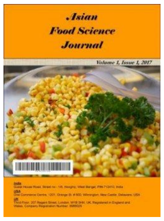

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Comparative Study on Proximate, Mineral and Anti-Nutrient Content of Composite Roasted Corn Flour with Its Traditional Roasted Corn Counterpart for Homemade Complementary Foods

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Authors' contributions

This work was carried out in collaboration among all authors. Author STB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RNP and DGG managed the analyses of the study. Author EBA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study aimed to produce and evaluate the physicochemical composition of an improved and enriched roasted corn flour with soybean (5%) and groundnut (5%) flours comparatively to its traditional preparation for homemade complementary foods. Samples of (corn, soybean and groundnut) were dried and milled to produce two types of roasted corn flour: the roasted corn flour with soy and peanut and the traditional roasted corn flour with corn only. Laboratory analyses of chemical proximate like nutrients, minerals and anti-nutrients properties were determined according to standard procedures. Data generated were subjected to one way analysis of variance using using SPSS 11.0 software. The results showed that there were significant differences ($P<0.05$) among the samples.

Regarding proximate composition, the composite roasted corn flour is distinguished by higher crude fat (5.83%), protein (19.66%), carbohydrate (62.31%), fiber (3.67%), ash (1.85%) and

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calorific (442.99 Kcal/100 g) value. Likewise, mineral contents increased significantly ($p<0.05$) in the composite roasted corn flour with high value in all the studied minerals including potassium (779.11 mg/100 g), phosphorus (242.83 mg/100 g), calcium (132.45 mg/100 g), zinc (2.67 mg/100 g) and iron (1.44 mg/100 g). The studied of anti-nutrients, showed that composite roasted corn flour also exhibit lower value in oxalate (8.03 mg/100 g) and phytic acid (3.48 mg/100 g). It could be concluded that the composite roasted corn flour appears to be suitable for homemade complementary foods to cover infant and young children needs.

Keywords: Homemade; corn; flour; complementary food; soybean; groundnut; anti-nutrient.

1. INTRODUCTION

Malnutrition is still a serious health problem affecting infant and young children in developing countries [1]. It contributes to 35% of deaths of children below 5 years of age in West Africa [2]. In Côte d'Ivoire, this prevalence is 40.6% and 30% of these children are stunted [3]. Though causes of malnutrition are diverse and interrelated, inadequate dietary intake during the complementary feeding period is considered to be major contributing factor [2].

Nutrition in early life has the greatest influence on child growth, development and survival [4]. Following six months of exclusive breast feeding, appropriate and adequate nutritious complementary foods should be introduced. The nutrients content of complementary foods should be adequate and diverse enough to meet the child's nutritional needs. Infants and young children are vulnerable to inadequate nutrient intake during period of complementary feeding (6-23 months). Indeed, nutrients requirements during this period are very high to promote high growth while the supply is insufficient to meet demand [4]. The first two years of life are a critical period of child development. During this period, child's development necessary to achieve the maximum growth rate is initiated. However, if nutritional requirements are not attained, growth faltering occurs inevitably [5]. Proper physical, cognitive and intellectual development is attained by adequate nutrition in childhood [6]. Therefore, in order to meet nutrient requirement, the complementary food need to contain all essential nutrients such as carbohydrates, proteins, fat, vitamins and minerals appropriate to facilitate optimal growth and development.

In sub-Saharan Africa, the first supplement foods are most often porridge-based cereals, roots and tubers. They are rich in carbohydrates and not in proteins. These foods are unable to cover all the nutritional needs of the child. In addition, good quality infant flours exist in the market but they are imported and expensive industrial products. To solve this problem [7] advocates that complementary foods should be made from locally available, low-income, nutritionally adequate products to meet nutrient needs of the child. Among these local products, maize (*Zea mays*) is an important cereal for its high food consumption in West Africa [8]. This cereal is known to provide appropriate amount of energy and carbohydrate unlike its low levels of proteins (10%) [2].

Moreover, it is well known that anti-nutritional factors like tannins, oxalates and phytates present in cereal grains chelate minerals divalent (iron, zinc and calcium) and proteins. Therefore, they have the ability to limit highly nutrients absorption and their availability for the body [9].

It has been reported that vegetable oilseeds and plant proteins such as soybean (Glycine max) and groundnut (*Arachis hypogaea* L.) could improve the balance diet in Africa if their consumption is increased [10]. Food fortification is therefore a recommended strategy for improving nutritional quality. Enrichment of corn with these different proteneous and lipids foods could improve (enhance) its nutritional quality and helped to diversify infant diet [11]. Different flours formulations of composite roasted corn (with roasted soy flour and roasted groundnut flour) were developed. A survey conducted in the Abidjan region showed the population's preference for the 90-5-5 corn-soya- groundnut formulation (data not shown). In order to make our contribution to the improvement of the quality of complementary foods during the weaning period, we are interested in studying the nutritional quality of cereal-based complementary flour used to prepare complementary food for infants and young children (6 - 23 months). Therefore, the aim of this study was to compare the physicochemical composition of an improved and enriched roasted corn flour formulation with its traditional roasted counterpart.

2. MATERIALS AND METHODS

2.1 Sample Procurement

Corn kernels (*Zea mays*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea* L.) used in this study were procured from the wholesale market of Adjamé (5°29′17″ north, 4°01′56″ west), a local market of Abidjan.

2.2 Production and Formulation of Flours

2.2.1 Production of traditional roasted corn flour

Corn kernels were cleaned and sorted by hand before being grilled at 120°C for 20 minutes in a MEMMERT (include the models) ventilated oven. The roasted corn kernels were milled in a heavy duty speed blender (include the models). The powder obtained (ground) was screened with a 250 µm mesh sizes to obtain a fine flour of roasted corn (Fig. 1). The flour produced was stored at 4°C, in hermetically sealed boxes, for the further use.

2.2.2 Production of composite roasted corn flour

The roasted soy and groundnut flours were separately obtained from each ingredient previously prepared and roasted in a ventilated oven type MEMMERT at 120°C for 20 min (soybeans) and 80°C for 24 h. the roasted materials were removed from the oven and crushed in a heavy duty speed blender, the ground products obtained were then sieved with a 250 µm mesh sizes. The different flours produced were stored at 4°C, in hermetically sealed boxes, for further use.

The 90-5-5% corn-soya-peanut flour formulation retained after a hedonic test (data not shown) was used to prepare the composite flour from the previously prepared flours. Composite flour samples were blended properly, packed in sealed bags and stored till further analysis. Fig. 1 is a flow chart showing how the raw ingredients were processed to get the final product.

2.3 Proximate Composition

The moisture, crude protein (N×6.25), fat, ash and fiber were determined in triplicate according to the Standard Association of Official Analytical Chemists [12] procedures. Carbohydrates were calculated by difference and the calorific value (energy) was calculated using the Atwater factors [13].

2.4 Minerals Analysis

A mineral extract was prepared by incinerating 0.5 g of each sample at 600°C overnight [14]. The ash was dissolved in a diluted HCl (1:3. HCl: distilled water, v/v) with addition of a few drops of concentrated nitric acid. The extracted solution was made up to 50 mL with distilled water and then filtered. Sodium (Na) and Potassium (K) contents were determined by a flame photometer (Corning, model 403, UK) and NaCl and KCl were used as standards. Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn) and Copper (Cu) were determined by atomic absorption spectrophotometer (Perkin-Elmer, 403, USA) as reported by [15]. The results were expressed in mg.100 g^{-1}.

2.5 Determination of Anti-nutritional Factors

2.5.1 Tannins content

The tannins content of each sample was determined by vanillin HCl method [16]. Briefly, 1.0 mL of dried extract methanolic solution (1:10 w/v) was added to 5.0 mL of vanillin reagent (4.5 mL of 4% HCl in methanol and 0.5 mL of vanillin in methanol) and then mixed. The reactants were incubated for 20 min at 30°C and thereafter the absorbance was read at 500 nm using a UV spectrophotometer. Standard curve was prepared using tannic acid (R^2= 0.971). The tannin content was expressed as tannic acid equivalents (mg.g^{-1}).

2.5.2 Phytic acid content

The phytic acid content of each sample was determined according to methods of AOAC [17]. Five grams from each sample was weighted into a 500 mL conical flask and soaked in 250 mL of 2% hydrochloric acid (HCl) for 3 h. the mixture was filtered through a filter paper (wathman no 4). Fifty milliliters of the filtrate was mixed with 100 mL of distilled water and 10 mL of 0.3% ammonium thiocyanate (NH_4SCN) solution. The mixture was then titrated against standard ferric chloride containing 0.00195 g iron per mL. The colour of the end point is slightly brownish-yellow, which remained stable for 4 min. The

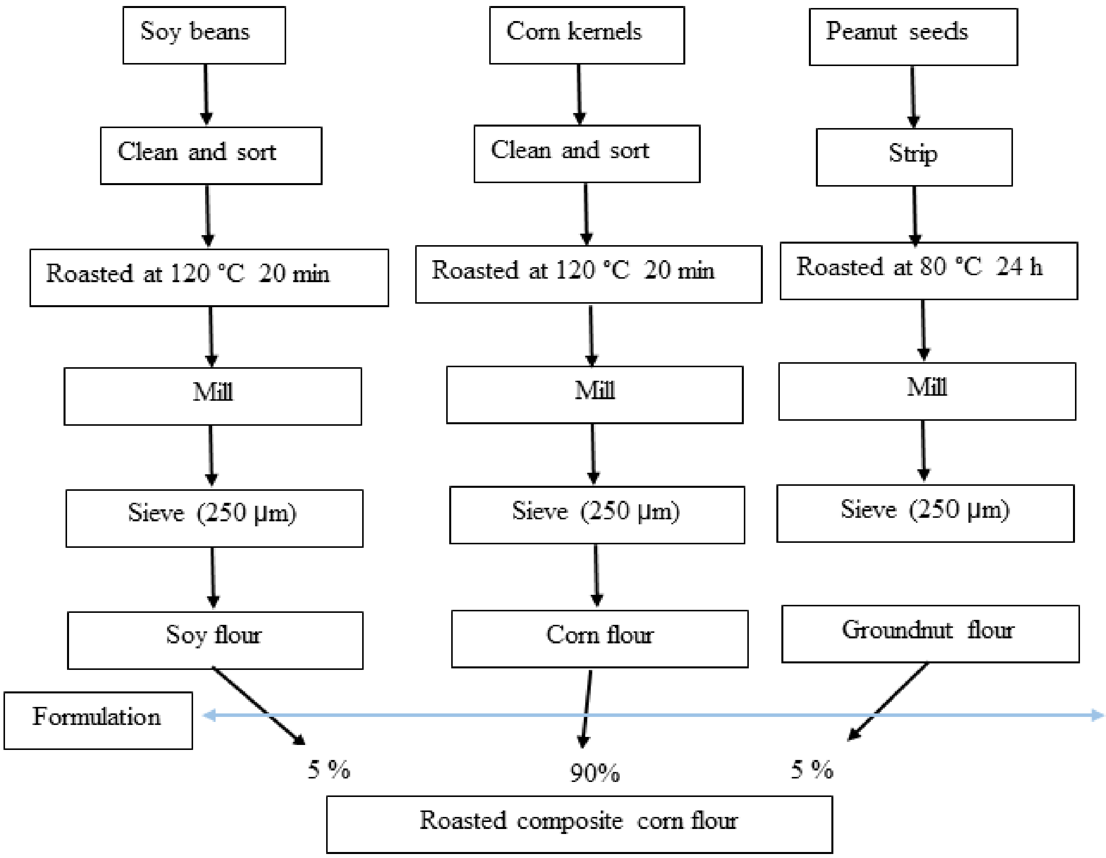

Fig. 1. Process flowchart on the preparation of flours

content of phytates was calculated as follow Eq (1):

$$\text{Phytates (\%)} = (T \times 1.19 \times 100)/0.00195 \quad (1)$$

Where T is the titer volume.

2.5.3 Oxalates content

Oxalates content was determined by the official methods of AOAC [12]. Briefly, 1.0 mL g from each sample and 75 mL of 3.0 mol.L^{-1} H_2SO_4 were carefully stirred for an hour and then filtered through a filter paper (Wathman no 1). Twenty-five milliliters of filtrate (extract) was titrated against hot (80-90°C) 0.1 mo.L^{-1} $KMnO_4$ solution to the point when a faint pink colour appeared that persisted for at least 30 s.

2.6 Data Analysis

Proximate analysis and anti-nutritional factors were carried out in three triplicates. The data collected were subjected to one way Analysis of Variance (ANOVA) ($p < 0.05$) using SPSS 11.0 software. Means with significant differences were separated by Turkey test.

3. RESULTS AND DISCUSSION

The result from the chemical analysis of the two roasted corn flours are shown in Table 1. The proximate composition (Table 1) revealed that both types of roasted corn flour show significant differences ($p < 0.05$) with regard to the studied parameters. In addition, while the traditional roasted corn flour exhibits the highest content in moisture, the composite roasted corn flour is distinguished by higher crude fat, protein, fiber, carbohydrate, energy value and ash content. The least moisture content (10.56%) highlight by the composite roasted corn flour (Table 1) compared to the traditional roasted corn flour (13.12%) could be due to the addition of soy and peanut. Indeed, [18] has reported that high proteins content of Soybean flour promotes high water absorption capacity. This leads to less water available in the flour and could explain the significant reduction in moisture content of composite roasted corn flour formulation [19]. Similarly, the low moisture content of raw peanut seeds (7.48%) as reported by Ayoola and Adeyeye [20], could also justify this low water content. Fortification using soybean and groundnut reduced the available water and thus would extend the shelf life of the composite roasted corn flour by reducing its susceptibility to microbial spoilage. Hence, the low moisture contents of this composite flour are recommended for convenient food for children associated with packaging and transport of products [21].

Results further show that roasted soy and groundnut flour fortification increased significantly the crude fat of the roasted composite corn flour to 05.83% comparatively to the traditional roasted corn flour with (04.63%) (Table 1). Samuel [18] reported similar findings, with fortification using soybean increasing the fat content of tapioca flour from 0.97 to 4.52% as soybeans and groundnut are rich in lipids of excellent qualities. Fat is essential for the supply of energy in the body, facilitate absorption of fat soluble vitamins and provide essential fatty acids that are required for normal brain development [22]. As all types of complementary flour was not able to provide them, this composite roasted corn flour will also play a nutritionally role in providing essential fatty acids. Indeed, its contents correspond to the recommended fat level for weaning foods [23] which should be less than 10%.

The protein content of the roasted corn flours are depicted on Table 1. Protein is one of the most important nutrients required in weaning foods. Of the two types of roasted corn flours analyzed, the composite flour had the highest protein content (19.66%). An over 90% increase in the protein content was observed for this composite corn flour, when compared to the traditional roasted corn flour (10%). A similar increase has been reported for soy-maize snacks [19]. The high protein contents of this formulation might be due mostly to inclusion of soybeans which boosted the overall protein content. Similarly, enrichment of protein content in cereals-based complementary food with protein dense foods have been reported by Steve and Babatunde [24]. In addition, this protein content was above minimum amount (14.52%) specified in Codex Alimentarius standards for maximum complementation of amino acids in foods and growth [25]. The adequate intake of protein is essential for meeting the growing demand of children especially during this critical stage of growth. Growing children require a constant supply of protein for growth, building up new tissues and body maintenance [26]. Thus, this formulation satisfy the protein demands of weaning foods for infants. This is a desirable attribute especially for a developing country like Côte d'Ivoire where other sources of protein are expensive.

The carbohydrate contents are shown on Table 1. Carbohydrate contents in the studied flour were all significantly different from each other at $p < 0.05$. The composite roasted corn flour recorded the higher carbohydrate value (62.31%) compared to the other studied corn flour. However, the carbohydrate contents of both types of studied flours were higher than the lower limit for carbohydrates (41.13 to 73.79%) of the Codex alimentarius Standards [25] indicating the adequacy on providing energy needed by the body.

The fiber contents are shown on Table 1. The crude fiber content of the studied flours were significantly different for each other at $p < 0.05$ with the formulated flours displaying the highest value (03.67%**)**. However, these both types of studied flours exhibited crude fiber contents well below the limit of 5% [26] recommending for fiber intake in infant's diets. The physiological role of fiber is to maintain an internal distension for peristaltic movement of the intestine [27]. Infant diet with high fiber content is not advisable as it tends to reduce nutrient digestibility as well as increase malabsorption of micronutrient, under this condition growth retardation may occur [28]. Hence low-fiber diets are suitable for weaning foods and in this case, both types of roasted corn flour would be suitable for weaning flours due to their low fiber content.The results for ash contents are also shown on Table 1. Ash content is an indication of the presence of mineral elements. The higher ash content of the composite roasted corn flour (01.85%) compared with traditional roasted corn flour (01.60%) probably indicates a higher mineral content. Fortification thus increases the ash content. No standard for ash content has been specified for weaning foods in the Codex Alimentarius Standards [25]. However, both types of roasted corn flour exhibited ash contents acceptable by the Protein Advisory Group standard which recommended that ash content should not exceed 5% [23].

The calorific (energy) values are depicted on Table 1. The energy contents of both types of roasted corn flour were significantly different at $p < 0.05$. Energy from the diet is recommended to be adequate to meet the physiological requirement of the body. The energy requirement is expressed as energy intake from the food that will balance energy expenditure [29]. Carbohydrate serves as a primary source of energy in the body. Carbohydrate caloric contents of 226.27 kcal and 233.66 kcal were recorded by traditional roasted corn flour and composite roasted corn flour. These values representing 56.57% and 52.75% of the total energy content of the previous diets, respectively were within the range of 50-60% recommended by PAG [23] for adequate energy intake. From this study, fat and protein content observed by the traditional roasted corn flour and the composite roasted corn flour provide 10.76 and 12.24% and 10 and 17.92% of the total energy, respectively. These values are within the recommended ranges of 10-20% [30]. The adequate supply of dietary fat to infant provide the body to receive adequate energy needed for growth and other body function hence promote the growth pattern. Nevertheless, attainment of daily recommended energy intake depends on the frequency of the meal, amount of the food consumed, and energy density of the food [23-30]. Therefore, adequate intake of energy promotes optimal growth and development.

Mineral contents of the different studied flours are depicted in Table 2. All the studied minerals increased significantly ($p< 0.05$) in the composite roasted corn flour compared to the traditional roasted corn flour. Indeed, mineral analysis of composite roasted corn flour revealed high levels of sodium (12.18 mg/100 g), potassium (779.11 mg/100 g), magnesium (90.11 mg/100 g), copper (2.87 mg/100 g), zinc (2.67 mg/100 g), phosphorus (242.83 mg/100 g), calcium (132.45 mg/100 g) and iron (1.44 mg/100 g). These minerals composition of roasted composite corn flours is due to the quality of the ingredients and the technological treatment applied to the different ingredients.

Thus, these mineral elements would be beneficial for the regulation of the water balance of the cells for the ossification and the biochemical reactions of the organism [31]. Potassium for instance, protects against high blood pressure [32]. Calcium values found in composite flour are adequate for bone and tooth development. Inadequate intakes of zinc and iron have been associated with severe anaemia, increased disease and mental disorders [31-32]. The results of the mineral analysis showed that the composite roasted corn flour would contribute substantially to the recommended dietary requirements for minerals.

Cereals and legumes are naturally containing anti-nutritional factors including tannin, phytic acid and oxalate which limits the bioavailability of minerals [33]. Table 3 depicted the content in these anti-nutrients factors (tannin, phytic acid and oxalate) in the different studied flours. Except for tannin, oxalate (8.03 mg/100 g) and phytic acid (3.48 mg/100 g) contents registered by the composite roasted corn flour are significantly ($p< 0.05$) lower than those of traditional roasted corn.

Also, low values of anti-nutritional factors have been reported by Ijarotimil and Kcshinro [34] on the supplementation of flours with underground beans. The low levels in tannins, oxalate and phytic acid are due to heat treatments during processing of the composite flour. Several authors have reported the value of treatments (physical, biochemical and thermal) in reducing and / or eliminating these anti-nutrients factors

Table 1. Proximate composition of traditional roasted and composite roasted corn flour

Physicochemical parameters	Traditional roasted corn flour	Composite roasted corn flour
Moisture (%)	13.12 ± 0.02^a	10.56 ± 0.13^b
Ash (%)	01.60 ± 0.04^b	01.85 ± 0.03^a
Carbohydrate (%)	60.34 ± 0.21^b	62.31 ± 0.01^a
Fibers (%)	03.00 ± 0.03^b	03.67 ± 0.29^a
Protein (%)	10.00 ± 0.02^b	19.85 ± 0.11^a
Fat (%)	04.63 ± 0.03^b	05.83 ± 1.72^a
`Calorific Value (Kcal/100 g)	400.075 ± 0.02^b	442.99 ± 0.12^a

Each value is the mean of triplicate analyses. The same letter in the same line indicate no statistical difference (p < 0.05)

Table 2. Minerals content of traditional roasted corn flour and composite roasted corn flour

Minerals (mg/100 g)	Traditional roasted corn flour	Composite roasted corn flour
Sodium (Na)	11.18 ± 0.02[b]	12.18 ± 0.02[a]
Potassium (K)	417.06 ± 0.11[b]	779.11 ± 0.15[a]
Magnesium (Mg)	78.04 ± 0.25[b]	90.11 ± 07.75[a]
Copper (Cu)	01.87 ± 0.14[b]	02.87 ± 01.08[a]
Zinc (Zn)	01.66 ± 0.25[b]	02.67 ± 00.50[a]
Phosphorus (P)	101.36 ± 0.11[b]	242.83 ± 03.33[a]
Calcium (Ca)	131.02 ± 0.20[a]	132.45 ± 01.9[a]
Iron (Fe)	01.32 ± 0.01[b]	01.44 ± 01.9[a]

Each value is the mean of triplicate analyses. The same letter in the same line indicate no statistical difference ($p < 0.05$)

Table 3. Anti-nutrient content of traditional and composite roasted corn flour

anti-nutrient content	Traditional roasted corn flour	Composite roasted corn flour
Tannin (mg/100 g)	09.12 ± 0.6[a]	9.10 ± 0,72[a]
Phytic acid (mg/100 g)	06.65 ± 0.80[a]	3.48 ± 0.84[b]
Oxalate (mg/100 g)	10.95 ± 0.9[a]	8.03 ± 1.15[b]

Each value is the mean of triplicate analyses. The same letter in the same line indicate no statistical difference ($p < 0.05$)

and in improving the digestibility of these seeds [34]. So these low levels of anti-nutritional factors registered would prove the nutritional quality of the studied composite flour.

4. CONCLUSION

This study aimed to compare the physicochemical composition of a composite roasted corn flour to its traditional counterpart. Enrichment of corn with soybean seed and groundnut flours at 5% level lead to significant improvements in proximate, mineral and anti-nutrients values in the composite product. As this improvement is sufficient to cover the infant and young child needs, it would be appropriate to introduce this composite corn flour in the diet of young children. This could help to enhance the attainment of adequate nutrients required so that infants and young children would be able to achieve the optimal growth potentials. It could be concluded that this composite roasted corn flour appears to be suitable for homemade complementary foods to cover infant and young children needs.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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