [11]. The crude fibre content was determined by taking about 3.0 g sample as a portion of carbohydrate that resisted sulfuric acid (1.25%) and NaOH (1.25%) digestion followed by sieving (75 µm), washing, drying and ignition to subtract ash from fibre AOAC [11]. The carbohydrate content was determined by deference that is by deducting the mean values of other parameters that were determined from 100. Therefore % carbohydrate = 100- (% moisture + % crude protein + % crude fat + % ash).

### 2.4 Mineral Analysis

The method described by AOAC [11] was used for mineral analysis. Flours were digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L) and analysed using an atomic absorption spectrophotometer. As for the total phosphorus, it was determined as orthophosphate following the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent [12].

### 2.5 Polyphenolic Compounds Determination and Antioxidant Activity

Total polyphenols were extracted and determined using the method reported Singleton et al. [13]. Tannins of samples were quantified according to Bainbridge et al. [14] method. The total flavonoids content was evaluated using the method reported by Meda et al. [15]. The total anthocyanin content was determined according to the pH differential method described by Giusti et al. [16] after extracting the anthocyanin with a solution of methanol acidified with 1% HCl.

The antioxidant assay was carried out using the 2,2-diphenyl-1-pycrilhydrazyl (DPPH) spectro-photometric method outlined by Choi et al. [17]. About 1 mL of 0.3 mM DPPH solution in ethanol was added to 2.5 mL of sample solution (1 g of flour sample mixed in 10 mL of methanol and filtered through Whatman No. 4 filter paper) and was allowed to react for 30 min at room temperature. Absorbance values were measured with a spectrophotometer (PG Instruments, England) set at 415 nm. The average absorbance values were converted to percentage antioxidant activity using the following formula:

Antioxidant activity (%) = 100 – [(Abs of sample – Abs of blank) x 100/Abs positive control].

## 2.6 Evaluation of Functional Properties

Bulk density was determined as described by [18]. Dispersibility of flours was measured according to the method of Mora-Escobedo et al. [19]. Water absorption capacity and water solubility index of flours were determined following the methods of Phillips et al. [20], Anderson et al. [21], respectively, while oil absorption capacity was evaluated as described by Beuchat [22]. Foaming capacity (FC) and foam stability (FS) were measured according to the method of Coffman and Gracia [23]. The volume of foam at 30 sec of whipping was expressed as FC. The volume of foam was recorded 3 h after whipping to determine FS as percent of the initial foam volume. The wettability was determined as described by Onwuka [24].

## 2.7 Statistical Analysis

Statistical analysis of data was done by the one way Analysis of Variance (ANOVA) using software IBM SPSS Statistics version 20.0. Differences between means were tested using the Duncan Multiple Range Test with 5% level of significant difference and figures were drawn on Excel 2013 Software.

# 3. RESULTS AND DISCUSSION

## 3.1 Proximate Composition

The proximate composition of flours from the three purple maize varieties was presented in Table 1. The results reveal that purple corn flours had highest in the protein (ranging from 9.72 to 10.09 g/100 g) and fat (ranging from 5.87 to 6.21 g/100 g) contents as well as energy value (ranging from 380.66 to 384.04 kcal/100 g) while carbohydrates and starch was found to be highest in yellow corn flour with values of 77.85 and 67.27 g/100 g. Globally, the ash and cellulose contents were statistically similar for all studied flours.

The moisture contents ranged between 5.05 to 6.25 g/100 g are lower than values (11.6 – 20%) reported by Enyisi et al. [25] for maize flours obtained from selected market in Kaduna state (Nigeria). Moreover, these values are largely lower compared with the 15 % as recommended by Codex-Alimentarius [26]. This is an indication that the studied flours could show good conservation abilities because low moisture content inhibits microbial growth and enzyme activities which greatly decelerates spoilage.

Maize is generally known to be high in carbohydrate and as such a good source of calories. This has been observed in different type of maize kernels analysed in this study which shown maximum carbohydrate content of 77.85 g/100 g. These values were greater than that of Quality Protein Maize from IITA (74.43%) as reported by Edema et al. [27]. Moreover, the starch contents (ranging from 64.43 to 67.27 g/100 g) confirm the fact that starch is the predominant component (61 to 78, dry matter basis) of normal corn kernel. Thus, the carbohydrate contents and mainly the high amount of starch would explain the high energy levels (380.66 to 384.04 kcal/100 g) provide by flours from the studied purple corn. Indeed, consumption of 100 g of these flours would provide about 20% of the daily energy intakes recommended for a 70 kg person. Furthermore, view the high amount of starch, the whole samples could be exploited either in food or non-food industries.

As regard no starch polysaccharides, it is well known that they mainly consist of cellulose also called crude fibre. So, the cellulose contents of the studied corn kernels, ranged from 1.39 to 1.60 g/100 g, were in agreement with the findings of Cisse et al. [4], who reported cellulose contents in the range of 1.31– 1.76 g/100 g, for ordinary maize and QPM varieties in Côte d'Ivoire. Maize contains a fraction of starch, known as resistant starch, which escapes the digestion in the small intestine and is passed into the large intestine for microbial fermentation. This starch, categorized as a type of dietary fibre as well as cellulose and hemicellulose, can provide potential colon health benefits after consumption. It has been demonstrated that fibre, particularly its insoluble fraction, helps normalize intestinal obstipation, accelerating and increasing the faecal bulk.

The protein and fat contents of the three studied purple corn varieties were greater than that of ordinary yellow variety taken as control. . Grain oil is an important source of essential fatty acids. These essential fatty acids help maintain the body's cells, protect the nervous system and also help fight against bad cholesterol [28]. As for proteins, they are involved in all vital processes of the body and their functions are essential for maintaining health [29]. With a value of 10.09 g/100 g, the dark purple variety has shown the highest protein content. There was no significant difference in the crude fats of the purple maize varieties. So the obtained values are in the range of normal corn kernels protein content (6 to 12 g/100 g) as well as normal corn kernels fat content (3 to 6 g/100 g) as reported by Yongfeng and Jay [30]. However, protein and fat contents of the studied purple maize varieties were higher than those found for Quality Protein Maize (9.72 and 4.85% for crude protein and crude fat, respectively) and common maize (9.80 and 4.50% for crude protein and crude fat, respectively) in Nigeria [31].

## 3.2 Mineral Composition

It is noteworthy that minerals play an important part in biological processes. The recommended dietary allowance (RDA) and adequate intake are generally used to quantify suggested daily intake of minerals. The mineral composition of flours from Ivorian purple corn varieties is shown in Table 2. Result reveals that potassium (236.56 – 307.29 mg/ 100 g) was the most predominant mineral followed by phosphorus (115.94 – 128.06 mg/ 100 g), magnesium (75.97 – 98.30 mg/ 100 g), calcium (10.49 – 12.41 mg/ 100 g), sodium (2.27 – 3.38 mg/ 100 g), iron (2.21 – 2.58 mg/ 100 g), zinc (2.18 – 2.32 mg/ 100 g) and copper (0.39 – 0.67 mg/ 100 g). There are significant differences in some mineral contents especially iron and calcium. The purple maize varieties are slightly richer in iron while yellow maize has the best grade regarding calcium. The consumption of 100 g of flours from purple corn would provide about 32% of the Recommended Dietary Allowances of iron. This corroborates the fact that except iron, maize as well as other cereals does not contain considerable amounts of minerals [32]. Moreover, the iron contents of studied purple corn varieties were greater than those reported by Edema et al. [27] for common maize (1.10%) and Quality Protein Maize from IITA (0.82%). So, these purple maize kernels might become an important source of iron for those who cannot afford better sources of this mineral such as meat or fish and their derivatives.

## 3.3 Polyphenolic Compounds and Antioxidant Activity

As shown in Table 3, purple corn samples contain higher total phenolic compounds (232.14 – 253.80 mg/ 100 g) compared to yellow corn variety (116.51 mg/ 100 g). Cereal polyphenols are important phytochemicals. They exhibit significant antioxidant activity in preventing oxidative damage in tissues by reducing lipid oxidation and/or inhibiting free radicals production [33]. These total polyphenols were mainly constituted of flavonoids (179.16 – 190.95 mg/ 100 g) especially anthocyanins (135.87 – 178.54 mg/ 100 g). Statistical analysis shows that the dark purple corn variety had the highest content of these compounds. It is this high anthocyanin content which gives the purple corn its colour since it has been reported by many researchers that anthocyanins are a class of water-soluble phenolic compounds that provide red, orange, purple, and blue colours to most fruits and vegetables. Indeed, it is the presence of anthocyanins and other phenolic compounds that differentiate purple corn from other conventional corn varieties and make it stand out as a health promoting food. Otherwise, these anthocyanins could be used as a natural dye both in the food, pharmaceutical and cosmetic industries. It is well known that a real craze for naturally occurring dyes has been catalysed by the prohibitions of artificial or synthetic colours for toxicological reasons. The commercial success of natural food colourants responds to current trends of consumers that require a return to the natural food. So, the maize "violet de Katiola" could be served as raw material for these natural colorant productions. Many authors have reported that a higher content of anthocyanins is associated to higher antioxidant capacity [34]. The antioxidant activities obtained in this study corroborate this assertion. The antioxidant activity of phenolic phytochemicals occurs mainly a result of their redox potential which result from mechanisms such as free radical scavenging activity, metal chelating activity and singlet oxygen quenching ability. These compounds can protect cells against oxidative damage caused by reactive oxygen species [35]. Purple corn phenolic has a larger number of active hydroxyl groups and more favourable configurations to allow for better interactions with the free radicals [36]. Thus, the dark purple corn variety with the highest anthocyanins content also presented the best antioxidant activity (69.22%). Therefore, consumption of these purple maize flours could play a key role in prevention of many metabolic and neurodegenerative diseases such as diabetes, hypercholesteraemic, hypertension, obesity, cancer, Alzheimer and Parkinson [8].

**Table 1. Proximate composition of flours from yellow and purple maize varieties**

| Parameters (g/100 g DM) | Flours | | | |
|---|---|---|---|---|
| | YC | DPC | LPRC | LPC |
| Dry matter | 94.01 ± 0.17$^{c}$ | 93.75 ± 0.22$^{c}$ | 94.80 ± 0.17$^{b}$ | 94.95 ± 0.29$^{a}$ |
| Ash | 2.00 ± 0.53$^{ab}$ | 1.89 ± 0.09$^{b}$ | 2.74 ± 0.22$^{a}$ | 2.19 ± 0.49$^{ab}$ |
| Crude proteins | 8.85 ± 0.04$^{c}$ | 10.09 ± 0.11$^{a}$ | 9.72 ± 0.09$^{b}$ | 9.90 ± 0.08$^{b}$ |
| Crude fats | 5.30 ± 0.00$^{b}$ | 6.21 ± 0.05$^{a}$ | 6.14 ± 0.08$^{a}$ | 5.87 ± 0.51$^{a}$ |
| Carbohydrates | 77.85 ± 0.04$^{a}$ | 74.66 ± 0.61$^{c}$ | 75.91 ± 0.70$^{b}$ | 75.35 ± 0.07$^{bc}$ |
| Starch | 67.27 ± 0.03$^{a}$ | 64.43 ± 0.63$^{b}$ | 64.86 ± 0.40$^{b}$ | 64.99 ± 0.06$^{b}$ |
| Cellulose | 1.39±0.02$^{b}$ | 1.45 ± 0.04$^{b}$ | 1.60 ± 0.08$^{a}$ | 1.44 ± 0.00$^{b}$ |
| Energy value (kcal/100 g) | 376.70 ± 0.00$^{b}$ | 380.66 ± 1.77$^{a}$ | 384.04 ± 0.92$^{a}$ | 381.74 ± 1.10$^{a}$ |

*Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05). YC: Yellow Corn; DPC: Dark Purple Corn; LPRC: Light Purple Red Corn; LPC: Light Purple Corn*

**Table 2. Mineral elements composition of flours from yellow and purple maize varieties**

| Minerals (mg/100 g DM) | Flours | | | |
|---|---|---|---|---|
| | YC | DPC | LPRC | LPC |
| Manganese | 0.61 ± 0.01$^{b}$ | 0.52 ± 0.00$^{c}$ | 0.43 ± 0.00$^{d}$ | 0.66 ±0.00$^{a}$ |
| Phosphorus | 127.25±1.39$^{a}$ | 125.52±1.41$^{a}$ | 115.94±1.63$^{b}$ | 128.06±0.81$^{a}$ |
| Iron | 2.21 ± 0.00$^{c}$ | 2.58 ± 0.01$^{a}$ | 2.57 ± 0.00$^{ab}$ | 2.55 ± 0.01$^{b}$ |
| Calcium | 12.41 ± 0.02$^{a}$ | 10.92 ± 0.00$^{c}$ | 11.52 ± 0.04$^{b}$ | 10.49 ± 0.08$^{d}$ |
| Magnesium | 98.17 ± 0.39$^{a}$ | 92.32 ± 0.26$^{b}$ | 75.97 ± 0.13$^{c}$ | 98.30 ± 0.48$^{a}$ |
| Potassium | 307.29 ±0.33$^{c}$ | 317.18 ±0.11$^{b}$ | 236.56 ±0.19$^{d}$ | 332.20 ±0.34$^{a}$ |
| sodium | 2.81 ± 0.00$^{c}$ | 3.17± 0.00$^{b}$ | 2.27 ± 0.01$^{d}$ | 3.28 ± 0.00$^{a}$ |
| Copper | 0.67 ± 0.02$^{a}$ | 0.44 ± 0.01$^{b}$ | 0.39 ± 0.02$^{b}$ | 0.42 ± 0.06$^{b}$ |
| Zinc | 2.20 ± 0.00$^{c}$ | 2.26 ± 0.00$^{b}$ | 2.32 ± 0.00$^{a}$ | 2.18 ± 0.00$^{d}$ |

*Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05). YC: Yellow Corn; DPC: Dark Purple Corn; LPRC: Light Purple Red Corn; LPC: Light Purple Corn*

**Table 3. Phenolic compounds and antioxidant activity of flours from yellow and purple maize varieties**

| Parameters(mg/100 g DM) | Flours | | | |
|---|---|---|---|---|
| | YC | DPC | LPRC | LPC |
| Total polyphenols | 116.51±0.00$^{d}$ | 253.80±0.00$^{a}$ | 236.77±0.07$^{b}$ | 232.14±1.04$^{c}$ |
| Flavonoids | 35.41±0.09$^{c}$ | 190.95±0.09$^{a}$ | 187.19±0.31$^{a}$ | 179.16±0.82$^{b}$ |
| Anthocyanins | 17.04±0.19$^{d}$ | 178.54±0.07$^{a}$ | 155.05±0.04$^{b}$ | 135.87±0.01$^{c}$ |
| Tannins | 60.45±0.00$^{a}$ | 52.89±2.74$^{b}$ | 43.99±3.64$^{c}$ | 43.17±2.39$^{c}$ |
| Antioxidant Activity (%) | 31.98±0.91$^{c}$ | 69.22±0.38$^{a}$ | 41.08±1.36$^{b}$ | 38.39±0.08$^{b}$ |

*Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05). YC: Yellow Corn; DPC: Dark Purple Corn; LPRC: Light Purple Red Corn; LPC: Light Purple Corn*

### 3.4 Functional Properties

Functional properties of foods are intrinsic physicochemical characteristics, which affect the behaviour of proteins in food systems during processing, manufacturing, storage and preparation [37]. They could be used to determine the suitability or otherwise of the studied flours as food additive.

The functional properties of flours from purple and yellow maize harvested in Côte d'Ivoire were summarized in Table 4. Results reveal that except dispersibility and foam capacity, there are no significant differences for all other parameters. The purple corn flours showed highest dispersibility (72.90 – 74.53%) and the best foam capacity (9.23%). The dispersibility is widely used in the flour and powder studies to estimate their reconstitute ability in water. It is a means of comparing the solubility of proteins in water. The collected values of dispersibility under investigation are higher than the values reported for various flour samples from selected Nigerian food crops [38]. The higher the dispersibility, the better the reconstitution property.

Regarding foam capacity, values obtained (8.05 – 9.23%) are slightly lower than those reported for pearl millet flour and quinoa flour (11.30 and 9% respectively). Contrarily, these foams exhibited very good stabilities which were estimated to 100% after 2 hours and about 87% at 3 hours (Fig. 1). Foam ability of a food material varies with the type of protein, solubility and other factors. Native protein has been shown to give higher foam stability than denatured protein. This suggests that the studied flours contained a considerable amount of native proteins. Also, this high foam stability make them attractive for products like cakes or whipping topping where foaming is important, since it is well know that foam stability refers to the ability of a foam to retain its maximum volume over time and it is usually determined by measuring the rate of leakage of fluid from the foam [39].

The bulk densities of the studied flours were statistically equal. It worth to note that the bulk densities reported (0.76 – 0.77 g/mL) in the present study for the four samples were higher than the previously reported values for maize (0.65 g/mL), sorghum (0.70 g/mL) and millet (0.71 g/mL) commonly consumed in Nigeria [38]. Bulk density is very important in packaging and transportation of powdery foods since high bulk density enables a higher amount of material occupies a smaller volume. However, high bulk density is desirable for the greater ease of dispersibility and reduction of paste thickness which is an important factor in convalescent and child feeding. This suggests that the studied flours would serve as good thickeners in food products.

As regards wettability, data showed that the studied flours wet very quickly (about 25 s). These wettability values are very lower than those previously found (92.66 – 99.5 s) for flours from edible mushrooms *Volvariella volvacea* and *Armillaria mellea* [40]. Less wettability seems to be linked to low fat content as suggested by Akpossan et al. [41]. Otherwise, wettability of proteins is affected by surface polarity, topography, texture, area and by the size and microstructure of the protein particles.

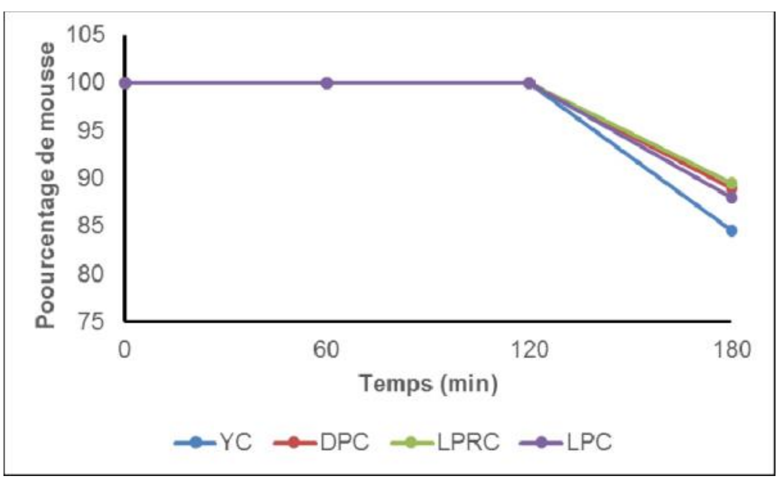


**Fig. 1. Foam stability of flours from yellow and purple maize varieties**

**Table 4. Functional properties of flours from yellow and purple maize varieties**

| Parameters | Flours | | | |
|---|---|---|---|---|
| | YC | DPC | LPRC | LPC |
| Dispersibility (%) | 70.37 ± 0.00[b] | 73.70 ± 1.15[a] | 72.90 ± 2.26[a] | 74.53 ± 0.41[a] |
| Bulk density (g/mL) | 0.76 ± 0.00[a] | 0.76 ± 0.00[a] | 0.76 ± 0.00[a] | 0.77 ± 0.00[a] |
| Wettability (s) | 26 ± 0.00[a] | 25 ± 0.00[a] | 25 ± 0.00[a] | 25 ± 0.00[a] |
| Water absorption capacity (%) | 70.59 ± 0.06[a] | 70.38 ± 0.12[a] | 69.24 ± 0.41[b] | 69.35 ± 0.51[b] |
| Oil absorption capacity (%) | 131 ± 0.89[a] | 130 ± 0.89[a] | 128 ± 1.78[b] | 128 ± 0.00[b] |
| Foam capacity (%) | 8.05 ± 0.00[c] | 9.23 ± 0.00[a] | 8.69 ± 0.00[b] | 8.75 ± 0.05[b] |

*Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (P=0.05). YC: Yellow Corn; DPC: Dark Purple Corn; LPRC: Light Purple Red Corn; LPC: Light Purple Corn.*

The water and oil absorption capacities are essential functional properties of protein which depend on pore size and the charges on the protein molecules. Water absorption capacity characterizes the ability of flour to rehydration which is the first step of its conversion into dough. The obtained values for this parameter were lower than the findings (149%) of Shad et al. [42] for maize flour from Pakistan. But the same authors reported water absorption capacity of 63.80% for wheat flour. This suggests that the studied flours are moderately hydrophilic. Water binding properties of food flours could be affected by intrinsic factors such as protein contents include amino acid composition, protein conformation and surface polarity/hydrophobicity. Also, this study reveals greater oil absorption capacities (about 130%) than those of maize (107%) and wheat (72.50%) flours from Pakistan). This oil absorption capacity would act favourably for flavour retention and increase the palatability of foods based on these flours.

## 4. CONCLUSION

It may be concluded that purple corn varieties contain the similar nutritional potential to the most widely grown and consumed in Côte d'Ivoire. However, they were greatest in protein and fat contents. Also, their high content of total polyphenols especially anthocyanins would give them a key role in prevention of many metabolic and neurodegenerative diseases. Therefore, purple maize varieties could valuably be recommended in the dietary habits of vulnerable populations including the elderly, women and children in all areas of the country. Flours from the studied maize varieties exhibited good functional properties as high bulk density, dispersibility and oil absorption capacity as well as good wettability and foaming characteristics. The obtained characteristics suggest the suitability of these flours for nutritional and industrial applications.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Dunn ML. Vijaya J, Klein BP. Stability of key micronutrients added to fortified maize flours and corn meal. Ann. N. Y. Acad. Sci. 2014;1312:15–25.
2. Gwirtz JA, Garcia-Casal MN. Processing maize flour and corn meal food products. Ann. N. Y. Acad. Sci. 2014;1312:66–75.
3. Shah TR, Kamlesh P, Pradyuman K. Maize a potential source of human nutrition and health: A review. Cogent Food Agric. 2016;2:1-9. Available:http://dx.doi.org/10.1080/23311932.2016.1166995
4. Cisse M, Megnanou R, Kra KAS, Soro RY, Niamke S. Physicochemical, biochemical and nutritive properties of QPM and regular maize flours grown in Côte d'Ivoire. Int. J. Res. Bio Sciences. 2013;2:26-32.
5. Wallington T, Anderson J, Mueller S. Corn ethanol production, food exports, ans indirect land use change. Environ. Sci. Technol. 2012;46:6379–6384.
6. Moreira R, Chenlo F, Arufe S, Rubinos SN. Physicochemical characterization of white, yellow and purple maize flours and rheological characterization of their doughs J Food Sci Technol; 2015. DOI: 10.1007/s13197-015-1953-6
7. Escribano-Bailón MT, Santos-Buelga C, Rivas-Gonzalo JCR. Anthocyanins in cereals. J Chromatogr A. 2004;1054:129–141.
8. Tsuda T, Horio F, Uchida K, Aoki H, Osawa T. Dietary cyanidin 3-O-beta-D-glucoside-rich purple corn color prevents obesity and ameliorates hyperglycemia in mice. J. Nutr. 2003;133:2125–2130.

9. Kouakou CK, Akanvou L, Konan YA, Mahyao A. Stratégies paysannes de maintien et de gestion de la biodiversité du maïs (*Zea mays L.*) dans le département de Katiola, Côte d'Ivoire. J. Appl. Biosci. 2010;33:2100–2109. French.
10. N'da HA, Akanvou L, Kouakou CK. Gestion locale de la diversité variétale du maïs (*Zea mays* L.) violet par les Tagouana au Centre-Nord de la Côte d'Ivoire. Int. J. Biol. Chem. Sci. 2013;7(5): 2058-2068. French.
11. AOAC. Official methods of analysis association of official analytical chemists. 16th ed. Virginia. USA; 1995.
12. APHA. Standard methods for examination of water and waste water, 19th ed., American Public Health Association, USA. 1995;113-11.
13. Singleton VL, Orthofer R, Lamuela-Raventos RM. Analysis of total phenols and other oxydant substrates and antioxydants by means of Folin-ciocalteu reagent, Methods Enzymol. 1999;299: 152-178.
14. Bainbridge Z, Tomlins K, Westby A. Analysis of condensed tannins using acidified vanillin. J. Food Sci. 1996;29:77-79.
15. Meda A, Lamien CE, Romito M, Millogo J, Nacoulma OG. Determination of total phenolic, flavonoid and proline contents in Burkina Faso honeys as well as their radical scavenging activity. Food Chem. 2005;91:571-577.
16. Giusti MM, Wrolstad RE. Anthocyanins characterization and measurement with UV-visible spectroscopy. In Current protocols in food analytical chemistry. New York: John Wiley & Sons, Inc. 2001;F1.2.1 - F1.2.13.
17. Choi CW, Kim SC, Hwang SS, Choi BK, Ahn HJ, Lee MZ, et al. Antioxydant activity and free radical scavenging capacity between Korean medicinal plant and flavonoids by assay guided comparaison. Plant Sci. 2002;163:1161-1168.
18. Okezie BO, Bello AB. Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. J. Food Sci. 1988;53:450-454.
19. Mora-Escobedo R, Paredes-Lopes O, Gutierrez-Lopes GF. Effect of germination on the rheological and functional properties of amaranth seeds. Lebensmittel - Wissenschaft Und Technol. 1991;24:241-244.
20. Phillips RD, Chinnan MS, Branch AL, Miller J, Mcwatters KH. Effects of pre-treatment on functional and nutritional properties of cowpea meal. J. Food. Sci. 1988;53(3): 805–809.
21. Anderson RA, Conway HF, Pfeifer VF, Griffin EL. Roll and extrusion-cooking of grain sorghum grits. Cereal Sci. Today. 1969;14:372–380.
22. Beuchat LR. Functional and electro-phoretic characteristics of succinylated peanut flour protein. J. Agric. Food Chem. 1977;25:258-261.
23. Coffman CW, Gracia VV. Functional properties of amino acid content of a protein isolate from mung bean flour. J. Food Technol. 1977;12:473-484.
24. Onwuka GI. Food analysis and instrumentation. Theory and Practice. Naphtali Prints, Lagos, Nigeria. 2005;133-137.
25. Enyisi SI, Umoh VJ, Whong CMZ, Abdullahi IO, Alabi O. Chemical and nutritional value of maize and maize products obtained from selected markets in Kaduna State, Nigeria. Afr J.Food Sci. Technol. 2014;5(4):100-104. Available:http:/dx.doi.org/10.14303/ajfst.2014.029
26. Codex-Alimentarius. Céréales, légumes secs, légumineuses, produits dérivés et protéines végétales. Programme Mixte FAO-OMS Sur Les Normes Alimentaires. Rome. 1995;7:164.
27. Edema MO, Sanni LO, Sanni AI. Evaluation of maize -soybean flour blends for sour maize bread production in Nigeria. Afr. J. Biotechnol. 2005;4:911-918.
28. Bressani R, Benavides V, Acevedo E, Ortiz MA. Changes in selected nutriment content and in protein quality of common and quality maize during tortilla preparation. Food Revue. Cereal Chemistry. 1990; 6(67):515-518.
29. Favier JC, Chevassus-Agnes S, Joseph A, Gallon G. La technologie traditionnelle du sorgho au Cameroun – Influence de la mouture sur la valeur nutritive. Annuaire of Nutrition and Alimentation. 1973;25:159.
30. Yongfeng A, Jay LJ. Macronutrients in corn and human nutrition. Compr Rev Food Sci Food Saf. 2016;15:581–598. DOI: 10.1111/1541-4337.12192
31. Abiose SH, Ikujenlola AV. Comparison of chemical composition, functional properties and amino acids composition of quality protein maize and common maize (*Zea*

*may L)* Afr. J. Food Sci. Technol. 2014; 5(3):81-89.
32. Paes MCD, Bicudo MH. Nutritional perspectives of quality protein maize. In: International symposium on quality protein maize, sete lagos. Quality protein maize: 1964-1994 - proceedings. Purdue University. 1997;65-78.
33. Tebib K, Rouanet JM, Besançon P. Antioxidant effects of dietary polymeric grape seed tannins in tissues ofrats fed a highcholesterol-vitamin E-deficient diet. Food Chem. 1997;59(1):135-141.
34. Lopez-Martinez LX, Oliart-Ros RM, Valerio-Alfaro G, Lee CH, Parkin KL, Garcia HS. Antioxidant activity, phenolic compounds and anthocyanins content of eighteen strains of Mexican maize. LWT - Food Sci. Technol. 2009;42:1187–1192. Available:http://dx.doi.org/10.1016/j.lwt.2008.10.010
35. Ukom AN, Ojimelukwe CF, Ezeama DO, Ortiz, Aragon IJ. Phenolic content and antioxidant activity of some under-utilized Nigerian yam (*Dioscorea spp*.) and cocoyam (*Xanthosomaffa (scoth)*) tubers. J. Env. Sci. Toxicol. Food Tech. 2014;8: 104-111.
36. Cevallos-Casals BA, Cisneros-Zevallos L. Stoichiometric and kinetic studies of phenolic antioxidants from Andean purple corn and red-fleshed sweetpotato. J Agric Food Chem. 2003;51:3313–9.
37. Onimawo IA, Akubor PI. Functional properties of food. Ambik Press Ltd, Benin City; 2005.
38. Oluwole O, Akinwale T, Adesioye T, Odediran O, Anuoluwatelemi J, Ibidapo O, et al. Some functional properties of flours from commonly consumed selected Nigerian Food Crops. Int. J. Res. Agric. Food Sci. 2016;1(5):92-98.
39. Kinsella JE. Functional properties of soy proteins. J Am Oil Chem Soc. 1979;56: 242–258.
40. Due EA, Koffi DM, Digbeu YD. Biochemical and functional properties of two wild edible mushrooms (*Volvariella volvacea* and *Armillaria mellea*) consumed as protein substitutes in South Côte d'Ivoire. J. Chem. Biol. Phys. Sci. 2016; 6(4):1197-1206.
41. Akpossan RA, Digbeu YD, Koffi DM, Kouadio JPEN, Due EA, Kouame PL. Protein fractions and functional properties of dried *Imbrasia oyemensis* larvae full-fat and defatted flours. Inter J Biochem Res Rev. 2015;5(2):116-126.
42. Shad MA, Nawaz H, Misbah N, Hafiz BA, Mazhar H, Akram MC. Functional properties of maize flour and its blends with wheat flour: Optimization of preparation conditions by response surface methodology. Pak. J. Bot. 2013;45(6): 2027-2035.



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