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Assessment of Nutritive Quality of Maize (*Zea mays* L.) Produced and Stocked from Rural Conditions in Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Author KD designed the study, wrote the protocol, fitted the data and wrote the first draft of the manuscript. Authors NGL and SD checked the first draft of the manuscript and achieved the submitted manuscript. Author KY performed the statistical analysis and assisted the experiments implementation. Author BHM expertized the results interpretations. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Maize (*Zea mays* L.) is a major staple food for millions of people in Côte d'Ivoire. Due to its high productivity and low cost of calorie it is preferred crop for food security of the country. Thus, this study was conducted to assess nutritive quality of maize produced and

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stocked in five purposively selected regions of Côte d'Ivoire which represents five agroecological settings.
Study Design: A total of 1500 samples of maize as grains, epis and spathes were collected at rate of 500 samples by region (Gbêkê, Poro, Hambol, Indénié-Djuablin and Gontougo) and sent to the laboratory in order to analyse their nutritional quality.
Place and Duration of Study: This study was carried out during March 2016 to January 2017. The collected sample were carried out at the laboratory unit of Food Sciences and Biochemistry of the Félix Houphouët-Boigny University, Abidjan.
Methodology: Proximate analyses were carried out using standard methods AOAC (2000).
Results: The results show significant difference from the biochemical compositions of maize type and region. Mean value intervals were as follow: dry matter (85.83 – 91.42%), ash (1.19 - 2%), proteins (7.99 - 9.32), lipids (3.21 - 4.47), carbohydrates (71.80 - 77.94), starches (62.30 - 68.44%), fibers (5.03 - 5.83%), total sugars (2,13 - 2.99%), reducing sugars (0.33 - 0.66%), free fat acidity (1.86- 4.50%), peroxide value (1.34 - 3.07 meq O_2/kg), iodine value (100.93 - 130.56 g I2/100 g), unsaponifiable (0.89 - 1.54%) and energy values (357.88 - 374.39 kcal).
Conclusion: A significant variability from one region to another can be noticed at level of maize quality regardless the type of maize. The nutritive quality of maize seems to be tied to postharvest treatments (drying), type of storage (epis, grains and spathes) and structure of storage.

Keywords: Nutritive quality; maize grains; maize epis; maize spathes; production region; Zea mays L.; Côte d'Ivoire.

1. INTRODUCTION

Agriculture is the mainstay of Côte d'Ivoire's economy and it provides dietary foods, raw materials for industries and products for export market [1]. Cereals are the major food grains produced in Côte d'Ivoire and they constitute the largest share of domestic food production. According to FAOSTAT [2] among cereals, maize ranked second to *rice both* in terms of area coverage (37.90% for maize and 62.10% for rice) and in total production in Côte d'Ivoire. Maize is a substantial contribution in the diets of rural and urban populations. Its cultivation increased gradually over the years thanks to adoption of best production technologies and improved varieties [3]. This crop is generally cultivated by small-scale farmers and widely grows across various ecological zones, from the northern savannah till the rain forest belt in the south [4], with a yield of 1,025,000 tons in 2017/2018 from 523,538 ha of total cultivated area [2]. Maize is a major source of food, feed and raw material for food industries [5]. In Côte d'Ivoire, the mean daily consumption of maize grains is estimated at 28.4 g [6]. It allows diverse dishes such as porridge, couscous or dense paste (tô) eaten with sauce [7]. However, after harvest, inadequate infrastructure and lack of economic means usually involve in storage of maize crops by farmers, either shelled or unshelled using traditional structures and processing, such as living rooms, cribs, baskets, polypropylene bags, earthen ware and granaries [8]. Unfortunately, crops kept in these conditions and structures are generally subject to deterioration. The primary factors affecting the grains during their storage are the moisture, the temperature and the relative humidity of the environment. Other maize deterioration agents are rodents, insect pests and microorganisms. Both primary and secondary factors lead to chemical changes, weight loss and finally to changes in the maize quality [9]. These are so important damages that the farmers often dispose of significant proportion of their stored grains due to deterioration [10].

In general, infestations start at fields and continue throughout the storage period [11]. The full losses resulting with deterioration are about 20-30% of the stored food grains [12]. Thus, proper conditions of maize storage could allow significant improvement in the national farmer's economy by controlling the losses. In fact, the storage technologies have major roles upon the final quality of the resulted grains. Ensuring optimal efficiency of the storage technologies is highly crucial for the safety of stored grain and for the consumer's health. A survey carried out in three major maize-producing regions in Côte d'Ivoire indicated that the majority of producers (97%) use traditional storage methods which expose their stored grains to pests' attack [8]. Indeed, crop harvesting and storage remains one of the key factors in a country's food security. Maize production is generally seasonal and consumers' needs extend throughout the year.

There are few reports on the nutritive quality of produced and stored maize in Côte d'Ivoire.

The present study aims to determine nutritive composition of maize harvesting and stored by small-scale farmers in traditional condition in Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Biological material

The biological material is composed of dry maize in the form of grains, epis and spathes deriving the major region production of this resource in Côte d'Ivoire.

2.1.2 Study site

The samples were collected from the regions of Gbêkê (Center), Poro (North), Hambol (North - Center), Indenié-Djuablin (Northeast) and Gountougo (East). Each of these regions has a geographical specificity and climatic characteristics which influence the seasons of maize production. Indeed, the regions of Gbêkê (7º50' nord 5º18' west), Hambol (8º10'nord 5º40'west), Indenié-Djuablin (7º02'nord 3º12'west) and Gountougo (8º30'N 3º20'West) are characterized by a humid tropical climate (*Baouléen* climate). It has four seasons including two rainy seasons favoring maize production twice a year and two dry seasons. Except the other four regions, the climate of region of Poro (9º27' nord 5º38' west) is of Sudanese type characterized by a rainy season favorable to maize production and a dry season [13,14]. Maize (*Zea mays* L.) is the main food crop in these regions taken into account in the study.

2.2 Methods

2.2.1 Sampling of stored maize

The strategy adopted consisted of two phases. The first phase consisted in identifying the regions where maize cultivation constitutes the main subsistence activity. In each region, meetings were organized with the traditional chiefdom to present the study. Then, samples of 1 kg of maize as spathes, epis and grains were taken from the stocks of producers constituting the second phase from March 2016 to January 2017. A total of 1500 samples were collected for each form of maize (500 grains, 500 epis, and 500 spathes, Table 1). Maize samples were then conveyed to laboratory for the biochemical properties' assessments.

2.2.2 Determination of the biochemical properties of maize stored

Proximate analyses were carried out using standard methods AOAC [15]. Thus, maize dry matter content was deduced after drying the samples in an oven (MEMMERT, Germany) at 105°C. Ash content resulted from incineration of 5 g of dried maize sample at 550°C in an oven (PYROLABO, France) for 12 h. For crude fibres, 2 g of crushed maize samples were taken. Then, extraction mixture was prepared using 0.100 M sulfuric acid and 0.31 M sodium hydroxide with intermittent boiling. After suction filtration, the insoluble residue was washed with hot water, dried with an oven (MEMMERT, Germany) at 100ºC for 2 h then incinerated. The final residue allowed estimation of the crude fibres content. The proteins contents were determined with use of the Kjeldhal method. The lipids contents resulted from a solvent (hexane) extraction using a Soxhlet device. Unsaponifiable matter were determined using the method described by IUPAC [16]. Free fat acidity value was determined by titrating diethyl ether / ethanolic solution of maize oil with an ethanolic solution of sodium hydroxide using phenolphthalein indicator. Peroxide value resulted by titrating chloroform/glacial acetic acid/potassium iodide solution of maize oil with an aqueous solution of sodium thiosulphate using starch as indicator. Iodine value was determined by the Wijs' method [15]. Starches contents were determined using iodine method of Jarvis and Walker [17]. Total soluble sugars amounts were determined by the method of [18] with phenol and sulfuric acid, then reducing sugars were mesured out according to the method of [19] basing on the 3, 5-dinitrosallicyclic acid reagent. Prior to their quantification, sugars were extracting with ethanol, zinc acetate and oxalic acid [20]. Total carbohydrate and energy (caloric value) were estimated using formulas indicated by FAO [21] as follow:

$$\text{Carbohydrates (\%)} = 100 - (\text{\% moisture} + \text{\% proteins} + \text{\% lipids} + \text{\% ash}) \quad (1)$$

$$\text{Energy (\%)} = (\text{\% proteins} \times 4) + (\text{\% carbohydrates} \times 4) + (\text{\%lipids} \times 9) \quad (2)$$

The results of biochemical parameters were expressed on the dry weight basis.

Table 1. Number of samples collected according to maize variety and department

Regions	Grains	Epis	Spathes	Total
Gbêkê	100	100	100	300
Poro	100	100	100	300
Hambol	100	100	100	300
Indénié-Djablin	100	100	100	300
Gontougo	100	100	100	300
Total	500	500	500	1500

2.2.3 Statistical analysis

All the analyses were carried out in three-fold test and data processed with software Statistical Product and Service Solutions, SPSS version 20.0, an IBM product since 2009. For each characteristic, the results were expressed in form of averages followed by their standard deviations as parameters of data spread. A two-way analysis of variance (ANOVA 2) was also made in order to test the impact of regions and the ways of preserving maize on assessed characteristics to 5% significant threshold statistical. For the statistically different averages, the Tukey's test served for the classification. Furthermore, the correlation between data and samples was estimated on basis of main components analysis (MCA), thanks to XLSTAT 2016 software.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Dry matter and nutrient constituents

The dry matter and nutrient constituents obtained vary significantly ($P<0.001$) depending on the regions and for all maize types regardless of grains, epis and spathes as shown in Table 2. For the maize grains, the dry matter average levels are between 85.82 ± 0.26% and 91.42 ± 0.19% with a high proportion observed at Poro, Gbêkê and Hambol and the lower proportions at Gontougo. The dry matter of samples collected at the level of maize epis is also lower at Gontougo (87.60 ± 0.41%) and Indenié-Djuablin (86.80 ± 0.54%) as compared with Gbêkê (90.15 ± 0.39%), Poro (89.39 ± 0.32%) and Hambol (88.10 ± 0.100%). With maize spathes, Table 2 shows that dry matter contents of samples at Gbêkê, Poro and Gontougo are statistically different (88.83 ± 1.40%, 88.84 ± 1.33% and 88.47 ± 1.35%, respectively) in comparison with Hambol (87.57 ± 1.45%) and Indenié-Djuablin (85.83 ± 1.55%).

With values ranging from 1.19 ± 0.12% to 2.00 ± 0.05%; 1.45 ± 0.12% to 1.88 ± 0.14% and 1.24 ± 0.15% to 1.83 ± 0.05% respectively for maize grains, epis and spathes, high proportion of ash contents were recorded in the regions of Hambol (grains), Gbêkê (grains and epis) and Poro (grains and spathes). The regions of Gontougo and Indénié-Djablin recorded the lowest levels. Likewise, the protein contents were detected in Gbêkê, Poro and Hambol on maize grains with fluctuating values between 8.99 ± 0.11 and 9.32 ± 0.07%. Concerning the samples of maize epis, it was the regions of Gbêkê, Hambol and Poro which recorded the high protein contents for average levels of 8.70 ± 0.26 to 8.98 ± 0.19%. The content was observed at Gontougo on the maize spathes' samples, for a concentration of 8.54 ± 0.24%. Regarding the lipid contents, the average values of maize grains do not indicate any significant difference ($P> 0.05$) with the regions for values ranging from 4.07 ± 0.22 to 4.47 ± 0, 08%. However, samples maize grains from Gbêkê, Poro and Hambol indicate high concentrations. Samples of maize epis and spathes showed significant differences ($P <0.05$). The high levels were revealed from Gbêkê, Hambol and Poro for maize epis and from Gontougo for maize spathes. As for the starches contents, with average levels between 62.30 ± 0.57 and 68.44 ± 0.21%, particularly for maize grains, epis and spathes, the regions of Indénié-Djablin and Gontougo showed the lowest values while the regions of Gbêkê, Hambol and Poro recorded high values for both maize grains and epis.

The contents of different macronutrients produce energy values with statistically different levels. Thus, the maize samples collected from Gbêkê, Poro and Hambol obtained values, unlike those from Indénié-Djablin, which presented lower values for maize grains, epis and spathes. These values range from 357.88 ± 1.58 to 374.39 ± 2.20 kcal for maize grains; from 359.95 ± 2.7 to 371.36 ± 1.36 kcal for maize epis, and from

356.59 ± 2.70 to 368.99 ± 1.90 kcal for maize spathes (Table 2).

3.1.2 Carbohydrate compound content

The carbohydrates, fibres, total and reducing sugars values are given in Table 3. Significant differences between their levels were recorded (P <0.05) depending on the regions and all maize types. The samples from the regions of Gbêkê (grains, epis and spathes), Poro (grains, epis and spathes) and Hambol (grains and epis) recorded highest levels of total carbohydrate content. These values generally fluctuated between 71.68 ± 0.68 and 77.94 ± 0.71%; 72.41 ± 0.67 and 300.34 ± 0.32%; 71.80 ± 0.74 and 74.53 ± 0.34% respectively for maize grains, epis and spathes. The analytical data show a great variability of the total sugars' contents according to the types of maize and the regions. The regions of Poro (maize grains), Hambol (maize grains) and Gbêkê (maize grains and spathes) have the levels which are respectively 3.22 ± 0.02 %, 2.99 ± 0.18%, 2.96 ± 0.10% and 2.61 ± 0.09%. In addition, samples of maize grains from the regions of Indénié-Djablin and Gontougo showed high values between 2.63 ± 0.08% and 2.62 ± 0.12%. As for the reducing sugars contents, results show significant difference (P <0.05). The high levels were recorded in the regions of Indénié-Djablin (epis and spathes), Gontougo (epis), Gbêkê (grains and spathes) and Poro (grains) with average variations between 0.55 ± 0.01% and 0.66 ± 0.05%. The fibres contents of the maize samples do not show any significant difference (P> 0.05) with the type and the department, with average values between 5.08 ± 0.23 and 5.55 ± 0.08%; 5.14 ± 0.100 and 5.83 ± 0.23%; 5.03 ± 0.14 and 5.97 ± 0.34% respectively for maize grains, epis and spathes (Table 3).

Table 2. Maize nutrients constituents in studied production regions

Parameters	Regions	Grains	Epis	Spathes
Dry matter (%)	Gbêkê	$91.10±0.22^{aA}$	$90.15±0.39^{aB}$	$88.83±1.40^{aC}$
	Poro	$91.42±0.19^{aA}$	$89.39±0.32^{aB}$	$88.84±1.33^{aB}$
	Hambol	$90.10±0.40^{bA}$	$88.10±0.100^{aB}$	$87.57±1.45^{bB}$
	Indénié-Djablin	$86.80±0.34^{cA}$	$86.80±0.54^{bA}$	$85.83±1.55^{cB}$
	Gontougo	$85.82±0.26^{Ba}$	$87.60±0.41^{Aa}$	$88.47±1.35^{Ac}$
Ash (%)	Gbêkê	$1.90±0.65^{aA}$	$1.88±0.14^{aA}$	$1.69±0.13^{bA}$
	Poro	$1.93±0.28^{aA}$	$1.81±0.05^{aA}$	$1.83±0.05^{aA}$
	Hambol	$2±0.20^{aA}$	$1.90±0.17^{aA}$	$1.64±0.32^{bA}$
	Indénié-Djablin	$1.50±0.14^{aA}$	$1.45±0.12^{aB}$	$1.24±0.15^{bB}$
	Gontougo	$1.19±1.05^{bB}$	$1.56±0.13^{aB}$	$1.51±0.12^{aA}$
Proteins (%)	Gbêkê	$9.32±0.07^{aA}$	$8,70±0.26^{aA}$	$8.23±0.13^{bB}$
	Poro	$9.27±0.10^{aA}$	$8.98±0.19^{aA}$	$8.42±0.12^{aA}$
	Hambol	$8.99±0.11^{aA}$	$8.84±0.23^{aA}$	$8.33±0.24^{aB}$
	Indénié-Djablin	$7.99±0.27^{bB}$	$8.35±0.08^{bA}$	$8.36±0.32^{aB}$
	Gontougo	$8.73±0.29^{aA}$	$8.28±0.15^{bB}$	$8.54±0.24^{aA}$
Lipids (%)	Gbêkê	$4.47±0.08^{aA}$	$4.01±0.11^{aA}$	$3.21±0.18^{bB}$
	Poro	$4.44±0.06^{aA}$	$4.12±0.21^{aA}$	$3.98±0.15^{aB}$
	Hambol	$4.41±0.08^{aA}$	$4.07±0.16^{aA}$	$3.62±0.18^{bB}$
	Indénié-Djablin	$4.08±0.21^{aA}$	$3.6±0.21^{bB}$	$4±0.38^{aA}$
	Gontougo	$4.07±0.22^{aA}$	$3.91±0.17^{aB}$	$4.03±0.13^{aA}$
Energy value (kcal/100g)	Gbêkê	$373.65±1.96^{aA}$	$366.100±1.09^{aA}$	$356.59±2.70^{bB}$
	Poro	$373.19±0.96^{aA}$	$369.46±1.62^{aA}$	$367.59±1.52^{aA}$
	Hambol	$374.39±2.20^{aA}$	$371.36±1.36^{aA}$	$360.18±1.67^{bB}$
	Indénié-Djablin	$357.88±1.58^{bB}$	$359.95±2.70^{bB}$	$368.99±1.90^{aA}$
	Gontougo	$367.60±1.30^{aA}$	$365.42±2.03^{aA}$	$368.18±2.20^{aA}$

By column and row, the averages covering the same letters are statistically identical. The lower-case letters are representative of columns and capital letters are representative of rows

Table 3. Maize carbohydrate compounds in studied production regions

Parameters	Regions	Grains	Epis	Spathes
Total carbohydrates (%)	Gbêkê	77.19±0.27^{aA}	73.34±0.32^{aA}	74.53±0.34^{aA}
	Poro	76.65±0.20^{aA}	73.27±0.48^{aA}	74.50±0.37^{aA}
	Hambol	77.94±0.71^{aA}	73.31±0.40^{aA}	72.56±0.22^{bB}
	Indénié-Djablin	71.68±0.68^{bA}	72.41±0.67^{aA}	71.80±0.74^{bA}
	Gontougo	73.88±0.79^{bA}	74.43±0.63^{aA}	72.76±0.45^{bA}
Starches (%)	Gbêkê	67.26±0.24^{aA}	65.46±0.31^{aA}	64.72±0.100^{aA}
	Poro	67.19±0.18^{aA}	65.44±0.51^{aA}	64.15±0.40^{aA}
	Hambol	68.44±0.21^{aA}	65.45±0.41^{aA}	62.70±0.64^{aA}
	Indénié-Djablin	62.300±0.65^{aA}	62.59±0.61^{bA}	62.30±0.57^{aA}
	Gontougo	64.47±0.70^{aA}	63.30±0.58^{bA}	64.63±0.41^{aA}
Fibres (%)	Gbêkê	5.24±0.81^{aA}	5.83±0.23^{aA}	5.57±0.27^{aA}
	Poro	5.36±0.78^{aA}	5.44±0.15^{aA}	5.03±0.14^{aA}
	Hambol	5.55±0.31^{aA}	5.64±0.19^{aA}	5.85±0.29^{aA}
	Indénié-Djablin	5.08±0.65^{aA}	5.14±0.100^{aA}	5.97±0.34^{aA}
	Gontougo	5.53±0.63^{aA}	5.55±0.16^{aA}	5.80±0.18^{aA}
Total sugars (%)	Gbêkê	2.96±0.10^{aA}	2.44±0.05^{bB}	2.61±0.09^{aA}
	Poro	3.22±0.02^{aA}	2.55±0.16^{aB}	2.01±0.19^{cB}
	Hambol	2.99±0.18^{aA}	2.50±0.11^{aB}	2±0.18^{bB}
	Indénié-Djablin	2.13±0.05^{bB}	2.63±0.08^{aA}	2.57±0.23^{aA}
	Gontougo	2.24±0.14^{bB}	2.62±0.12^{aA}	2.41±0.20^{aA}
Reducing sugars (%)	Gbêkê	0.55±0.01^{aA}	0.33±0.02^{bB}	0.60±0.03^{aA}
	Poro	0.66±0.05^{aA}	0.35±0.03^{bB}	0.48±0.03^{bB}
	Hambol	0.45±0.02^{bA}	0.41±0.100^{aA}	0.55±0.05^{aA}
	Indénié-Djablin	0.38±0.06^{bB}	0.65±0.06^{aA}	0.57±0.06^{aA}
	Gontougo	0.51±0.04^{abA}	0.57±0.07^{aA}	0.49±0.05^{bA}

By column and row, the averages covering the same letters are statistically identical. The lower-case letters are representative of columns and capital letters are representative of rows

3.1.3 Degradation indices and unsaponifiable content

Fat quality indices (fat acidity, peroxide and iodine indices) and the unsaponifiable content are recorded in Table 4. Statistical analysis of the data indicates significant differences between type of maize and regions. The regions of Gontougo and Indénié-Djablin recorded the highest values of acid and peroxide indices for the three type of maize (grains, epis and spathes). These levels ranged from 3.01 ± 1.05 to 4.50 ± 0.30% for fat acidity and from 2.31 ± 0.07 to 3.07 ± 0.04 meq O_2 / kg for peroxide value. The regions of Gbêkê, Poro and Hambol presented low values for these degradation indices. The lowest levels were obtained on maize grains samples of corn on the cob at Gbêkê for fat acidity and peroxide values. Regarding iodine value, maize grains samples from Poro, Hambol and Gbêkê regions recorded high values with values ranging from 500.22 ± 2.83 to 130.56 ± 1.82 g I_2/100g. The same observation was made for maize epis with average levels in order of 120.19 ± 2.05 to 122.65 ± 2.30 g I_2/100g. Likewise maize spathes, it's rather the locality of Gbêkê which presented the high value of iodine value (123.59 ± 2.26 g I_2/100g). As for the unsaponifiable matter content, the all type of maize samples showed no significant difference ($P > 0.05$) regardless the regions. However, differences are recorded at maize type level and the high contents were recorded in the regions of Indénié-Djablin and Poro respectively on maize epis (1.27 ± 0.04%) and maize grains (1.28 ± 0.06%).

3.1.4 Correlations between nutrient Parameters regarding the different regions

The different biochemical parameters studied were correlated with 3 factors. However, factors F1 and F2 are used to perform PCA according to Kaiser's rule. They accumulate 68.87% of the total variability. The factor (F1) records an eigenvalue of 7.24 and expresses 51.62% of the total variability (Table 5). Ten parameters that are: lipid, protein, fibre, ash, starch, total and reducing sugars, total carbohydrate, iodine value and energy content are positively correlated with this factor. On the other hand, free fat acidity and peroxide value are negatively correlated. With an eigenvalue of 2.41, the factor (F2) expresses 17.19% of the total variability. The unsaponifiable matter is positively correlated with it, while the dry matter contributes negatively to its formation (Fig. 1A). The projection of samples in the same design highlights 2 groups. Group 1 is composed of three individuals presenting values in lipid, protein, fibre, ash, starch, total and reducing sugars, total carbohydrate, iodine value and energy content. These are maize grains samples from Gbêkê, Hambol and Poro. Group 2 includes individuals having high free fat acidity and peroxide value. It deals with spathes, epis and grains maize coming from Gontougo and Indénié-Djablin and also epis and spathes maize coming from Gbêkê, Poro and Hambol (Fig. 1B).

3.2 Discussion

Storing maize is an important step in preserving food security and increasing the income of rural populations. Maize is not only cultivated for family food because it allows some farmers to pass the lean season without too many problems, but also to increase income [10,22]. Analysis of nutrient parameters showed that sample compositions vary significantly with maize type and department. This situation could be explained by cultural and climatic conditions (type of soil, addition of fertilizer, cultivation period) and also by the maize varietal differences cultivated. The study of [23] have listed about twenty varieties of maize cultivated by small-scale farmers in the West African sub-region. In other hand, the variation in nutrient parameters can be explained by the difference in postharvest storage technology for maize [24,25]. Similar observations were made in the Center-North area of Côte d'Ivoire by [26]. These authors reported that in addition to the local varieties of maize cultivated, producers were turning to the new improved varieties because of their high productivity and drought resistance. Moreover, according to [27], storage method is also an important factor influencing the composition of stored cereals. In addition, a survey of maize storage typologies in five regions of Côte d'Ivoire

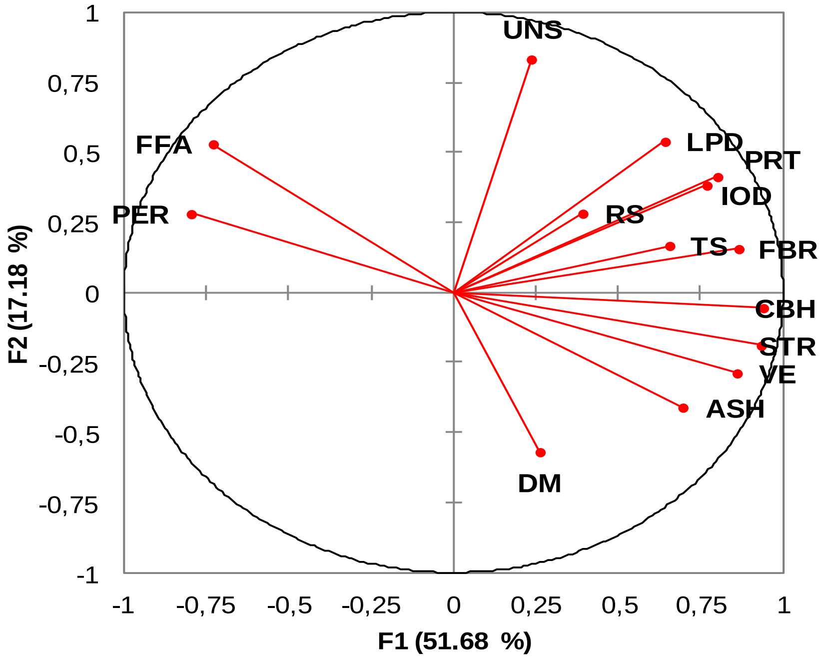
Table 4. Degradation indices and unsaponifiable content in studied production regions

Parameters	Regions	Grains	Epis	Spathes
Free fat acidity (% oleïc acid)	Gbêkê	$2.100±0.20^{bA}$	$1.80±0.72^{cB}$	$2.63±0.65^{bA}$
	Poro	$1.86±0.50^{bB}$	$2.43±0.62^{bA}$	$2.88±0.74^{bA}$
	Hambol	$2.20±0.40^{bB}$	$2.12±0.67^{bB}$	$2.69±0.76^{bA}$
	Indénié-Djablin	$4.50±0.30^{aA}$	$3.01±1.05^{aB}$	$3.50±1.11^{aB}$
	Gontougo	$4.16±0.21^{aA}$	$3.28±0.81^{aA}$	$3.38±0.31^{aA}$
Peroxyde value (meq O_2/kg)	Gbêkê	$1.61±0.15^{bA}$	$1.34±0.09^{bB}$	$2.07±0.15^{bA}$
	Poro	$1.59±0.13^{bB}$	$1.98±0.10^{aA}$	$2.22±0.17^{bA}$
	Hambol	$1.68±0.100^{bB}$	$2.15±0.08^{aA}$	$2.20±0.15^{bA}$
	Indénié-Djablin	$2.83±0.21^{aA}$	$2.31±0.10^{aB}$	$3±0.07^{aA}$
	Gontougo	$2.62±0.04^{aA}$	$3.07±0.11^{aA}$	$2.98±0.07^{aA}$
Iodine value (g I_2/100g)	Gbêkê	$127±4.01^{aA}$	$121.61±1,80^{aA}$	$123.59±2.26^{aA}$
	Poro	$130.56±1.82^{aA}$	$122.65±2.30^{aA}$	$118.5±3.27^{aB}$
	Hambol	$500.22±2.83^{aA}$	$120.19±2.05^{aA}$	$113.21±2.30^{aB}$
	Indénié-Djablin	$113.83±2.28^{bA}$	$112.12±3.04^{bA}$	$100.93±1.50^{bB}$
	Gontougo	$114.100±1.33^{bA}$	$116.13±2.21^{bA}$	$110.73±3.27^{bA}$
Unsaponifiable matter (%)	Gbêkê	$1.16±0.13^{aA}$	$1.06±0.04^{aA}$	$0.99±0.07^{aA}$
	Poro	$1.28±0.31^{aA}$	$1.04±0.05^{aA}$	$1.01±0.08^{aA}$
	Hambol	$0.99±0.12^{aA}$	$1.00±0.02^{aA}$	$0.89±0.03^{aA}$
	Indénié-Djablin	$1.30±0.11^{aA}$	$1.54±0.05^{aA}$	$1.13±0.22^{aA}$
	Gontougo	$1.27±0.37^{aA}$	$1.27±0.04^{aA}$	$1.15±0.09^{aA}$

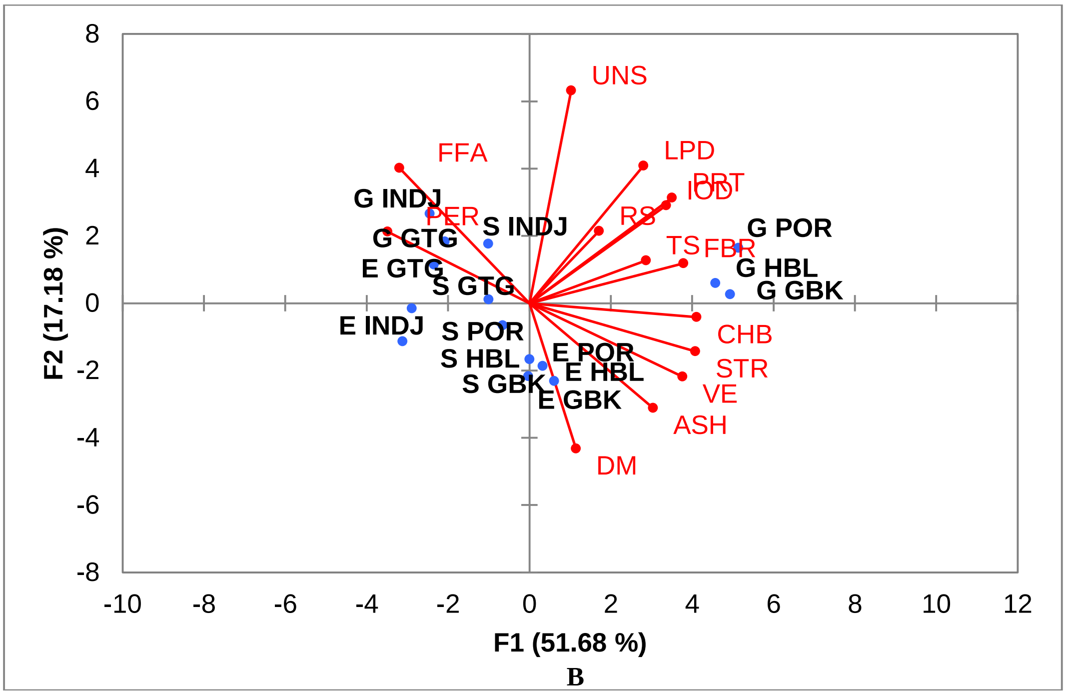
By column and row, the averages covering the same letters are statistically identical. The lower-case letters are representative of columns and capital letters are representative of rows

Table 5. Proper values of parameters

Components	Component 1	Component 2	Component 3
Proper values	7.24	2.41	1.33
Expressed variability (%)	51.68	17.19	9.51
Accumulation of expressed (%)	51.68	68.87	78.38



A



B

Fig. 1. Projection of biochemical parameters (A) and individuals (B) of grains, epis and spathes of maize in factorial plan 1-2 of the analysis of main components

DM, dry matter; LPD, lipid content; PRT, protein content; STR, starch content; ASH, ash content; FBR, fibres content; CBH, total carbohydrate content; VE, energy content; TS, total soluble sugar content; RS, reducing sugar content; UNS, unsaponifiable matter; FFA, free fat acidity; PER, peroxide value
GBK: Gbêkê; POR: Poro; HBL: Hambol; INDJ: Indénié-Djablin; GTG: Gontougo; G: Grains; E: Epis; S: Spathes

carried out by [8] revealed that the seeds used by producers in these regions come from different sources. Indeed, these seeds come from previous harvests or are bought on the market or obtained from institutional structures or obtained thanks to a relative parent. Maize grains from the different regions presented high levels of lipids, fibres, proteins, starch, carbohydrates, unsaponifiable matter, energy value, iodine value, total and reducing sugars unlike other forms which exhibited high levels of free fat acidity and peroxide value. Similar values of high nutritional content were reported by [28], on the nutritive parameters evolution of maize seeds of the GMRP-18 variety conserved by triple bagging system with biopesticides from *Lippia multiflora* and *Hyptis suaveolens*. These values are between 8.60-8.01%, 5.51-5.11%, 300.20-60.14%, 5.78 - 5.60%, 1.68 - 1.55%, 2.62 - 2%, 0.47-0.40% and 384.78-370.79 kcal respectively for protein, fat, starch, fibres, ash, total and reducing sugars and energy value. In addition, the contents of ash, total sugars, reducing sugars, proteins, unsaponifiable and dry matter are similar to those found in the study of [29] which focused on the biochemical and nutritional characterization maize flour from ordinary varieties and QPM grains. Also, total carbohydrate levels in this study are similar to those of varieties popularized by IITA in Nigeria (74.43%) [30]. The lipid contents are similar to those (3-4%) of ordinary or conventional maize produced in the United States [31] and considerably higher than those (1.5%) of maize commonly grown in Nigeria [32]. However, the starch, lipid, carbohydrate and energy values were lower than those determined on QPM maize varieties (starch 73%, lipids 5%, carbohydrates 85% and energy values 403 to 422 kcal) [29]. Our results agree with those of [33]. These authors determined values between 8.1 - 8.5%, 4.0 - 4.2%, 1.3 - 1.4% and 69.3 - 70.0% for proteins, lipids, ash and total carbohydrates on maize grain stored at different temperatures of 5, 15, 100 and 35°C in silos for 12 months. Good conservation of maize is also linked to the free fat acidity and peroxide value, which constitute alterability parameters of maize fat. The samples studied show free fat acidity and peroxide values lower than 5% of oleic acid and 10 meq O_2 / kg, respectively, those are the limit value recommended by the FAO for vegetable oils intended for human consumption [34]. For this purpose, maize grains samples of Gbêkê, Poro, and Hambol exhibited the lowest free fat acidity and peroxide value. These results agree with those of [35]. Regarding the iodine value, the variability of the levels observed from the maize type and regions could be explained by the different varieties of maize cultivated and stored by the farmers. For the different type of maize studied, the iodine numbers are lower than those of maize oils grown in Pakistan [36].

4. CONCLUSION

This study investigated the nutritional quality of maize produced and stocked as grains, epis and spathes in five production regions in Côte d'Ivoire. It shows that this nutritional quality is better in the regions of Gbêkê; Poro and Hambol regardless of the maize form (grains). It would be important to sensitize producers on good post-harvest practices and the use of structures suitable for storing different forms of maize in order to help improve the profitability of their agricultural production and ensure food security.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. MINAGRI, Ministère de l'agriculture. Production céréalière en Côte-d'Ivoire. Document 1 du séminaire national sur les potentialités et les contraintes de la production céréalière en Côte d'Ivoire. 2010 ;15-20.
2. FAOSTAT. Statistical databases on African countries food commodities trade, production, consumption, and utilization. FAO, Rome, Italy. Available:http://www.uneca.org/sites/default/files/uploads/ice17-report-secu-aliment-industrie-fr-ecawa.2020-09-final.pdf
3. Baoua I, Laouali A, Ousmane B, Baributsa D, Murdock LL. PICS bags for post-harvest storage of maize grain in West Africa. J. Stored Prod. Res. 2014; 58:20-28.
4. Kouakou K, Akanvou L, Konan A, Mahyao A. Stratégies paysannes de maintien et de gestion de la biodiversité du maïs (*Zea mays* L.) dans le département de Hambol, Côte d'Ivoire. J. Applied Bio. 2010 ;33: 2100-2109.
5. Deffan PK, Akanvou L, Akanvou R, Nemlin GP, et Kouamé PL. Evaluation morphologique et nutritionnelle de variétés locales et améliorées de maïs (*Zea mays* L.) produites en Côte d'Ivoire. Afr. Sci. 2015 ;11:181-196.
6. Beugre GA, Yapo BM, Blei SH, Gnakri D. Effect of Fermentation Time on the Physico-Chemical Properties of Maize Flour. Int. J. Res. Stu. Bios. 2014;2:30-38.
7. Ngessan Y, Bedikou M, Megnanou R-M, Niamké S. Importance of local cereal flours in the diet habit ofconsumers in the district

of Abidjan Cote d'Ivoire. J. Fac. Food Eng. 2014; XIII:134-146.

8. Niamketchi L, Chatigre O, Amane D, Nyamien Y, Ntchobo F, Ezoua P, Kouame D, Biego H. Descriptive study of maize storage methods (*Zea mays* L) used in rural environment in three zones of Côte d'Ivoire. Glo. Adv. Res. J. Agri. Sci. 2015; 4:663-672.
9. Kent NL, Evers AD. Technology of Cereals. 4th ed. Elsevier Sci. Ltd, U.K. 1993;104.
10. Bamba S, Biego H, Coulibaly A, Nyamien Y. Konan Y, Sidibe D. Determination of merchantability of maize (*Zea mays* L.) as epis, spathes and grains stocked in the production regions of Côte d'Ivoire. J. Agri. Eco. Res. Inter. 2019; 20(4):1-10.
11. Johnson F, N'Zi K, Seri-Kouassi et Foua-Bi K. Aperçue des problèmes de stockage et incidences des insectes sur la conservation du riz et du maïs en milieux paysans: Cas de la région de Bouaflé - Côte d'Ivoire. Eur. J. Sci. Res. 2012; 83:349-363.
12. Yao VG, Konan KC, Niamketchi GL, Aka BA., AC, Biego HMG. Evolution of merchantability during storage of maize triple bagged containing biopesticides (*Lippia multiflora* and *Hyptis suaveolens*). Eur. J. Nutri. & Food Saf. 2019;11(4):274-283.
13. Kouassi A, Kouamé K, Goula B, Lasm T, Paturel J, Biémi J. Influence of climatic variability and modification of land use on the rain-flow relationship from a global modeling of the N'zi (Bandama) watershed in Ivory Coast. Ivoi. Sci. Tech. Rev. 2008;11:207-229.
14. Amani M, Koffi F, Yao B, Kouakou B, Jean E, Sekouba O. Analyse de la variabilité climatique et de ses influences sur les régimes pluviométriques saisonniers en Afrique de l'Ouest : cas du bassin versant du N'zi (Bandama) en Côte d'Ivoire. Eur. J. Geo. 2010;12:200-222.
15. AOAC: Official methods of analysis. Association of Official Analytical Chemists. Washington. DC. USA. 2000;376–384.
16. UICPA. Méthodes d'analyses des matières grasses et dérivés. Technique et Documentation Ed, Paris.1979;190 p.
17. Jarvis CE, Walker JR. Simultaneous, rapid, spectrophotometric determination of total starch, amylose and amylopectin. J. Sci. Food Agri. 1993; 63:53-57.
18. Dubois M, Gilles K, Hamilton J, Rebers P, Simith F. Colorimetric method for determinations of sugars and related substances. Ana. Chem. 1956; 280:350-356.
19. Bernfeld D. Amylase β et α, In: method in enzymology 1, Colowick S.P. and Kaplan N.O., Academic Press. 1955;149-154.
20. Agbo N, Uebersax M, Hosfieldn G. An efficient extraction technique of sugars from dry edible beans (*Phaseolus vulgaris* L.) and estimation HPLC. Anna. Uni. Natio. Conf. 1985; 20:167-187.
21. FAO. Food energy-methods of analysis and conversion factors. FAO Ed, Rome. 2002;97.
22. Baributsa D, Bakoye O, Baoua I, Murdock L. Performance of five postharvest storage methods for maize preservation in Northern Benin. Insects. 2020;11(541):1-12.
23. Semassa AJ, Padonou SW, Anihouvi VB, Akissoé NH, Aly D, Adjanohoun A, Baba-Moussa L. Diversité variétale, qualité et utilisation du maïs (*Zea mays* L.) en Afrique de l'Ouest: Revue Critique. Eur. J. Sci. Res. 2016;12(18):197-217.
24. FAO. Le mais dans l'alimentation humaine. FAO Ed, Genève. 1993;147.
25. Yoka J, Loumeto J, Djego J, Houinato M, Aouango P. Adaptation d'un cultivar de niébé (*Vigna unguiculata* L. Walp.) aux conditions pédoclimatiques de la zone de Boundji (République du Congo). Afri. Sci. 2014;10(1):217-2100.
26. N'da A, Akanvou L, et Kouakou K. Gestion locale de la diversité variétale du maïs (*Zea mays* L.) violet par les Tagouana au Centre-Nord de la Côte d'Ivoire. Inter. J. Bio. Chem. Sci. 2013;7:2058-2068.
27. Guèye MT, Seck D, Wathelet J-P, et Lognay G. Typologie des systèmes de stockage et de conservation du maïs dans l'Est et le Sud du Sénégal. Biotec. Agro. Soc. Envi. 2012;16:49-58.
28. Die GR, Chatigre KO, Fofana I, Biego GHM. Nutritive parameters evolution of maize seeds conserved by triple bagging system and biopesticides (*Lippia multiflora* and *Hyptis suaveolens*) leaves in Côte d'Ivoire. International J. Biochem. Res. Rev. 2019;28(3):1-15.
29. Cissé M, Megnanou R-M, Kra S, Soro R, Niamke S. Physicochemical, biochemical and nutritive properties of QPM and regular maize flours grown in Côte d'Ivoire. Int. J. Res. Bios. 2013;2(2):26-32.

30. 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.
31. Moreau RA, Singh V, Eckhoff SR, Powell MJ, Hicks KB, Norton R. A comparison of the yield and composition of oil extracted from corn fiber and corn bran. Cereal. Chem. 1999; 76:449-451.
32. Nweke FN. Rate of water absorption and proximate analysis of different varieties of maize cultivated in Ikwo local government area of Ebonyi state, Nigeria. Afr. J. Biotechnol. 2010; 52:8913-8917.
33. Paraginski R, Vanier N, Berrios J, De Oliveira M, Elias M. Physicochemical and pasting properties of maize as affected by storage temperature. J. Stored Prod. Res. 2014; 59:209-214.
34. Codex Alimentarius Commission. Graisses et huiles végétales. FAO/WHO. 2019; codex stan du 20-23, 1981.
35. Niamketchi., Chatigre O, Konan Y, Biego H. Nutritive compounds evolution of postharvest maize (*Zea mays* L.) stored in granaries with biopesticides from rural conditions in Côte d'Ivoire. Int. J. Innova. Res. Techno. Sci. 2016;4(2):50-64.
36. Qasim A, Anwar F, Ashraf M., Saari N, Perveen R. Ameliorating effects of exogenously applied proline on seed composition, seed oil quality and oil antioxidant activity of maize (*Zea mays* L.) under drought stress. Int. J. Mol. Sci. 2013; 14:818-835.

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