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Mob: +92 300 3008585, Fax: +92 41 8815544

E-mail: editorpjn@gmail.com

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Assessment of Some Chemical and Nutritional Properties of Maize, Rice and Millet Grains and Their Weaning Mushes

Brou Kouakou*[1,2], Gbogouri Albarin[1], Ocho Anin Louise[1],
Djeni N'Dédé Théodore[3], Kone Youssouf[1] and Gnakri Dago[1]
[1]Laboratoire de Nutrition et Sécurité Alimentaire, Université d'Abobo Adjamé,
Abidjan (Côte d'Ivoire) UFR-STA
[3]Laboratoire de Microbiologie et Biologie Moléculaire, Université d'Abobo Adjamé,
Abidjan (Côte d'Ivoire) UFR-STA

Abstract: This study was conducted to assess some chemical and nutritional properties of maize, rice and millet grains and their derivate mushes. Results showed on one hand that the density of studied cereal grains was very near to the one of the Chinese chive. But their capacities of hydration and inflation were very low in comparison to these of the same grains. Rice grains has a low capacity of hydration and a low index of hydration compared to maize and millet grains. With respect to their permeability and toughness, the studied cereal grains could be ranked as follow: rice > corn > thousand. Mushes flours also showed very low moisture content, high starch and carbohydrates contents, poor levels in lipids and proteins. They contain some essential minerals such as calcium, magnesium, iron, copper and zinc in variable concentrations. Contents in phytic acid were also variable. In consequence, the energy density of these flours appeared very high but it was lower than the one of the existing complement flours of Côte d'Ivoire markets.

Key words: Mushes, cereals, phytic acid, capacity of hydration, capacity of inflation, index of hydration, digestibility

Introduction

In developing countries, children endure damaging growth delay to their physical and intellectual development. According to the worldwide Health Organization (WHO), 42% of less than five year children suffer from malnutrition, what represents about 25 millions of children (Anonymous, 1998). These unrests generally occur at the time of the passage of maternal nursing to mixed feeding integrating foods of complement, in general weaning mushes that are constituted of cereals. If these cereals constitute important sources of proteins, carbohydrates, vitamins, minerals and fibres for worldwide population, (Helland *et al.,* 2002) however, their nutritional quality and this of their derivative products remain lower than to milk and milk products quality (Blandino *et al.,* 2003). Indeed, they contain low content of proteins and they are often rich in antinutritional factors such as phytates, polyphénols and oxalates (Chavan and Kadam, 1989) that reduce the bioavailability of minerals. Thus, these minerals are ineffectively and variably absorbed in these foods: iron (<1-30%) and zinc (<15-50%) (Lestienne *et al.,* 2005). This phenomenon must be taken in account while preparing mushes of complement in developing countries, where young children endure deficiency in micronutrients such as anaemia, caused by a deficiency in iron (Hurrell, 1997) and where the rate of growth decreases because of deficiency in zinc (Gibson and Ferguson, 1998). Stephenson *et al.* (1994) showed that the energetic density of these traditional weaning mushes is often weak because of the high volume of water added during preparations. Thus, young children do not consume a sufficient quantity of these mushes to cover their need in energy. In this way, the regular consumption of such foods will drag a high prevalence of malnutrition, affecting infantile populations. This malnutrition leads to important human losses and to term to a weak economic activity, braking so the development of generations and countries. The struggle against malnutrition should be a priority. In Côte d'Ivoire, scientific informations concerning these traditional foods of complement are in existent or very limited. Therefore, this study was carried out to assess the chemical and nutritional quality of some cereals (rice, maize, millet) grains and their derivate mushes of complement.

Materials and Methods

Plant material: The biological material used was made up of three types of cereals: yellow maize (*Zea mays*) grains, Paddy rice (*Orysa sativa*) and of millet [*Pennisetum glaucum* (L)] R. BR) grains. Cereals were bought from various markets of Abidjan in the southern area of Côte d'Ivoire. These cereals were selected because of the frequency of their production and their intense utilization for the preparation of mushes (commonly called "*baca*" in local language) used as traditional complement foods for children.

Chemicals: Chemicals used in this study were: Trichloro-acetic acid (TCA), Folin-ciocateus reagent, hydrochloric acid, ethanol, n-hexane (MERCK), dinitro-acetic salicylic acid (DNS) (Fluka AG), cooper II sulphate, potassium sodium tartrate (LABCM company), sodium hydroxide of potassium permanganate (OMPLOU CHEMISTRY (OMC)), bovine albumin serum (BSA), sulphuric acid 96%, sodium carbonate, sodium acetate, zinc acetate (PANRACS). All chemicals were analytical grade. Enzyme used for digestibility test was extracted from gastric juice of snail (*Achatina baltéata*).

Sampling: Two kilograms (2 kg) of each cereal were bought in markets of Abidjan, Côte d'Ivoire by mushes sellers previously selected. A part of each cereal grains was used for the chemical properties study while the other part was processed into flour for mushes preparation by the selected sellers. Five hundred grams (500 g) of rice, millet and maize mushes were taken and put in 250 ml flask for freezing. And then, the frozen mushes were lyophilized. The obtained flours were ground with a mill and then sieved with a traditional sieve in order to get fine flours that were preserved for chemical analyses.

Preparation of rough enzymatic extract from gastric juice of snail: The extraction of snail gastric juice was carried out on a batch 50 snails (*Achatina baltéata*) beforehand put without food during three days. The digestive tract was insulated and emptied of its contents. The liquid collected was mixed with 20 ml of a sodium chloride solution (NaCl 0.9 %). The resulting mixture underwent to a sonication for 10 min and a centrifugation at 5000 tours/min during 30 min. The supernatant, constituting the enzymatic crude extract was preserved at -20°C for digestibility study of prepared flours.

Dosage of proteins in the rough enzymatic extract: Proteins were determined according to the method of Lowry *et al.* (1951). The dosage was carried out on 100 µl of extract in presence of 2 ml of potassium sodium tartrate solution 1% (w/v) to 600 nm.

Chemical characterization of cereal grains:

Density of grains: One hundred grams (100 g) of each cereal grains were transferred in a measuring test-tube containing 100 ml of distilled water. The volume of grains was obtained after subtracting from the final volume the initial 100 ml of water. The density was then calculated and expressed in g/cm^3.

Capacity of grain hydration (CHG): Fifty grams (50 g) of each cereal grains weighed were counted and dispersed in a measuring test-tube containing 50 ml of water. The test-tube was then covered with an aluminum leaf and left overnight at the ambient temperature (27-29°C). The following day, grains were taken out of the test-tube and cleaned with filters papers. The swollen grains were then weighed and the capacity of grain hydration was determined by the following relation:

$$CHG(g) = \frac{\text{weight of Soaking grains - weight of grains before Soaking}}{\text{Number of grains}}$$

Index of hydration (IH): The index of hydration is determined from the capacity of hydration by grain of the following manner:

$$IH = \frac{\text{Capacity of hydratations per grain}}{\text{weight of a grain}}$$

Capacity of inflation by grain (CIG): Fifty grams (50 g) of each cereal grains were counted. Grains were then soaked overnight in a test-tube and the volume of soaked grains was measured with measuring test-tube. The capacity of inflation by grain (CGG) is determined using the following formula:

$$CIG = \frac{\text{Volume after Soaking- Volume before soaking}}{\text{Nombre de grains}}$$

Biochemical analysis cereal mushes flours: The dry matter was measured after flours drying at 105°C for 24 hours according to AOAC (1990). Ash content was determined by incineration of flour at 500°C in an oven. Flour sugars were analyzed after their extraction according the ethylic alcohol method as described by GAY LUSSAC. Total sugars were determined by the phenol sulphuric acid method according to Dubois et *al.* (1956) while the reducing sugars were quantified as previously described by Bernfeld (1955). Total carbohydrates were determined according to the method of Bertrand and Thomas (1910). Starch content was deducted by calculating the difference between total carbohydrates content and total sugars content. The fatty matter was extracted with the soxhlet using n-hexane. The dosage of total nitrogen was achieved according to the method of Kjeldahl (AOAC, 1990). Phytic acid was measured out according to the modified method of Makower (1970).

Determination of the energy value in kilocalorie: The energy value (VE) was calculated with 4 Kcal/g for carbohydrates, 4 Kcal/g for proteins and 9 Kcal/g for lipids according to Atwater and Benedict (1902).

VE = [9 × Lipids (%) + 4 × Proteins (%) + (4 × carbohydrates (%)].

***In vitro* digestibility of flours:** The starchy substrates used for this test were the different cereal flours obtained after mushes lyophilization. *In vitro* flour digestibility consisted to a reaction between the enzymatic crude extract and an amount of flour at 1% (w/v). The reaction medium was constituted as follow: 400 μl of acetate buffer (100 mM, pH 5), 25 µl of enzymatic crude extract and 75 µl of 1% of flour. The mixture was then incubated at 37°C for 3 hours in a Marie-bath. Aliquots of the reaction medium were taken every 10 min for reducing sugars determination according to the method of Bernfeld (1955).

Statistical analysis: Results are expressed as mean± standard deviation. The non parametric test of DUNCAN was used for the analysis of the difference between means using STATISTICA software (statistica, 99th Edition, France) at the significance of 5%.

Results and Discussion

The density, the capacity of hydration, the index of hydration and the capacity of grain inflation are presented in table 1. Millet grains had a density of 1.63 g/cm^3 and this density was significantly higher ($p < 0.05$) than the density of rice and maize grain whose values were 1.21 and 1.26 g/cm^3 respectively. But, the capacity of hydration of maize grains (0.08 g/grains) significantly ($p < 0.05$) differed to that this of rice (0.05 g/grains) and millet (0.06 g/grains). Results also showed that millet grains had the highest index of hydration (0.66) compared to those of rice (0.20) and maize (0.26) and the capacity of inflation by grain was significantly more important for maize grains (0.45 ml/grains) than the others. Values of cereal grains density were similar to those found by Guohua *et al.* (2005) in Chinese chive grains with a density value of 1.27 g/cm^3. However, values of capacity of inflation and capacity of hydration were very weak compared to those of the same grains. These results could be explained by the poverty of these grains in fibers. Indeed, the works of Guohua *et al.* (2005) showed that wealth high fiber contents of Chinese chive grains conferred them strong capacities of hydration and inflation. The physical characteristics studied (capacity of hydration and capacity of inflation by grain) are parameters that play an important role in foods cooking. Indeed, it was demonstrated by Ahmed and Shehata (1982); Wang *et al.* (2003) that foods having high capacities of hydration and inflation by grain require short cooking time. Moreover, the use of flours in the preparation of mushes depends in large part of interactions with water in the process of hydration. Rice had low capacity of hydration and low index of hydration, that reflects the relative toughness and the impermeability of rice grains compared to the other grains. The order of permeability and toughness of studied cereal grains would be : rice > maize > millet.

Table 1: Physical characterization of rice, millet and maize grains

	Kind of cereal grains		
Characteristics	Rice	Maize	Millet
Density (g/ml)	1.21±0.06[a]	1.26±0.02[a]	1.63±0.03[b]
CHG (g/grain)	0.05±0.03[a]	0.08±0.02[b]	0.06±0.02[a]
IH	0.20±0.03[a]	0.26±0.01[a]	0.66±0.02[b]
CIG (ml/grain)	0.03±0.01[b]	0.45±0.01[c]	0.04±0.02[a]

Values are means of three determinations; In a row, means values followed by different superscript are statistically different (P = 0.05). IH = Index of hydration, CHG = Capacity of grain hydration, CIG = Capacity of inflation by grain

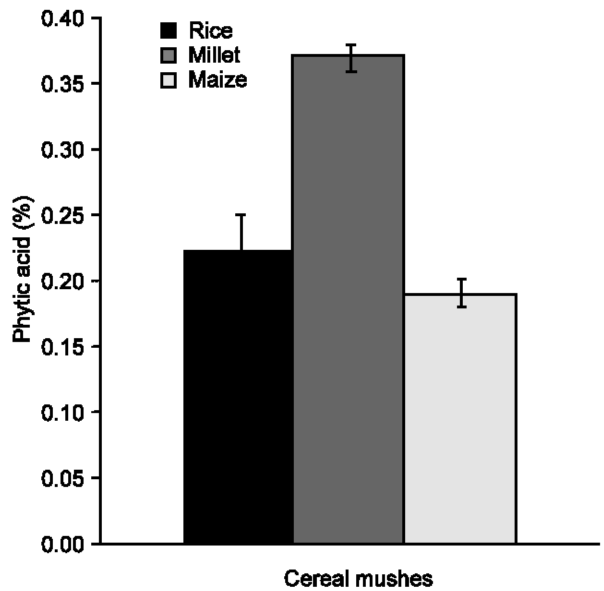

Fig. 1: Phytic acid content (%) of rice, millet and maize mush flours

Therefore, rice would require a long cooking time contrarily to millet and maize. The global chemical composition of mushes is given in Table 2. The dry matter contents were very high in the different flours studied. Values were 94.30%, 93.63%, 93.61% respectively for rice, millet and maize. So, these flours could be preserved for a long time without risk of microbial proliferation. Total ash contents were variable. Values were 1.75%, 1.95% and 1.06% respectively for rice, millet and maize. Flours also constitute good sources of carbohydrates and total sugars. For carbohydrates, values were 87.12%, 80.37% and 88. 02% and for total sugars 7.28%, 5.46% and 10.09% respectively for rice, millet and maize. Concerning fat matter content, a significant difference ($p < 0.05$) was observed in the different samples with 0.69% for rice, 0.57% for millet and 0.54% for maize. And proteins contents were 7.63%, 7.66% and 7.69% respectively rice, millet and maize mushes. The contribution of legume such as soy (which contains 21% of fat matters and 39% of protein) (Alais and Linden, 1997) could be

Table 2: Chemical composition of mush flours of rice, millet and maize

Characteristics	Kind of mush flour Rice	Millet	Maize
Dry matter (%)	94.30±0.10[b]	93.63±0.30[a]	93.61±0.40[a]
Ash (%)	1.75±0.56[b]	1.95±0.39[b]	1.06±0.28[a]
Reducing sugars (%)	2.36±0.07[a]	2.43±0.01[a]	6.34 ± 0.20[b]
Total sugars (%)	7.28±0.51[b]	5.46±1.31[a]	10.09±3.27[c]
Total carbohydrates (%)	87.12±1.23[b]	80.37±0.89[a]	88.02±0.67[c]
Fatty matter (%)	0.69±0.74[b]	0.57±0.17[a]	0.54±0.21[a]
Proteins (%)	7.63±0.16[a]	7.66±1.72[b]	7.69±0.20[c]
Starch (%)	72.49±0.07[b]	67.50±0.13[a]	71.55±0.56[b]
Energy Densité (Kcal/100g)	385.21	357.25	387.7

Values are means of three determinations; In a row, means values followed by different superscript are statistically different (P = 0.05).

Table 3: Minerals composition of rice, maize and millet mushes

Minerals	Kind of mush Rice	Maize	Millet
Ca (%)	0.21±0.06[a]	0.44±0.10[b]	0.14±0.01[a]
Mg (%)	0.05±0.01[a]	0.53±0.15[b]	0.12±0.02[a]
Fe (%)	0.14±0.04[a]	0.13±0.02[a]	0.06±0.02[b]
Zn (%)	0.008±0.002[a]	0,011± 0.002[b]	0.006±0.001[a]
Cu (%)	0.001±0.001[a]	0.002±0[a]	0.001±0.001[a]

Values are means of three determinations; In a row, means values followed by different superscript are statistically different (P = 0.05).

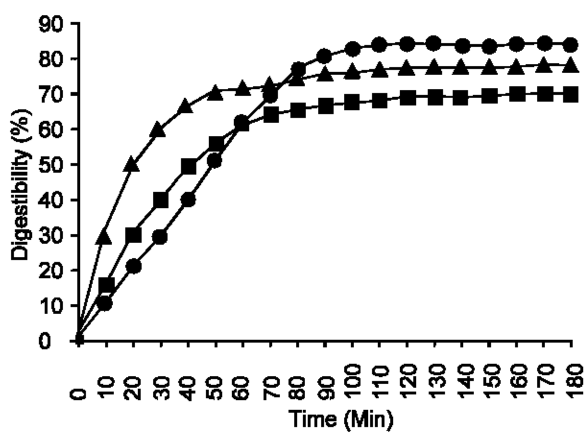

Fig. 2: *In vitro* Digestion of rice, maize and millet mush flours with gastric juice of snail (*Achatina baltéata*)

used to enrich these foods in proteins and in lipids. Results also indicated that mushes contained high rates of starch that with significant differences ($p<0.05$) between rice (72.49%) and millet (67.5%) on one hand and on the other hand between millet (67.5%) and maize (71.55%). Mineral contents of different flours expressed in percentage of dry matter are presented Table 3. Qualitatively, data indicated that these flours contained some essential minerals such as Mg, Fe, Zn and Cu. In 1998, WHO defined iron, calcium and zinc as problematic nutrients in developing countries complement foods because of the unbalance of these minerals in foods and children needs (Dewey and Brown, 2003). A similar tendency is observed in this study. Indeed, calcium content in millet flour (0.44%), maize four (0.14%) and rice flour (0.21%) were weakly represented. Results were similar for magnesium and zinc. These mushes, because of their low content in minerals, require a supplementation in these elements. Phytic acid content is represented in Fig. 1. Values in mushes flours were 0.19% for maize, 0.37% for millet and 0.22% for rice. The flour of millet mush presented the highest rate of phytic acid (0.37%). The presence of phytic acid in these different mushes at variable concentrations could compromise the bioavailability of minerals. Indeed, Blandino *et al*. (2003) and Liang *et al*. (2008) reported that phytates were powerful inhibitors of minerals. Therefore, the inhibition of minerals absorption in the studied mushes would be responsible of the low statute in iron and zinc met with children after their weaning in developing countries. It is why the utilization of these cereals for the preparation of complement foods requires some suitable treatments such as germination and fermentation to eliminate this antinutritional factor (Blandino *et al*., 2003). Fig. 2 shows results of different mushes flours digestion with gastric juice of snail. There was significant difference on the kinetic of digestibility of the different cereal species. From 0 to 80 min, the millet mush flour was better digested than the others, with a digestion rate about 74%. It was followed by rice mush flour with a percentage of hydrolysis about 70% and maize mush flour with 60%. From 100 min, the degree of hydrolysis reached 80%, 72% and 65% respectively for mush flours of millet, rice and maize. This increase of the hydrolysis could be explained on one hand by the reduction of particles size during grinding (Anguita *et al*., 2006) and on the other hand by the process of gelatinization. Indeed, it was shown by that there was an interaction between heating and incubation time. More incubation time was long, more starch particles were sufficiently gelatinized, what allows the digestive enzymes to exercise efficiently their activity.

Conclusion : The results obtained from the analysis of cereal grains and their derivate mushes showed that these different mushes of complement were very poor in lipid and protein, but also in minerals. Thus, they presented a low energy density compared to other foods of complement already on Côte d'Ivoire markets. In spite of these major inconveniences, these mushes were very digestible, so could constitute a potential source of energy. With these advantages, the contribution of legume such as soy during the preparation of these mushes could be foreseeable to remedy the proteino-energizing malnutrition of which endures children of developing countries. However, complementary studies may be achieved to put in place more nutritional complete complement foods for our children of which we want to improve the feeding.

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