Optimization of the nutritive quality of potash-treated yellow maize flour for *tô* manufacture, a traditional local cereal dish in Abidjan (Côte d'Ivoire)

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Abstract

The consumption levels of local cereal meals in Abidjan, namely potash-treated yellow maize meals, call for investigations into new methods of processing to improve the nutritive quality of their flours. Optimum conditions for manufacturing the flour was determined by experimental design method. The yellow maize flour was manufactured from decorticated grains by wet-milling, after steeping for 2 h 45 min instead of soaking overnight meaning 15 h or longer in the traditional procedure. Significant gain in proteins (78 %), fibers (380 %) and lipids (19 %) content was registered ($p < 0.05$). On the minerals composition, Fe and Zn content registered an increase of 269 % and 11 % respectively. The *tô* produced from the optimized flour was acceptable and compared favourably with the control.

Keywords: experiment design, potash-treated maize flour, *tô*, sensory evaluation, nutritive quality.

Optimisation de la qualité nutritive de la farine de maïs jaune issue d'un traitement à la potasse pour la production du *tô*, met traditionnel de céréale consommé à Abidjan

Résumé

La forte consommation des mets issus des céréales locales à Abidjan, notamment ceux du maïs jaune traité avec la potasse, nécessite des procédés de transformations qui confèrent une qualité nutritive acceptable à leurs farines. Une modélisation par la méthode du plan d'expérience a été faite pour optimiser leur qualité nutritive. Une durée de trempage de 2 h 45 min, au lieu de 15 h, pour des grains décortiqués de maïs jaune cendré a pu être établie. Une amélioration significative des teneurs en protéines (78 %), fibres (380 %) et lipides (19 %) est observée comparativement au témoin de 15 h ($p < 0.05$). S'agissant des matières minérales, ce sont des gains significatifs de 269 % et 11 % pour le fer et le zinc qui ont été enregistrés. Les tests d'acceptabilité du mets de tô issu de cette farine après optimisation ont donné des résultats assez concluants.

Mots-clés : plan d'expérience, farine de maïs jaune cendrée, *tô*, évaluation sensorielle, valeur nutritive.

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Introduction

Maize (*Zea mays*) is the major source of dietary energy and proteins in many countries of the developing world (Lipton et Longhurst, 1989). So, it is commonly used as an inexpensive source of calories. In Côte d'Ivoire, 62 % of maize is grown in savannah zones (northern areas) and is used as staple foods by the native population (Mbata *et al.,* 2009 ; Kouakou *et al.,* 2010). Recent study on local cereals consumption provided an overview on the potential for convenient yellow and white maize flours in the urban setting (N'guessan *et al.,* 2014). The consumers survey, in the districts of Abidjan, showed that these flours are predominantly manufactured into a stiff porridge (called *tô*) accompanied with soup. Like many parts of Africa, the study revealed that, white maize which lacks carotenoids (precursors of vitamin A) is preferred for human consumption (FAO, 1997). However, studies have shown that yellow maize has the potential to succeed as a strategy of dealing with the serious problem of vitamin A deficiency, especially among children of preschool age (De Groote and Chege, 2008 ; Muzhingi *et al.,* 2008). In Côte d'Ivoire, vitamin A deficiency affect more than 60 % of pregnant women and over 40 % of children ; it is assumed to be the cause of 18 % of infant morbidity (Aguayo et Adou, 2002 ; Kirthee *et al.,* 2011).

It emerged from previous studies that yellow maize grains are subjected to an alkaline treatment with potash crystals prior to milling in order to soften the grains (Nguessan et al, 2014a). Indeed, non-alkali treated yellow maize tô paste are characterized as being too stiff and obviously seems to be a barrier to its consumption. It should be noted that alkali treatment induces physical, structural and chemical changes that lead to soften and swollen kernels (Bello *et al.,* 1992 ; Almeida-Dominguez *et al.,* 1997). The benefits associated with alkaline treatment also include increased bioavailability of niacin to the point of being protective against pellagra (WHO, 2000 ; Kumaravel, 2000). Increased ash content is known to occur in alkali treated maize flours (Sefa-Dedeh *et al.,* 2004). In this context, N'guessan *et al.,* (2014b) reported 263 % increase of ash content in potash treated maize flour substantiated by the potassium content that went from 247.76 to 1092.30 mg/100 g. However, such potassium rate in products are unsafe for people suffering from kidney failure because of a potential risk of hyperkalaemia (He, 2000).

Refined maize flour is popular than whole maize flour. However, the habit of dehulling maize leads to considerable losses of nutrients (West *et al.,* 1988 ; Favier, 1989). Traditionally, the decorticated maize grains are soaked overnight prior to milling in order to insure maximum brittleness to the grains. This very practice happens to be impoverishing to products because of the leaching of nutrients (Ndjouenkeu *et al.,* 1989). Indeed, nutrients deficiency is a recurrent theme associated with West African traditional cereal dishes (Adeyemi *et al.,* 1987, Plahar *et al.,* 2003). By using this soaking technique, proteins losses may be as high as 50 % in ogi manufacture, a Nigerian cereal thin porridge (Akingbala *et al.,* 1981). Thick porridges such as *tô* in Mali (ICRISAT, 2015) *agidi* and *tuwo* in Nigeria (Adeyemi and Beckly, 1986 ; Onyeka et Dibia, 2002 ; Ikya *et al.,* 2013) are also reported to display inherent poor nutritive value. The poor processing method could result in deficiency disease, a major public health problem in developing world (FAO, 2007). For this purpose, protein malnutrition has been particularly reported among the young children consumers of *tuwo* and *agidi* who are fed with these products as weaning food (Plahar *et al.,* 2003 ; Adeoti *et al.,* 2013).

Because of this, efforts have been geared towards the development of adequate complementary foods by using locally available cereal-legume mixes (Onuoha, 2006). Also, the protein content of maize meal was increased by combination with soy flour (Plahar et Leung, 1983 ; Ikya *et al.,* 2013), blends of roasted soybean and peanut meals (Aminigo et Ossai, 1999). Earlier attempts at improving the nutrient qualities of *agidi* and *ogi* included process modification. A reduction in protein loss was achieved by using an improved wet-milling technique (Banigo et Muller, 1972). In the same context, Sokari *et al.,* (1991) reported that *ogi* can be produced within 24 h rather than 72 h or longer, as it has been the case traditionally, the porridge obtained was organoleptically acceptable to consumers.

The present work aims at improving the process of maize flour production that would enable a compromise between an adequate steeping period and the reduction in nutrient loss by using an experimental design method. The sensory properties of *tô* dish produced from the optimized maize flour were also determined.

Materials and methods

Yellow maize grains were obtained from retailers on regular markets. Flours were processed in laboratory conditions by applying the commercial transformation step. Wet milling was done using a laboratory blender. Four types of maize flours were optimized and analysed. Unhulled, non-soaked and 15 h soaked maize flours were used as control (standard).

Experimental design

Experimental design methodology was used to optimize the nutritive quality of traditionally produced maize meals. Its use provides the relevant information in the shortest time with the least number of experiments (Goupy, 2001). Multilevel factorial design was adopted for this study prior to optimization. At this stage, three factors were considered, namely hulling, steep times (h) and addition of potash crystals to the soaking water for yellow maize as seen in table I. Selected responses were grains friability and their proteins content. Proteins content were quantified according to the AOAC (1990) method while grain friability, based upon the rate of passage through a sieve, was determined according to the protocol defined by N'djouenkeu et al., (1989). Twenty five (25) grams of decorticated or non-decorticated maize grains are first tempered with water (which contains dissolved potash crystals) for an appropriate soaking time. The grains are removed, dried with blotting paper, milled (mill, RETSCH, SM100), then, sieved through a sieve with an aperture of 500 microns.

Table I. Values of independent variables (multilevel factorial design 2^2 X 3)

Independent	**variables**	**Variable**	**Level**
	Coded	**Coded**	**Uncoded**
Quantity of potash (g)	X_1	-1	5
		0	-
		1	50
Soaking periods (h)	X_2	-1	0
		0	3
		1	15
Hulling	X_3	-1	No
		0	-
		1	Yes

Polynomial model

The polynomial model for yellow maize flour processing is displayed as followed :

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_{12}X_1X_2 + a_{13}X_1X_3 + a_{23}X_2X_3 + a_{123}X_1X_2X_3$$

With Y being response variable (i.e., friability and protein content) ; a_n, the regression coefficients ; X_1 is the code for potash quantity, X_2 is the code for soaking times, X_3 is the code for hulling. The factor matrix was obtained from executing the following syntax M = fullfact ([2 3 2]) by using MatLab R2014a software. The values of the variables are presented in table I and the experimental design in table II. All experiments were carried out in a randomized order to minimize any effect of extraneous factors on the observed responses. Three replicates at the central point of the design are used to allow for estimation of the experimental error (Se). A linear regression analysis is used to calculate the coefficients and the determination coefficient (R^2). The most significative coefficients, meaning those who display an absolute value |an| greater than 2*Se, were retained (Feinberg, 1996).

Table II. The experimental design and data of responses analysis

Runs	Coded variables								
	X_1	X_2	X_3	X_1X_2	*X1X3*	X_2X_3	$X_1X_2X_3$	$Y_{protein}$	$Y_{friability}$
1	-1	-1	-1	1	1	1	-1	9.19	0.36
2	1	-1	-1	-1	-1	1	1	9.26	0.41
3	-1	0	-1	0	1	0	0	9.19	0.37
4	1	0	-1	0	-1	0	0	8.48	0.41
5	-1	1	-1	-1	1	-1	1	10.05	0.48
6	1	1	-1	1	-1	-1	-1	9.84	0.49
7	-1	-1	1	1	-1	-1	1	7.56	0.40
8	1	-1	1	-1	1	-1	-1	7.58	0.41
9	-1	0	1	0	-1	0	0	7.57	0.41
10	1	0	1	0	1	0	0	7.57	0.66
11	-1	1	1	-1	-1	1	-1	5.12	0.71
12	1	1	1	1	1	1	1	4.37	0.82

Processing of yellow maize flours

This was done essentially in accordance with observations collected during a survey on local cereal flours production (N'guessan *et al.*, 2014a). The diagram of flour production is presented in figure 1. Hulled and unhulled grains were used for this purpose ; they were soaked at given periods of time (0h, optimal time, 15h) and then milled.

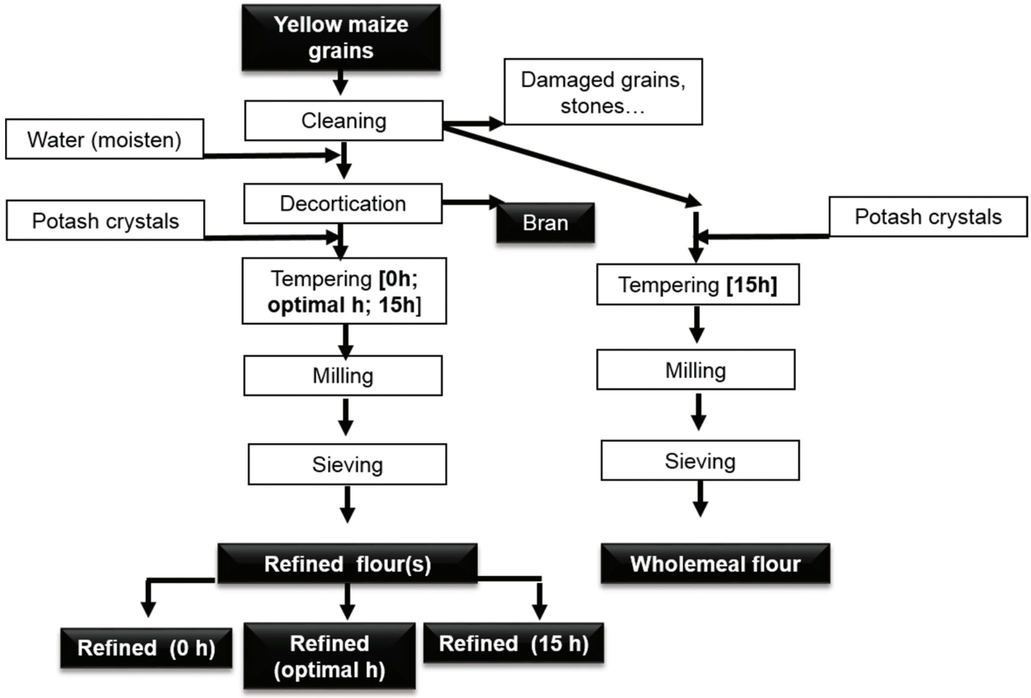

Figure 1. Flow diagram for the production of yellow maize flours.

Proximate analysis

Proximate analysis was performed using the AOAC (1990) standard methods. Ash fraction was determined by the incineration of dried sample (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The percentage residue weight was expressed as ash content. pH was determined as follow: 10 g of flour sample was homogenized with 100 mL of distilled water and then filtered. The pH values were recorded after the electrode of pH-meter (Hanna, Spain) was immersed into the flours filtered solution. For crude fibres, 2 g of sample were weighed into separate 500 mL round bottom flasks and 100 mL of 0.25 M sulphuric acid solution was added. The mixture obtained was boiled under reflux for 30 min. Thereafter, 100 mL of 0.3 M sodium hydroxide solution was added and the total volume boiled again under reflux for 30 min, cooled and filtered through a Whatman paper (100 μm diameter). The insoluble residues were incinerated, and then weighed for the determination of crude fibres content. Proteins and lipids content were determined through the Kjeldhal and the hexanic Soxhlet extraction methods.

Mineral analysis

Minerals contents were determined by the ICP-MS (inductively coupled argon plasma mass spectrometer) method described by CEAEQ (2013). The dried powdered samples (5 g) were burned to ashes in a muffle furnace (Pyrolabo, France). The ashes obtained were dissolved in 10 mL of HCl/HNO_3 (v/v) and transferred into 100 mL flasks and the volume was made up using deionized water. The mineral composition of each sample was determined using an Agilent 7500c argon plasma mass spectrometer. Calibrations were performed with external standards prepared from a 1000 ppm single stock solution made up with 2% nitric acid.

Preparation of *tô* and sensory evaluation

Several types of dough were made from the different maize flours. Dehulled grains were steeped for 0 h and 15 h with potash to serve as control samples and compared to the optimized one. Unhulled grains were also soaked for 15 h to produce a whole meal. Tô dishes were cooked according a traditional method, with 1:4 (w/v) ratio of flour (250 g) and water (1 L) (Bolade *et al.,* 2009). Consistency (texture in the hand, texture in the mouth, (Da *et al.,* 1982), appearance (smooth or grainy) and overall acceptability of the tô samples were the criterions evaluated by a 20-trained member panel. A 5 point hedonic scale with 1 representing the least score and 5 the highest, 1=very bad to 5=very good was used. Data obtained were subjected to appropriate statistical analysis using ANOVA to detect differences in the mean scores and Fisher's Least Difference was used to separate the differences in the means.

Statistical analysis

Statistical analysis of all data was done using Excel 2013 and Statistica 7.1 softwares. Statistically significant differences (Least Significant Difference, LSD) were used to separate the means while MatLab R2014a was used to set the factor matrix.

Results and discussion

A linear regression analysis was used to calculate the coefficients and the total determination coefficient (R^2). The regression coefficients for the first-order polynomial models of friability and protein content are listed in table III. Analysis of variance (ANOVA) of independent variables was performed and indicates that the models reasonably fit to the experimental data ($p < 0.05$). The linear model equations obtained on the basis of the Se values, are presented as followed:

$$Y_{proteins} = 7.98 - 0.63*X_2 - 0.50*X_3 - 1{,}20*X_2X_3 \quad \text{with} \quad R^2 = 0.85$$
$$Y_{friability} = 0.49 - 0.11*X_2 - 0.08*X_3 - 0.07*X_2X_3 \quad \text{with} \quad R^2 = 0.96$$

Table III. Regression coefficients of the first-order polynomial for two responses (proteins and friability).

Coefficients	Proteins (g/100g)	Friability (%)
a_0	7.98	0.49
a_1	-0.41	0.03
a_2	-0.63	0.11
a_3	-0.50	0.08
a_1a_2	0.40	0.02
a_1a_3	-0.25	0.03
a_2a_3	-1.20	0.07
$a_1a_2a_3$	-0.17	0.01
R^2	0.85	0.96
Se	0.49	0.04

a_n : regression coefficients ; R^2: correlation coefficient ; Se experimental error

The optimization by multi-objective function of the combined models ($Y_{proteins}$ and $Y_{friability}$), using Excel solver 2013, sets the process condition at 2 h 45 min for decorticated grains with potash crystals (50 g per Kg of maize grains). The results of the proximate composition are shown in table IV. The wholemeal flour sample displayed, predictably, the highest scores on all the parameters evaluated ($p< 0.05$). Proteins and lipid contents fall within the range reported in the literature for lipids (3.21-7.71%), proteins (7.71-14.60%) and fibers (0.80-2.32%) (Ikram *et al.,* 2010). The percentage of proteins in the current study was found closely related to those reported on regular and quality protein maize (QPM) varieties already reported in Côte d'Ivoire (Cissé *et al.,* 2013). Concerning the optimized flours (2 h 45 min) and the refined ones (0 h), proximate analysis showed basically no significant differences ($p>0.05$) between values obtained for dietary fibers and proteins. As might be expected, the ash content increases owing to the alkali processing. Actually, 20 % increase was thus recorded in the optimized flour. This notion is in agreement with the results of Owusu-Kwarteng and Akabanda (2013). These authors registered that crude ash contents was higher in nixtamalized cereal dough than in non-nixtamalized samples. Nixtamalization is a process of cooking and soaking cereals in lime (calcium hydroxide) solution. When comparing the optimized sample (2 h 45 min) to the traditional one (15 h), a significant increase in proteins, fibers and lipids was observed ($p <0.05$). Proteins increased from 5.56 ± 0.43 to 7.56 ± 0.66, which equates to a 36 % gain; the fibers content increased from 0.25±0.01 to 1.20 ± 0.10 g/100g, this represents a gain of 380 %, and lipids content increased from 1.26 ± 0.03 g/100 g to 1.49 ± 0.11 g/100g, which means almost a 19 % gain. Contrary to its content in proteins, fibers and lipids, the traditional flour recorded the highest ash value. Except the increase in ash content, the level of essential nutrients of the optimized flours were consistent with the recommendation of the Codex Alimentarius for degermed and decorticated maize meals (Codex-Stan 154, 1985 ; FAO, 1985).

Table IV. Proximate chemical composition of the of yellow maize potash treated flours (g/100g)

	Types of yellow maize flours			
Parameters	**Refined 0h**	**Optimized 2h 45min**	**wholemeal 15h**	**Refined 15 h**
pH	$6.30^{ab} \pm 0.01$	$7.09^{c} \pm 0.04$	$6.39^{b} \pm 0.4$	$7.50^{d} \pm 0.01$
Ash	$1.00^{a} \pm 0.01$	$1.20^{b} \pm 0.02$	$2.40^{d} \pm 0.28$	$1.38^{c} \pm 0.01$
Fibers	$1.22^{b} \pm 0.10$	$1.20^{b} \pm 0.10$	$5.03^{c} \pm 0.86$	$0.25^{a} \pm 0.01$
Proteins	$7.96^{b,} \pm 0.51$	$7.56^{b} \pm 0.66$	$9.13^{c} \pm 0.21$	$5.56^{a} \pm 0.43$
Lipids	$2.67^{c} \pm 0.10$	$1.49^{b} \pm 0.02$	$4.72^{c} \pm 0.00$	$1.26^{a} \pm 0.07$

Data are represented as means ± SD (n=3). Mean with different letters in the same line are statistically different ($P < 0.05$) according to Fisher's LSD test.

The results of the mineral composition of different yellow maize flours are shown in table V. The analysis of minerals shows the range of values of magnesium (68.94 ± 1.11- 100.90 ± 1.34), phosphorus (357.50 ± 5.11 - 488.98 ± 14.25 mg/100g), and potassium (466.65 ± 3.27- 718.08 ± 10.9 mg %), iron (0.48 ± 0.0-3.31 ± 0.045 mg/100g) and zinc (37.05-52.4 ppm). The whole maize flour sample (unhulled) registered nearly the highest percentage for most analysed minerals except for the K content found in the traditional sample (hulled 15 h). The higher mineral content can be explained by the fact that most minerals are concentred in the maize bran

(Sule *et al.,* 2014). Therefore, the removal of the bran amounts to the removal of most important minerals. The increase in potassium value of the traditional sample is probably due to its penetration and absorption into the endosperm and germ matrices during potash treatment (Sefa-Dedeh *et al.,* 2004). The comparison of the mineral content between the optimized and the non-soaked samples revealed minimal loss of nutrients after 2 h 45 min of soaking. This is substantiated by the fact that no significant differences were recorded among the minerals analysed with the exception of potassium which showed a slight increase in value. Compared to the traditional sample, the optimized one displayed significant increase in rate of analyzed macro-minerals (Ca, Mg, Na,) and micro-minerals (Fe, Zn). A gain of 269 % and 11 % in Fe and Zn content was registered, respectively. The sensible reduction of 33 % in potassium content of the optimized sample, brings the level down to 481.93 ± 2.85 mg/100g. Although the potassium content remains high for people suffering with kidney failure, the resulting flour dishes might meets clinical needs. Indeed, thick porridge which is prepared by cooking the flour in a 1:4 ratio with water will necessarily produce reduction in nutrients. In this respect, the patients are advised to avoid high potassium foods, which contain more than 250 mg per serving. In the same context, Wolmarans et al., (2010) reported that, South African maize porridges prepared from flour in 1:1 and 1:3 (v/w) water ratio, presented 135 mg /100g and 71 mg /100g potassium content, respectively. Another study, reported even lower values for similar dishes, meaning, 71 and 29 mg/100g (Spearing *et al.,* 2012).

Table V. Minerals composition of yellow maize potash treated flours

Parameters	**Types of yellow maize flours**			
(mg/100g)	**Refined 0 h**	**Optimized 2 h 45min**	**Wholemeal 15 h**	**Refined 15 h**
Ca	4.84[c] ± 0.12	3.10[b] ± 0.14	6.85[d] ± 0.02	1.15[a] ± 0.57
Cu	1.81[b] ± 0.09	1.76[b] ± 0.00	2.77[c] ± 0.05	1.28[d] ± 0.09
Fe	1.77[b] ± 0,14	1.72[b] ± 0,05	3.31[c] ± 0.045	0.48[a] ± 0.04
K	466.65[a] ± 3.27	481.93[b] ± 2.85	598.07[c] ± 3.97	718.08[d] ± 10.9
Mg	73.39[b,] ± 0.93	73.71[b] ± 0.29	100.90[c] ± 1.34	68.94[a] ± 1.11
Mn	0.05[a] ± 0.00	0.05[a] ± 0.01	0.73[b] ± 0.09	0.00[a] ± 0.00
Na	4,09[c] ± 0,00	2,31[b] ± 0,07	5,37[d] ± 0,05	0,20[a] ± 0,05
P	395.30[b] ± 5.75	387.54[b] ± 16.74	488.98[c] ± 14.25	357.50[a] ± 5.11
Zn	1.86[b] ± 0.01	1.81[b] ± 0.08	3.06[c] ± 0.01	1.64[a] ± 0.01

Data are represented as means ± SD (n=3). Mean with different letters in the same line are statistically different. ($P < 0.05$) according to Fisher's LSD test.

Table VI shows the results of sensory evaluation of tô dishes. The sensory evaluation showed that the traditional sample (15 h) was most preferred by panelists for all parameters assessed. However, the scores of the optimized sample indicates that it was greatly appreciated. The smooth appearance of the dough was attested by the score 4.45c ± 0.37 (table VI) and confirmed that the friability of the soaked grains was more than adequate. The overall acceptability score of the optimized tô sample, shows that it displays a close rating with the traditional sample in less time than it takes for its preparation. Hence, the organoleptic parameters scores suggest that it is possible to make culturally acceptable tô of flour issued from modified conditions. Indeed, it is reported that food habits, unlikely, are slow and difficult to change. Particularly, the traditional foods of childhood, such as tô dish, which evoke a deep-seated psychological response (Diallo, 1994). On the wholemeal tô dish, the acceptance was quite mixed (3.00 ± 1.01). However, the organoleptic parameters can be improved with adequate soaking period; indeed, 48 to 72 h are generally required (Enujiugha, 2006). For the sake of their nutritional quality, unrefined cereal tô meals are now being promoted among rural populations despite the social stigma that associates the presence of bran with laziness and poverty (ICRISAT, 2015).

Table VI. Means of sensory scores of the yellow maize potash treated tô dishes

Parameters	Refined 0 h	Optimized 2 h 45mn	Refined 15 h	Wholemeal 15 h
Texture in the hand	$1.05^{a} \pm 0.22$	$4.50^{c} \pm 0.27$	$4.90^{d} \pm 0.09$	$2.95^{b} \pm 1.36$
Texture in the mouth	$1.05^{a} \pm 0.22$	$4.40^{c} \pm 0.10$	$4.90^{d} \pm 0.09$	$3.30^{b,c} \pm 1.34$
Appearance	$1.55^{a} \pm 0.99$	$4.45^{c} \pm 0.37$	$5.00^{d} \pm 0.00$	$3.40^{b,c} \pm 1.27$
Overall acceptability	$1.02^{a} \pm 0.34$	$4.66^{c} \pm 0.08$	$4.89^{d} \pm 0.13$	$3.00^{b} \pm 1.01$

Data are represented as means ± SD (n=3). Means with different letters in the same line are statistically different. ($P < 0.05$) according to Fisher's LSD test.

Conclusion

Proximate composition of the flour showed an increased in essential nutrients and the sensory evaluation of the tô dish displayed a comparative sensory acceptability with respect to the control (15 h maize *tô*). In view of this, the modification of the traditional wet milling process of potash treated yellow maize may be used to enhance the nutritional status of the populace especially the child. These results will be useful to address the very issue of poor traditional methods of food processing and provide consumer with familiar traditional food which is somewhat satisfying and reassuring.

References

Adeoti O., Elutilo O., Babalola J., Jimoh K., Azeez L., Rafiu K., 2013. Proximate, Mineral, Amino Acid and Fatty Acid Compositions of Maize Tuwo-Cirina Forda Flour Blends. *Greener J. of Biological Sci.,* 3 (4):165-171.

Adeyemi I., 1983. Dry milling of sorghum for ogi manufacture. J. of Cereal Sci., 1: 221-227.

Adeyemi I., Beckly O., 1986. Effect of Period of maize fermentation and souring on chemical properties and amylograph pasting viscosity of ogi. *J. of Cereal Sci.*, 4:353-360.

Adeyemi I., Ogunsanmi A., Fakorede M., 1987. Effect of corn varieties on ogi quality. *J. of Food Sci*. 52:322-324.

Aguayo V., Adou P., 2002. Nutrition en Côte d'Ivoire, Un appel à l'action. Afri. *J. of Food and Nutriti*. Sci., 2 (2):86-91.

Akingbala J., Rooney L., Faubion J., 1981. A laboratory procedure for the preparation of ogi, a Nigerian fermented food. *J. of Food Sci.,* 46:1523-1526.

Almeida-Dominguez H., Suhendro E., Rooney L., 1997. Corn alkaline cooking properties related to grain characteristics and viscosity (RVA). *J. of Food Sci.,* 62:516-519.

Aminigo E., Akingbala J., 2004. Nutritive composition and sensory properties of ogi fortified with okra seed meal. *J. of Appl. Sci. and Env. Management,* 8 (2): 23-28.

Aminigo E., Ossai G., 1999. Production and evaluation of high-protein roasted maize meal. *Journal of Appl. Sci. and Env. Management,* 3:17-22.

AOAC, 1990. Official Method of Analysis, 15th edn, Association of Official Analytical Chemists. Washington DC, 684 p.

Banigo E., Muller H., 1972. Manufacture of ogi (a nigerian fermented porridge): comparative evaluation of corn, sorghum and millet. *Can. Inst. Food Sci. Technol. J.,* 5, 217-221.

Bello A., Rooney L., Waniska R., 1992. Factors affecting quality of tô, a thick porridge. *Cereal Chemist.,* 67: 20-27.

Bolade M., Adeyemi A., Ogunsua A., 2009. Influence of particle size fraction on the physicochemical properties of maize- based non-fermented food gel. *International Journal of Food Sci. and Tech.,* 44: 646-655.

Carpenter K., 1983. The relationship of pellagra to corn and the low availability of niacin in cereals. *Exp. Supplementum,* 44:197-222.

CEAEQ, 2013. Détermination des métaux: méthode par spectrométrie de masse à source ionisante au plasma d'argon. MA. 200 – Mét 1.2, Rév.4, 24 p.

Cisse M., Megnanou R., Kra K., Soro R., Niamke S., 2013. Physicochemical, biochemical and nutritive properties of QPM and regular maize flours grown in Côte d'Ivoire. Int. *J. of Research in BioSci.,* 2: 26-32.

Codex-Stan 154, 1985. Norme pour la farine de maïs complet, 3 p.

Da S., Akingbala J., Rooney L., Scheuring J., Miller R., 1982. Evaluation of *tô* quality in a sorghum breeding program. International symposium on sorghum grain quality. L.W. Rooney, D.S Murty and J. V. Mertin eds. ICRISTAT, p. 11-23.

De Groote H., Chege K., 2008. Comparing consumer preferences for color and nutritional quality in maize: application of a semi-double-bound logistic model on urban consumers in Kenya. *Food Policy,* 33: 362-367.

Diallo A., 1994. La transformation des produits agricoles locaux au Burkina Faso: les innovations en échec : analyse du cas de la méconnaissance du marché. Programme de Recherche Politiques et Développement Agricoles et Agro-Industriels au Burkina Faso ORSTOM, 22 p.

Enujiugha V., 2006. Supplementation of ogi, a maize-based infant weaning food, with African oil bean seed (*Pentaclethra macrophylla* Benth). Int. *J. of Postharvest Tech. and Innovati.,* 1(2): 202-211.

FAO, 2007. Les bonnes pratiques d'hygiène dans la préparation et la vente des aliments de rue en Afrique. Rome, 188p.

FAO, 1985. Précis technique sur les farines composées. Commission économique pour l'Afrique des nations unies. Application des techniques existantes. Rome, 168 p.

Favier J., 1989. Valeur nutritive et comportement des céréales au cours de leurs transformations. Céréales en régions chaudes AUPELF-UKEF, Eùs John Libbey Eurotext, Paris Q p. 285-296.

Feinberg M., 1996. Validation des méthodes d'analyses. Une approche de l'assurance qualité au laboratoire. Masson, p. 206-266.

Goupy J., 2001. Introduction aux Plans d'expériences Ed. Dunod. Paris. 303 p.

He F., Marciniak M., Carney C., Markandu N., Anand V., Fraser W., Dalton R., Kaski J., and MacGregor G., 2010. Cardiovascular risk factors, and bone turnover in mild hypertensives.effects of potassium chloride and potassium bicarbonate on endothelial function. Hypertension 55: 681-688.

ICRISAT, 2015. Rebranching bran: teaching nutrient-rich cooking in Mali. *Bulletin Afrique de l'Ouest et du Centre,* 10p. http://www.coraf.org/documents/publication/2015-04.

IITA, 2013. Breakthroughs in maize breeding. *Review* Issue 10.

Ikram U., Muhammad A., Arifa F., 2010. Chemical and Nutritional Properties of Some Maize (Zea mays L.) Varieties Grown in NWFP, Pakistan. *Pakist. J. of Nutri.,* 9 (11): 1113-1117.

Ikya J., Gernah D., Sengev I., 2013. Proximate composition, nutritive and sensory operties of fermented maize, and full fat soy flour blends for "agidi" production. *Afri. J. of Food Sci.,* 7(12): 446-450.

Kaski J., MacGregor G., 2010. Cardiovascular risk factors, and bone turnover in mild hypertensives effects of potassium chloride and potassium bicarbonate on endothelial function. *Hypertension* 55: 681-688.

Kirthee P., Siwela M., Derera J., Veldman F., 2011. Consumer acceptance of yellow, provitamin A-biofortified maize in KwaZulu-Natal. *The South Afri. J. of Clinical Nutri.,* 24 (4): 186-191.

Kouakou C., Akanvou L., Konan Y., Mahyao A., 2010. Stratégies paysannes de maintien et de gestion de la biodiversité du maïs (*Zea mays* L.) dans le département de Katiola, Côte d'Ivoire. *J. of Appli. Biosci.,* 33: 2100 - 2109.

Kumaravel R., 2000. Pellagra in the United States: a historical perspective. *Southern Medical J.,* 93 (3):272-277.

Lipton-Longhurst, 1992. *New seeds and poor people. Eco. Develop. and Cultural Change,* 40 (2): 444-447.

Mbata T., Ikenebomeh M., Alaneme J., 2009. Studies on the microbiological, nutrient composition and antinutritional contents of fermented maize flour fortified with bambara groundnut (*Vigna subterranean* L). *Afri. J. of Food Sci.,* 3:165-171.

Muzhingi T., Langyintuo A., Malaba L., Banziger M., 2008. Consumer acceptability of yellow maize products in Zimbabwe. *Food Policy,* 33:352–61.

N'guessan Y., Bedikou E., Megnanou R., Niamke S., 2014a. Local cereal flours repartition on markets and sellers approach on production and conditioning in the districts of Abidjan Côte d'Ivoire. *Europ. Sci. J.,* 10 (24):34-47.

N'guessan Y., Bedikou E., Megnanou R., Niamke S., 2014b. Importance of local cereal flours in the diet habits of consumers in the District of Abidjan, Côte d'Ivoire. *Food and Env. Safety,* 13: 134-146.

N'guessan Y., Bedikou E., Zoue L., Goualie B., Niamke S., 2014c. Physicochemical, nutritive and safety evaluation of local cereal flours sold in areas of the District of Abidjan-Côte d'Ivoire. *J. of Appli. Biosci.,* 83:7579-7594.

Ndjouenkeu R., Mbofung C., Etoa F., 1989. Étude comparative de quelques techniques de transformation du maïs en farine dans l'Adamaoua in Céréales en régions chaudes: conservation et transformation. Paris, France, AUPELF/UREF, Edit. *John Libbey Eurotext*, p. 179-186.

Odebode T., Odebode S., 2005. Protein Energy Malnutrition and the Nervous System: the Impact of socioeconomic Condition, Weaning Practice, Infection and Food Intake, an Experience in Nigeria. *Pakist. J. of Nutri.*, 4(5): 304-309.

Onuoha N., 2006. Production and evaluation of a low-cost micronutrient-rich complementary food. Ph.D Thesis, Department of Home Science, Nutrition and Dietetics, University of Nigeria, Nsukka, p. 19-120.

Onyeka U., Dibia I., 2002. Malted weaning food made from maize, soybean, groundnut and cooking banana. *J. of the Sci of Food and Agri.,* 82: 513-516.

Owusu-Kwarteng J., Akabanda F., 2013. Applicability of Nixtamalization in the Processing of Millet-based Maasa, a Fermented Food in Ghana. *J. of Food Res.,* 2(1):59-60.

Plahar W., Leung H., 1985. Storage stability of dehydrated and soy-fortified fermented maize meals. *J. of Food Sci.,* 50(1): 182-187.

Plahar W., Okezie B., Gyato C., 2003. Development of a high protein weaning food by extrusion cooking using peanuts, maize andsoybeans. *Plant Foods Human Nutr.,* 58:1-12.

Sefa-Dedeh S., Cornelius B., Saky-Dawson E., Afoakwa E., 2004. Effect of nixtamalization on the chemical and functional properties of maize. *Food Chemistry,* 86:317-324.

Sokari T., Karibo P., Manuel L., 1991. Substitution of boiling for steeping in ogi production. *Discovery Innovation,* 3:87-90.

Spearing K., Kolahdooz F., Lukaswich M., Mathe N., Khamis T., Sharma S., 2012. Nutritional composition of commonly consumed composite dishes from rural villages in Empangeni, Kwa-Zulu Natal. *South Africa. J. of Human Nutri. and Dietetics* 26(3):10.111/jhn.12001.

Sule E., Umoh V., Whong C., Abdullahi I., Alab O., 2014. Chemical and nutritional value of maize and maize products obtained from selected markets in Kaduna State, Nigeria. *African Journal of Food Sci. and Tech.,* 5(4): 100-104.

USAID, 2013. Estimation des volumes et de la valeur du commerce régional des denrées de base en Afrique de l'Ouest, étude réalisée pour le programme ATP, Accra, 44 p.

West C., Pepping F., Temalilwa C., 1988. The composition of foods commonly eaten in East Africa, Wageningen agricultural University on behalf of CTA and ECSA. 84 p.

WHO, 2000. Pellagra and its prevention and control in major emergencies. Geneva, Switzerland: World Health Organization, 40p.

Wolmarans P., Danster N., Dalton A., Rossouw K., Schonfeldt H., 2010. Condensed Food Composition Tables for South Africa. Medical Research Council, Parow Valley, Cape Town, 126p.