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Research Paper

Physicochemical, biochemical and nutritive properties of QPM and regular maize flours grown in Côte d'Ivoire

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Abstract

QPM dissemination throughout the word increases continuously. Due to cultivation effects, those introduced and cultivated in Côte d'Ivoire had to be valorized before being accepted and involved in people feeding habit . Hence their physicochemical, biochemical and nutritive characteristics were statistically compared to those of local maize, in order to note their nutritive value. The whole maize presented moisture ranging from 10.07±0.31 to 12.13±0.22 g/100g), and high amount of dry matter (87.87±0.22 – 89.93±0.31 g/100g), energy (401.42±0.20 – 422.52±0.45 Kcal/100g), carbohydrate (83.70±0.15 – 85.09±0.19 g/100g), starch (73.13±0.02 – 73.98±0.24 g/100g), protein (8.36±0.11 – 9.78±0.07 mg/100g) and fat (5.23±0.04 – 5.62±0.01 g/100g). White QMP recorded the most important carbohydrate, starch, energy, total sugar (2.89±0.28 g/100g) and calcium (22.38±1.66 mg/100g) contents, when yellow one topped the most important proteins, reducing sugar (0.86±0.03 mg/100g), vitamin A (8.42 µg/100g) and E (164.83.µg/100g) contents. Yellow regular contained the greatest amount of iron (2.38±0.1 mg/100g), magnesium (104.26±0.88 mg/100g), zinc (2.51±0.007 mg/100g) and phosphorus (295.74±2.40 mg/100g). Ash and cellulose contents of the whole ranged from 1.17±0.11 to 1.35±0.04 g/100g and 1.31±0.04 to 1.76±0.10 g/100g, respectively. In summary, QPM presented higher energy and nutritive factor than regular maize did.

Keywords: Quality protein maize, physicochemical, characterization.

Introduction

Cereals, in general and maize, in particular constitute a solution to the high food demand throughout the world. Indeed, it is one of the staple foods in Africa, Asia and Latin America [1, 2]. Moreover, maize area harvested goes increasing by more than 25 per cent across Africa and Asia and the Pacific between 2001 and 2010. More than any other continent, Africa depends on maize as a food source [3]. In southern Africa, for instance, maize has become the most important staple food and supplies more than 50% of the energy in local diets. Global statistics for cereal consumption calculated by the World Health Organization indicate average total cereal consumption in the African diet is 291.7 g/person/ day, including an average maize consumption of 106.2 g/person/ day [4]. However, the majority of maize produced and consumed in Africa is white maize [5]. In fact, the estimated average share of white maize in total maize production ranges from 90 to 100%; the exception being Côte d'Ivoire, in which the average share of white maize is 70%. The other varieties are yellow, purple, and red.

Maize importance is also linked to its trade throughout the word [6] its wide exploitation in industries (food, chemical, pharmaceutical) and its various mode of consumption [6, 7]. Worldwide consumption of maize is more than 116 million tons, with Africa consuming 30% and sub-Saharan Africa 21%.Taking into account its great consumption and because of malnutrition linked to its poor protein quality, some genetic manipulation for the nutritive fortification were performed and leaded to quality protein maize or QPM [8]. QPM contains twice amount of amino acids lysine and tryptophan than regular maize does, respectively 0.36% and 0.10%.

The target countries for large scale cultivation of QPM have been those where maize finds substantial use for human consumption and animal feed. This has been largely possible due to the finding of QPM research at CIMMYT by NIPPON foundation Japan and Canadian International Development Agency (CIDAR). In sub-saharan Africa, several countries are growing QPM on around 200 000 hectares with Ghana alone accounting for about 70 000 hectares [8]. Burkina, Mali and Senegal also cultivate QPM, where it is involved in people feeding habit. Nevertheless, according to FAO [7], the cultural conditions (soil for instance) would affect maize quality. In Côte d'Ivoire, maize contributes to a third of the cereal production and consumption throughout various forms everywhere in the country. Nevertheless, QPM introduced and cultivated in Côte d'Ivoire, despite the great consumption of maize, had to be valorized.

The present study aimed to valorize the QPM cultivated on Ivorian soils for an efficient vulgarization and adoption by Ivorian people. So the physicochemical, biochemical and nutritive characteristics of yellow and white QPM were determined and compared to regular maize or the same colors, through statistical analysis.

Materials and Methods

The vegetable material consisted in four varieties of maize, namely two regular (white and yellow) and two QPM (white and yellow). These different samples were cultivated in the same period (April-May-June) on separated lands (500 m each from other, to avoid inter pollination), on the soil of deep sandy and loamy trays, under the tropical (and humid) climate of Yamoussoukro, the political capital of Côte d'Ivoire. The resulting seeds of each sample were kindly provided by the National Rice Program (NRP). Seeds presented different physical parameter as indicated on (Table 1). The different varieties of maize were ground in an electric crusher, sieved (500 µm for mesh size) and kept in a dessicator at room temperature (25°C), along the experience. Moisture, dry matter, ash and minerals contents were determined using methods from the thirteen edition of AOAC 1980 [9]. BIPEA 1976 [10] methods were used to determine celluloses, fat and protein contents. The reducing and total sugars amounts were evaluated with the methods of Bernfeld [11] and Dubois et al.[12] respectively. As for carbohydrate and starch contents, they were calculated by following the FAO [13] expression:

Carbohydrate content = 100 – (% Moisture + % Ash + % Fat + % Protein)
Starch content = 0.9 (% Carbohydrate – Total sugars).

Table 1: **Physical parameters of maize sample seeds**

Physical parameters	White QPM	Yellow QPM	White Regular maize	Yellow regular maize
Visual color	Beige	Yellow-orange	Beige	Yellow-orange
Length (mm)	8 – 10	7 – 10	8 – 10	8 - 9
Breadth (mm)	7 – 8	5 – 7	7 – 8	6 - 8
Thickness (mm)	4 – 5	3.95 – 4.00	3.00 – 4.00	3.90 – 4.00
One seed weight (g)	0.210 – 0.331	0.209 – 0.237	0.215 – 0.226	0.183 – 0.372
One thousand seed weight (g)	258.06 - 262.85	215.37 – 219.94	219.58 – 219.86	254.92 – 255.32
Seed moisture at storage (g/100g)	7	7	7	7

Legend: Values provided by the PNR.

Energy value was also calculated using the relation proposed by Atwater and Rosa [14] concerning starchy foods:

$$\text{Energy value} = (4 \times \text{protein}) + (3.75 \times \text{carbohydrate}) + (9.3 \times \text{fat}).$$

Flours content in vitamins A and E were determined by ultra high performance liquid chromatography recommended by ISO 14565 [15]. The standard (vitamins A and E) were prepared according to the procedure of the test. The samples injection was read at 325 nm and 292 nm, respectively for vitamins A and E; and the flow rate was set at 0,25ml/min at 70°C.

All analyses were performed in triplicate, except for vitamin A and E quantification. The data were unregistered using EXELL and analyses were carried out on XLSTAT version 2007. Duncan test (95% confidence level) of the ANOVA revealed the variability between the samples.

Results and Discussion

Physical characteristics of maize flour samples

Duncan test of the ANOVA performed on flour maize samples physical characteristic, revealed a significant difference from a sample to another, either on the basis of the type of maize (Regular and QPM) or on the color (yellow and white maize). Indeed, samples at the whole contained 10.07±0.31 to 12.13±0.22 g/100g amount of moisture, respectively recorded by the white regular and white QPM samples (Table 2). These latest samples topped, consequently, the highest (89.93±0.31 g/100g) and the lowest (87.87±0.22 g/100g) dry matter. As for the ash content, it ranged from 1.17±0.11 g/100g (yellow QPM) to 1.35±0.04 g/100g (yellow regular).

Table 2: **Physical characteristics of maize flours**

Characteristics	Yellow QPM	Yellow Regular Maize	White QPM	White Regular Maize
Moisture (g/100g)	10.73 (±0.17)^{b}	11.93 (±0.08)^{a}	**12.13 (±0.22)^{a}**	10.07 (±0.31)^{c}
Dry matter (g/100g)	89.27 (±0.17)^{b}	88.07 (±0.08)^{c}	87.87 (±0.22)^{c}	**89.93 (±0.31)^{a}**
Ash (g/100g)	1.17 (±0.11)^{b}	**1.35 (±0.04)^{a}**	1.18 (±0.02)^{b}	1.28 (±0.01)^{ab}

Legend: Highest values are in bold when the weakest are underlined

Biochemical characteristics of maize flour samples

At the whole, samples presented relatively high amount of starch (73.13±0.02 -73.98±0.24 g/100g), carbohydrate (83.70±0.15 - 85.09±0.19 g/100g) and energy (401.42±0.20 – 422.52±0.45 Kcal/100g) as shown on (Table 3). Nevertheless, Duncan test of ANOVA underlined a significant variability among samples. The yellow samples (QPM and regular maize) had the less important starch, carbohydrate and cellulose contents, compared with the white ones. Moreover, white QPM registered the greatest amount of carbohydrate, starch and total sugar (2.89±0.28 g/100g), when the yellow one recorded the highest energy value and reducing sugar (0.86±0.03 g/100g). The regular maize as for them, presented at the whole, lower content of starch, carbohydrate, energy value, reducing and total sugars than QPM did, but they got the most important cellulose content.

Nutritive characteristics of maize flour samples

Concerning proteins and fats, values were relatively high for all the samples, since the lowest ones were 8.36±0.11 and 5.23±0.04 g/100g, respectively for proteins and fats (Table 4). Nevertheless, yellow colored maize QPM (9.78±0.07 and 5.44±0.04 g/100g) and regular (9.33±0.05 and 5.62±0.01 g/100g) registered the highest contents, successively for protein and fat, compared with the white maize.
Vitamins A and E as for them were differently distributed in samples. Indeed, white colored maize (Regular and QPM) did not contain vitamin A contrary to yellow ones. Nevertheless, the entire sample had got vitamin E (Table 4). Moreover, the amounts of existing vitamins varied from a color to another and from QPM to regular maize (Table 4). Really, yellow maize recorded highest content in vitamins comparatively to

white ones. In fact, yellow QPM and regular maize got 8.42 µg/100g and 0.58 µg/100g of vitamin A, and also 164.83 µg/100g and 134.22 µg/100g of vitamin E, respectively. In parallel, white (QPM and regular) maize presented lower amount (0.00 and 0.00 µg/100g; 127.52 and 98.36 µg/100g) of the same vitamins A and E, successively.

Table 3: Biochemical characteristics of maize flour samples

Characteristics	Yellow QPM	Yellow Regular Maize	White QPM	White Regular Maize
Cellulose (g/100g)	1.31 (±0.04)[a]	1.37 (±0.04)[a]	1.45 (±0.31)[a]	1.76 (±0.10)[a]
Reducing Sugar (g/100g)	**0.86 (±0.03)[a]**	0.55 (±0.03)[b]	0.55 (±0.03)[b]	0.42 (±0.01)[c]
Total Sugar (g/100g)	2.12 (±0.08)[b]	2.45 (±0.06)[ab]	2.89 (±0.28)[a]	2.37 (±0.22)[ab]
Carbohydrate (g/100g)	83.70 (±0.15)[c]	83.71 (±0.03)[c]	85.09 (±0.19)[a]	84.24 (±0.13)[b]
Starch (g/100g)	73.41 (±0.18)[ab]	73.13 (±0.02)[b]	73.98 (±0.24)[a]	73.68 (±0.32)[ab]
Energy value(kcal/100g)	**422.52 (±0.45)[a]**	403.57 (±0.1)[b]	422.07(±1.07)[a]	401.42 (±0.20)[c]

Legend: Highest values are in bold when the weakest are underlined.

Table 4: Protein, fat and vitamins (A and E) contents in maize flour samples

Characteristics	Yellow QPM	Yellow Regular Maize	White QPM	White Regular Maize
Protein (mg/100g)	9.78 (±0.07)[a]	9.33 (±0.05)[b]	8.36 (±0.11)[c]	9.25 (±0.07)[a]
Fat (g/100g)	5.44 (±0.04)[ab]	5.62 (±0.01)[a]	5.36 (±0.20)[ab]	5.23 (±0.04)[b]
Vitamin A (µg/100g)	8.42	0.58	0	0
Vitamin E (µg/100g)	164.83	134.22	98.36	127.52

Legend: Highest values are in bold when the weakest are underlined

About minerals (Table 5), all the maize flour samples contained macro-mineral calcium, potassium, sodium and phosphorus, and oligo-mineral like manganese, iron, magnesium, copper and zinc, in relatively low amount; but no heavy metal was noticed. However, there were significant differences about these contents from a sample to another. In fact, regular maize, precisely the yellow one, recorded more importance amounts of mineral than QPM.

Table 5: Minerals component and content of maize flour samples (mg/100g)

Minerals	Manganese	Iron	Calcium	Magnesium	Potassium	Sodium	Copper	Zinc	Phosphorus	Lead
White QPM	0.56± 0.01c	2.14± 0.05b	22.38± 1.66a	97.75± 1.66b	263.80± 3.33c	1.28± 0.35c	0.2± 0.00a	2.12± 0.00b	247.05± 1.44c	ND
White Regular	0.46± 0.00d	2.21± 0.05b	12.14± 0.90b	90.70± 1.80c	304.67± 2.76b	3.02± 0.35a	0.16± 0.00b	1.49± 0.03c	268.16± 2.56b	ND
Yellow QPM	0.92± 0.02a	2.11± 0.02b	19.77± 1.58b	88.39± 0.26d	261.68± 0.91c	2.115± 0.04b	0.13± 0.00c	2.09± 0.00b	245.16± 1.82c	ND
Yellow Regular	0.63± 0.01b	2.38± 0.01a	14.13± 0.96c	104.26± 0.88a	322.19± 1.18a	3.28±0 .41a	0.16± 0.00b	2.51± 0.01a	295.74± 2.40a	ND

The high number of genotypes would be responsible of the diversity of maize color, which would be linked to the presence or not of pigments. However, independently to the color, the whole samples of the present study unregistered relatively high dry matter, energy values, carbohydrates, starch and total sugars. If the dry matter could be explained by moisture contents (weak), it is worth underlining the importance of that relative weakness. Indeed, these low moisture contents of flours; compare with Codex-Standard (15%) [16], might inhibit the multiplication of alteration microorganism; hence, it is interesting for their conservation for a relative long period. If these moisture contents are at far superior to those reported by Edema et al., [17] for QPM (6.90%) and for commercial maize flour (7.15%), they are nevertheless, inferior to 15%. Moreover, they are in conformity with the moisture of different types of maize identified by FAO [7]. However, the moisture obtained for sample flours were more important than those of the corresponding seeds in their storage condition (7%). That situation could be explained by the humidification of flour during grinding step.

The whole flours (QPM and regular) would then get the advantage not only of long shelf-life but also of giving a consistent texture to their derivate product. Concerning the high energy values, they were more important than those noticed by FAO [7] about white (356 Kcal/100g) and yellow (370 Kcal/100g) colored maize, and those of Guira [18] about QPM (385 Kcal/100g). Whatever, these high levels of energy would be explained by carbohydrate contents and mainly by the relatively high amount of starch, as suggested by FAO [19] and Aryee et al. [20] about cassava flour. This situation confirms the quality of caloric crop attributed to maize and its derivate products, and might justify their importance as staple food for many people throughout the world (mainly in developing countries) [6]. Moreover, the starch content unregistered here, independently to the variety and the color, was higher than those of the QPM (66.88%) reported elsewhere [18]. Hence, the whole samples could be exploited either in food or non-food industries. As potential utilization, they could for instance, be exploited in pharmaceutical industry in pills, be used in the production of gluten [7], in pastry manufactories, in gelatinized food (frost, soup, ice-creamand many other feeding products like biscuits and flake. Concerning the previous usages, it is worth to underline the implication of sugars (mainly reducing sugar) in the texture (crispiness) of derivate products such as biscuit. Indeed, that characteristic would result from Maillard's reaction between reducing sugars and amino acids [21]. Moreover, this content in sugar might give natural sweeten taste to products (without sugar adding).

About nutritive factors, the protein contents of the whole samples confirm FAO assertion who considers proteins as the second most important component of maize after starch. Nevertheless, the present contents were inferior to those of Improved and local maize of Nigeria published by Iken et al.[22], and those concerning QPM reported by previous authors [16, 18]. The difference revealed between the proteins content of the present QMP and those of the previous authors could be explained by the cultural conditions as underlined by FAO [7]. Hence that situation would confirm the necessity of performing experimentation on QPM after cultivation from a country to another before any vulgarization. About fats content, values were at far, superior to those published by FAO [7] and another author [16], but in conformity with QPM fats amount given elsewhere [18]. It would be worth noting, here that either proteins, or fats or ash content, the whole sample, independently to the color and the quality, responded to international standard [17] about maize flours. In fact ash content might be inferior to three (3), when proteins and fats might exceed eight (8) and three point seven (3.7) percent. Moreover, no heavy metal was detected, and samples contain minerals like calcium, magnesium, phosphorus, zinc, copper and iron, which would be essential in children feeding and important for their growing [23]. Added to the previous components, samples also contained vitamins A and E. Nevertheless, if the whole samples were concerned by vitamin E, vitamin A as for it were absent in white maize (regular and QPM).This situation could be explained by the fact that white maize would be essentially devoid of yellow carotenoid pigments, including those that serve as a source of provitamin A [24] According to the previous authors, yellow maize, as for it, would be a good vitamin A provider, and might be involved in children feeding to fight against malnutrition and blindness [25]. Above all, yellow QPM also recorded the highest amount of vitamin E. It is important recalling, here, that QPM are twice richer than regular maize in amino acids lysine (4 versus 2% of total protein) and tryptophan (0.8 versus 0.4% of total protein) which would be essential in infants and children feeding [8] According to the same authors, in India and Ghana, for instance, study on children fed with QPM (comparatively to local maize) were encouraging as the growth parameters recorded were comparable to those of milk.

Conclusion

White QPM presented the higher energy, carbohydrate, starch and total sugar than the other sample did. Yellow QPM, as for it, got more important nutritive factor such as proteins, vitamin A and E, so did reducing sugar. Hence, the QPM cultivated in Côte d'Ivoire could valuably be involved in people feeding habit, like local maize. Indeed, if the fact of presenting similar characteristics with local maize would represent a great advantage in QPM adoption, the fact of getting moreover (than local maize) qualities such as proteins content and component (lysine and tryptophan), as for it, would confirm QPM adoption.

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