International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 2103-2108

Received: 04-01-2020
Accepted: 05-02-2020

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Nutritional composition of some artisanal infant flours produced locally in Ivory Coast

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DOI: https://doi.org/10.22271/chemi.2020.v8.i2af.9061

Abstract
Objective: This work aims to assess the nutritional composition of some Ivorian artisanal flours.
Methodology: Five varieties of artisanal infant flours were collected. Flour 1 (corn, millet, rice, soybean); flour 2 (fermented millet, soya, tapioca); flour 3 (fermented millet, soy, tapioca); flour 4 (fermented corn, sprouted corn, *Macrotermes subhyalinus*); flour 5 (fermented millet, sprouted mil, *Macrotermes subhyalinus*). Moisture, ash, protein, lipid and fiber contents were determined according to AOAC standards. Minerals (calcium, magnesium, sodium, potassium, iron, copper, zinc and manganese) were determined by atomic absorption spectrophotometry and phosphorus by colorimetry.
Results: The analyzes show that the composition of the various flours varies from one sample to another: moisture (4.82 - 6.82g / 100g); proteins (13.65 - 15.07 g / 100g); lipids (5.10-11.16 g / 100g) ash (0.99 - 2.26 g / 100g); fiber (2.12 - 3.98 g / 100g); carbohydrates (68.53 - 76.30 g / 100g) energy (402.58 - 434.26Kcal / 100g); potassium (510.34 - 976.38mg / 100g); phosphorus (100.21 - 334.85 mg / 100g); Calcium (23.66-70.96 mg / 100g); Magnesium (62.38 - 99.73 mg / 100); Sodium (56.80 - 389.56 mg / 100g); Zinc 3.84 - 11.2 mg / 100g); manganese 9.6 - 107.67 mg / 100g); iron (5.01 - 9.60 mg / 100g); copper (4.25-13.1 mg / 100g). *Macrotermes subhyalinus* dried powder and soybeans significantly improve the protein and mineral content.
Conclusion: All flours have a good protein content around 15%. The incorporation of *Macrotermes subhyalinus* dried powder has improved the lipid and mineral content of flours 4 and 5. The energy values of the flours analyzed are important. FAO / WHO recommends that weaning foods be energy rich. These data could be exploited for the choice of flours for a better feeding of children.

Keywords: Local infant flour, Nutritional composition, Ivory Coast

Introduction

Protein and energy deficiency and mineral deficiency are public health problems in developing countries (FAO, 2010) [13]. Children are the most vulnerable layer. Malnutrition contributes to 35% of deaths of children under 5 in West and Central Africa. Currently, one million children in this age group die each year in this region because of malnutrition (UNICEF, 2010) [32]. Serious forms of malnutrition include marasmus, kwashiorkor and nutritional anemias (UNCEF, 2009) [33]. In Ivory Coast, despite an improvement due to the efforts made, the nutritional situation of the population, in particular that of children under five, is still worrying. Chronic malnutrition or stunting is 21.6% and global acute malnutrition is 6% (EDS III, 2012). According to the World Health Organization (WHO), the poor quality of food supplements given to children from 6 months in addition to breastfeeding and in particular, their low energy density is recognized as an etiological factor of the protein-energy malnutrition in young children. In fact, the health and well-being of each individual depends on a sufficient intake of good quality nutrients, such as fat, protein, carbohydrates, vitamins and minerals (Latham, 2001) [23]. According to, the work of Shankar, (2000) [27]; Shuichi and Masanobu, (2004) [28] foods modulate the immune system. One of the causes of this malnutrition is also the lack of nutritional data on locally produced infant flours. Thus, the present work aims to determine the nutritional composition of some artisanal infant flours of Ivory Coast.

Material and Méthods

Preparation of the raw powder of *Macrotermes subhyalinus*

The termites once caught were immediately put in coolers containing ice (in order to preserve their freshness) and then were sent to the laboratory.

2 kilograms of termites were then cleaned, rinsed, drained, blanched, placed on trays and dried in an oven at 65 ° C for 72 hours. The termites were subsequently removed from their wings and legs (figure 1), crushed in a blender and sieved to obtain the raw meal of *Macrotermes subhyalinus* (figure 2). The raw powder was put into cans and kept at + 4 ° C.

Fig 1: *Macrotermes subhyalinus* dried

Fig 2: *Macrotermes subhyalinus* crushed

Preparation of delipidated *Macrotermes subhyalinus* powder: To the raw flour of *Macrotermes subhyalinus* was added hexane at the rate of 3 g of flour per 10 ml of hexane. The mixture was stirred magnetically for 6 hours. The cakes from this extraction were desolventized first in the open air for 1 hour and then in an oven at 45 ° C for 2 hours before being ground again. After drying, the delipidated residue of *Macrotermes subhyalinus* was put in a box and stored at + 4° C.

Production of simple flours

The production of artisanal flour requires many steps; thus several unitary operations enter into the manufacture of these flours. This involves sorting, roasting, pulping, grinding, sieving, mixing and packaging.

Plant and biological material

Five varieties of artisanal infant flours were collected in the production structure in Yaoundé. These are: Flour 1 (corn, millet, rice, soybean); flour 2 (fermented millet, soya, tapioca); flour 3 (fermented millet, soy, tapioca); flour 4 (fermented corn, sprouted corn, *Macrotermes subhyalinus*); flour 5 (fermented millet, sprouted mil, *Macrotermes subhyalinus*). The percentage of each ingredient used in the formulation of each flour is shown in Table 1.

Fig 3: delipid *Macrotermes subhyalinus* powder

Table 1: Flour composition

Flour	**Compositions (%)**	**Scientific names of major ingredients**
Flour 1	Maize (25%) ; Mil (25%) ; Rice (25%) ; Soy (25%)	*Zea mays ; Glycine max*
Flour 2	Fermented millet (50%) ; Soy (20%) ; Tapioca (30%)	*Pennicetum glaucum ; Glycine max.*
Flour 3	Fermented millet (50%) ; Soy (30%) ; Tapioca (20%)	*Pennicetum glaucum ; Glycine max.*
Flour 4	Fermented maize (65%) ; Maize sprouted (10%), *Macrotermes subhyalinus defatted* (25%).	*Zea mays ; Macrotermes subhyalinus*
Flour 5	Fermented Mil (67,5%) ; Mil sprouted (10%) ; *Macrotermes subhyalinus defatted* (22,5%)	*Pennicetum glaucum ; Macrotermes subhyalinus*

Fig 4: Flour 1

Fig 5: Flour 2

Fig 6: Flour 3

Fig 7: Flour 4

Fig 8: Flour 5

Methods

Moisture, ash, protein, fat, fiber, fiber and carbohydrates

Levels of water, ash, protein, fat and crude fiber were determined according to AOAC (2000) [5]. All analyzes were done in triplicate. The carbohydrate content was calculated by difference.

Mineral Content: The mineral contents: calcium, magnesium, sodium, potassium, iron, copper, zinc were determined according to the Benton and Vernon method, (1990) [7] using the atomic absorption spectrophotometer: Perkin-Elmer Analyst 700 spectrophotometer (Norwalk, CT, USA). Phosphorus was colorimetrically determined using the vanado molybdate method (AOAC, 1999) [4]. All analyzes were done in triplicate.

Statistical analysis: The results of the analyzes are presented as mean ± standard deviation. The results were processed by analysis of the variances (ANOVA) at the significance level *P*<0.05. These tests were performed using SPSS for Windows software version 17.0.

Results and Discussion

A) Nutritional value

Table 2: Moisture, fat, protein, crude fiber, carbohydrate (g / 100g dry matter) and energy value (Kcal / 100g dry matter) contents of flours

Flour	Fours 1	Fours 2	Fours 3	Fours 4	Fours 5
Humidity	$5,83^{ab} \pm 0,11$	$6,82^{b} \pm 0,09$	$6,23^{b} \pm 0,07$	$4,82^{a} \pm 0,01$	$4,97^{a} \pm 0,91$
Protein	$14,65^{a} \pm 1,02$	$13,65^{b} \pm 0,44$	$15,07^{a} \pm 0,17$	$14,86^{a} \pm 1,76$	$14,35^{a} \pm 1,12$
Lipids	$5,10^{a} \pm 1,21$	$6,99^{b} \pm 0,25^{b}$	$8,47^{c} \pm 0,29^{c}$	$11,02^{d} \pm 1,41$	$11,16^{d} \pm 1,21$
Ashes	$2,26^{a} \pm 0,77$	$0,99^{b} \pm 0,01$	$1,17^{ab} \pm 0,03$	$2,14^{a} \pm 0,39$	$2,04^{a} \pm 0,86$
Raw fibers	$2,93^{a} \pm 0,23$	$2,12^{a} \pm 3,21$	$2,24^{a} \pm 0,12$	$3,07^{ab} \pm 0,70$	$3,98^{b} \pm 0,52$
carbohydrates	$75,07^{a} \pm 2,31$	$76,30^{a} \pm 0,3$	$73,09^{b} \pm 0,11$	$68,91^{c} \pm 1,80$	$68,53^{c} \pm 1,74$
Value energy	$404,58^{a} \pm 2,1$	422,89b ± 1,55	$429,05^{bc} \pm 1,66$	$434,26^{c} \pm 4,21$	$431,96^{c} \pm 4,81$

The results are presented as mean ± standard deviation; averages with different letters exhibiting within the same column are significantly different (*P*<0.05).

The moisture of the flours analyzed varied from 4.97 (flour 5) to 6.82 g / 100 g (flour 2) and showed significant differences (*P*<0.05). This low water content is due to the fact that these flours come from dried seeds (corn, soybean, millet, tapioca) and other dry products such as dried and delipidated *Macrotermes subhyalinus* termite powder. A large quantity of water in these flours would compromise their preservability; in fact, water promotes the proliferation of microorganisms capable of using their amylases, to hydrolyze the starch contained in the flours and thus to facilitate the acidification of the latter (Sall, 1998) [29].

These flours have water contents close to those of cassava + soy flour (5 g / 100 g) and attiéke + soy flour (5 g / 100 g) produced by Zannou *et al.* (2011) [34] in Côte d'Ivoire and below the moisture content of maize (12.38g / 100g) and millet (19.71g / 100g) flours found by Sall (1998) [29] in Senegal. The protein contents of the flours analyzed varied from 13.65 (flour 2) to 15.07 g / 100 g (flour 3) and did not show significant differences (*P*<0.05). The presence of dried *Macrotermes subhyalinus* termite powder and soy in flours may explain these high levels. Indeed, according to Niaba, (2011) [22], dried *Macrotermes subhyalinus* termite powder is a great source of animal protein (16.5g / 100g), unlike cornmeal which contains only 7g / 100g. ACC/SCN (2001) [1] demonstrated that when locally available cereals, legumes and / or animal products are mixed, the resulting protein content is improved. In addition, Ibeanu (2009) [20] noted that the use of compound flours could help improve the quality of weaning foods in developing countries. These protein contents are higher than that found by Ukegbu and Anyika (2012) [31] (2.17 g / 100 g) in the maize porridge prepared in Nigeria, especially in Ngor-okpala in the state Imo and comparable to those found by Ponka *et al.* (2015) [9] (8.91-13.69 g / 100 g) in the porridges consumed in the Far North of Cameroon more specifically in the city of Maroua. All flours have a protein value in accordance with the standards recommended by FAO/WHO (2008) for weaning foods (11-21 g / 100g). Proteins play a role in the defense of the body and cover the nitrogen expenditure caused by the renewal of tissues and the synthesis of certain compounds involved in the proper functioning of the body (enzymes, hormones) (Sguera, 2008) [26]. The lipid contents of the flours show significant differences (*P*<0.05).

The lowest content (5.1 g / 100 g) is found in flour 1 while the highest content is found in flour 4 and 5. These last levels (11.16 and 11.02 g / 100 g) could explain by adding in flour 4 and 5 dried termite *Macrotermes subhyalinus* termite powder. These levels are higher than the values of 1.66 and 2.2 g / 100 g respectively found in corn and millet porridge prepared in Kaduna State, Nigeria (Anigo *et al.*, 2010) [2].

Flour 1 has the highest content (2.26 g / 100g) of ash while flour 2 has the lowest value (0.99 g / 100 g). These different levels do not differ significantly (*P*<0.05). However, the high ash content of the flours could be explained by the presence of soy and termite powder in the latter. These levels are lower than that found by *Ponka et al.* (2015) [9] (1.35 g / 100 g) in millet (Gari karal) porridge consumed in the far north of Cameroon, specifically in the city of Maroua.

The raw fiber contents of the flours show significant differences (P<0.05). Thus, the different flours have low fiber contents. These low fiber contents would be due to the unit operations necessary for the production of flours in this case the shelling which leads to a removal of the rich fiber sound. Cereals and oilseeds are shelled in order to reduce the fiber content of the product to acceptable levels and to reduce and, if possible, eliminate phytates, tannin and other phenolic compounds, which are trypsin and chymotrypsin that can decrease protein digestibility, amino acid bioavailability and mineral uptake.

Fibers can also reduce the caloric density of complementary food preparations; the dietary fiber content of the complementary food preparations should therefore not exceed 5 g / 100 g of product on a dry weight basis (FAO / WHO, 1994). These values are lower than those of cassava + soy flour (8 g / 100 g) (Zannou *et al.* 2011) [34] and comply with the *codex alimentarius* standard on complementary foods for infants (<5 g / 100 g) (FAO/WHO, 1994). The fibers regulate the intestinal transit and capture some of the lipids and carbohydrates, which helps to regulate part of the blood sugar and avoid excess cholesterol. Due to their high degree of saturation, these fibers have a positive effect against overweight and metabolic diseases (Henauer and Frei, 2008) [18]. Flours 1, 2 and 3 have the highest levels of carbohydrate, while flours 4 and 5 have the lowest values and a significant difference is observed between these values (P<0.05). The high levels of carbohydrate in flours are justified by the presence in these cereals and starch more than 70%; indeed, cereals and starchy foods are very high in carbohydrate foods that can contain 60-80% of carbohydrate (ANSES, 2013) [3]. These levels are lower than the values of (82.10 - 86.85 g / 100 g) found in the slimes consumed in the Far North of Cameroon, specifically in the city of Maroua (Ponka *et al*,. 2015) [9], and comparable to that of (73.52 g / 100 g) found in the Akamu slurry consumed at Nsukka located in northern Nigeria at Enugu state (Okéke and Eze, 2006) [24].

Carbohydrates have an essentially energetic role, they constitute the source of energy quickly usable by the organism and are involved in the anabolism of the proteins. Some carbohydrates have a role called "constitution", they are part of the composition of fundamental tissues of the body: cartilage, nucleic acids, mucus, antigenic substances (Sguera, 2008) [26]. The energy values of the flours analyzed ranged from 404.58 (flour 1) to 434.26 kcal / 100 g (flour 4) and showed significant differences (P<0.05). These values are higher than that of standard flour (400 kcal / 100 g) (Sanogo *et al.*, 1994) [30] and comparable to energy values (409.16-490.17 kcal / 100 g) of maize containing other items such as soy, shrimp, peanut or milk eaten in Ngor-okpala, Imo state in Nigeria (Ukegbu and Anyika, 2012) [31]. Energy comes from the foods and drinks we consume. FAO / WHO (1985) [15] recommends that weaning foods be rich in energy. This FAO recommendation is important because the low energy density of some porridges tends to limit the total amount of energy consumed for proper functioning of the young child's organism as well as the use of other essential nutrients.

Given the small size of their stomachs (30 to 40 g / kg body weight or 150 to 200 ml), children need high-energy foods to meet their energy needs (Brown, 1992) [8]. (1992) and FAO / WHO (1985) [15], the daily energy requirements of an older infant (06-12 months) amount to 950 Kcal, to cover them, the latter should consume daily 238g of our infant flours on average which is difficult knowing that this quantity of flour could lead to the preparation of 2.5 liters of porridge, hence the importance of fortification of weaning foods.

B) Mineral content

Table 3: Mineral content of flours (mg / 100g)

Minerals (mg / 100 g of MS)	Flour 1	Flour 2	Flour 3	Flour 4	Flour 5
Sodium	56,8^{a} ± 0,4	89,53^{b} ± 3,7	104,63^{c} ± 3,2	389,56^{d} ± 0,89	225,52^{e} ± 0,55
Potassium	525,31^{a} ± 0,4	510,34^{a} ± 1,1	599,36^{b} ± 1,9	830,61^{c} ± 1,01	976,38^{d} ± 1,23
Calcium	70,96^{a} ± 0,4	40,59^{b} ± 3,1	47,39^{b} ± 2,4	29,60^{c} ± 0,87	23,66^{c} ± 1,12
Magnesium	94,75^{a} ± 0,4	62,38^{b}± 1,1	99,73^{a} ± 12	85,47^{c} ± 0,36	78,03^{d} ± 0,42
Phosphorus	100,21^{a} ± 0,5	105,68^{a} ± 5	141,17^{b} ± 2,5	334,85^{c} ± 1,33	286,32^{d} ± 1,31
Iron	9,60^{a} ± 0,4	5,01^{b} ± 0,4	7,70^{c} ± 0,01	7,77^{c} ± 0,27	6,41^{d} ± 0,57
Copper	09,61^{a} ± 0,4	10,23^{a} ± 0,7	13,1^{b} ± 0,4	9,25^{a} ± 0,08	4,25^{c} ± 0,06
Zinc	03,84^{a} ± 0,4	9,1^{b} ± 0,1	11,2^{c} ± 0,5	10,73^{c} ± 0,27	8,83^{b} ± 0,05
Manganese	11,20^{a} ± 0,4	9,6^{a} ± 0,10	11,17^{a} ± 01	107,67^{b} ± 0,33	90,40^{c} ± 0,41

The results are presented as mean ± standard deviation; averages with different letters exhibiting within the same line are significantly different (P<0.05).

Potassium and phosphorus are the most abundant minerals in flours. The potassium and phosphorus contents range from 510.34 (flour 2) to 976.38 mg / 100g (flour 5) and 100.21 (flour 1) to 334.85 mg / 100g (flour 4), respectively. The other minerals and their contents are: calcium, 23.66 (flour 5) to 70.96 mg / 100g (flour 1); magnesium, 62.38 (flour 2) at 99.73 mg / 100g (flour 3); sodium, 56.80 (flour 1) at 389.56 mg / 100g (flour 4); zinc, 3.84 (flour 1) at 11.2 mg / 100g (flour 3); manganese, 9.6 (flour 2) to 107.67 mg / 100g (flour 4) and iron, 5.01 (flour 2) to 9.60 mg / 100g (flour 1) and copper with grades that vary of (4.25-13.1 mg / 100g). A significant difference is observed between the distribution of all minerals (P<0.05). Potassium levels (> 250 mg / 100g) are higher than the potassium content (217.78 mg / 100g) of cornmeal prepared in northwestern Nigeria (Anigo *et al.* 2010) [2]. Potassium is needed for the regulation of the water balance of cells, the use of carbohydrates and the construction of proteins. It acts against disturbances of the cardiac rhythm and intervenes in the regulation of the osmotic pressure of the cell. Potassium participates in membrane transport and enzyme activation and plays a role in muscle contraction (increased neuromuscular excitability) (EUFIC, 2016) [11]. Phosphorus levels of Flours 1, 2 and 3 analyzed (100.21-141.17 mg / 100g) were lower than those of cornmeal (171.32 mg / 100 g) consumed in northwestern Nigeria (Anigo *et al.*, 2010) [2].

Phosphorus combines with calcium in the form of calcium phosphate, a hard substance that gives the body its rigidity. Phosphorus is necessary for the production and use of energy, the preservation of bones and teeth (FAO, 2001) [17]. In

humans, calcium plays a major role in the constitution of the skeleton, but also in various metabolic functions such as muscle activity, nerve stimuli, enzymatic and hormonal activities, and oxygen transport (FAO, 2001) [17].
The magnesium contents of the flours analyzed (62.38 - 99.73 mg / 100 g) are comparable to the levels of (49.35-80.56 mg / 100 g) found in the slurries consumed at Maroua in the far north. of Cameroon (Ponka *et al.,* 2015) [9]. Magnesium is found mainly in the bones, but also in most of the tissues of the body. Most diets contain enough magnesium, but in case of diarrhea for example, wastage is important and can induce weakness, behavioral problems and sometimes convulsions (FAO, 2001) [17].
The sodium contents of the flours analyzed (56.8-389.56 mg / 100 g) are higher than those (2.10-2.75 mg / 100 g) found in corn-based slurries containing other elements such as soy, shrimp, peanut or milk eaten in Ngor-okpala, Nigeria (Ukegbu and Anyika, 2012) [31]. Sodium is involved in the acid-base balance and body moisture balance. It promotes nerve function and muscle contraction. Sodium salts are very common in foods and are easily absorbed by the digestive tract and major cations of body fluids (EUFIC, 2006) [11].
The zinc contents of the flours analyzed (03.84-11.20 mg / 100 g) are higher than those (0.17-0.30 mg / 100 g) found in the cornmeal consumed in Nigeria (Ogbonnaya, 2012) [21]. Zinc is present in many enzymes essential for metabolism (FAO, 2001) [17]. The manganese contents of the flours analyzed (9.6-107.67 mg / 100 g) are higher than that (4.41 mg / 100 g) found in the corn meal consumed in Nigeria, in particular at Jos plateau (Solomon *et al.,* 2000) [25].
Manganese is involved in bone and tendon growth, and plays an important role in the synthesis of complex carbohydrates and proteins (EUFIC, 2006) [11]. The iron contents of the flours analyzed (5.01-9.60 mg / 100 g) are greater than the 2.49 mg / 100 g value contained in the maize porridge produced at Umua-hia Abia in Nigeria (Unaeze, 2011) [19]. Iron is also involved in the formation of hemoglobin, myoglobin and enzymes that play a key role in many metabolic reactions (Badham *et al.,* 2007) [6]. The copper contents of the flours analyzed (4.25-13.1 mg / 100 g) are higher than the values of (0.17-0.30 mg / 100 g) found in the slurries consumed in Maroua in the far north. of Cameroon (Ponka *et al.,* 2015) [9]. Copper is involved in the absorption of iron, metabolism and the formation of elastic and connective tissues. It also has an enzymatic function because it acts as a cofactor in certain enzymatic reactions of the body (EUFIC, 2006) [11].

Conclusion and application of results

This work made it possible to determine the nutritional composition of 5 varieties of Ivorian artisanal infant flours. Analyzes show that the composition varies from one flour to another. All flours have a good protein content around 15%. The incorporation of dried *Macrotermes subhyalinus* termite powder has improved the lipid and mineral content of Flours 4 and 5. The energy values of the flours analyzed are important, FAO / WHO recommends that weaning foods be energy rich. These data could be exploited for the choice of flours for a better feeding of children.

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