International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 42 No. 1 Mar. 2024, pp. 102-112

http://www.ijias.issr-journals.org/

Supplementary food formulation based on plantain, enriched with peanuts

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ABSTRACT: Plantain suffers post-harvest losses of 40 %, due to a lack of adequate means of preservation and processing. The aim of this study is to contribute to the valorization of plantain and the reduction of post-harvest losses through its transformation into instant infant flour. Material balance and overall material balance equations enabled us to formulate two feeds. Flour (F1) consisted of plantain, peanut and germinated maize; flour (F2) of plantain, peanut and ungerminated maize. Physico-chemical and organoleptic characteristics were determined using standard methods. The results show that flour (F1) incorporated with germinated maize flour recorded values in line with WHO-recommended standards. Protein contents ranged from 13.49 ± 0.03 g / 100 g MS (F2) to 14.54 ± 0.08 g / 100 g MS (F1). Iron levels range from 18.95 ± 0.64 mg / 100 g MS (F2) to 21.80 ± 0.64 mg / 100 g MS (F1). Leucine levels ranged from 792.49 ± 1.56 mg / 100 g MS (F2) to 799.56 ± 3.12 mg / 100 g MS (F1). The results obtained show that the slurry in the absence of germinated cereal is viscous. Viscosities ranged from 1.34 ± 0.06 Pa s (F1) and 4.42 ± 0.07 Pa s (F2). In overall, the panelists liked the sprouted corn slurry more than the panelists. The panelists' acceptance of F1 porridge over F2 porridge for their children is justified by its fluidity. Composite flour incorporating germinated maize could be recommended for children, helping to combat infant malnutrition.

KEYWORDS: Plantain, instant flour, germinated maize, viscosity, energy density.

1 INTRODUCTION

The plantain is the only fruit classified as a starch product for mass consumption in the world due to its socio-economic and nutritional importance [1]. This raw material is an excellent source of energy and nutrients such as magnesium, potassium, calcium and phosphorus [2]. Global plantain production in 2017 was estimated at over 45 million tons [3]. In Ivory Coast, with production estimated at 1.7 million tons per year, plantain has always been a very important traditional staple food for rural and urban populations; this has earned it 4th place in terms of food consumed after yam, cassava and rice [4]. Despite its importance, plantain suffers from post-harvest losses of 40 % [5], due to the lack of adequate means of conservation and processing. This situation seems likely to compromise Ivory Coast's ambitions for food self-sufficiency. As for many starch products, the main way of valorization that it is relevant to consider is its transformation into flour, however, its nutritional value is limited by its low protein and lipid content [6]. It is therefore necessary to add lipid and protein sources to banana-based infant meals. Peanut, rich in protein (30 g / 100 g) and lipid (45 g / 100 g), could be used to enrich infant food formulations [7]. Also, the germination of the cereals being at the origin of many biochemical modifications in the grains make it possible to fluidify the slurries and, consequently, to allow the increase of their energy density [8], to decrease their phytate content [9] and to increase their digestibility after processing into flour [10]. Germination increases the calcium, zinc, iron [11] and vitamin (ascorbic acid, riboflavin, niacin, tocopherols and thiamine) contents of the grains [12].

The overall objective of the present study is to contribute to the valorization and reduction of post-harvest losses of local food products through their transformation into instant infant flour.

2 MATERIALS AND METHODS

2.1 BIOLOGICAL MATERIAL

The biological material used in this study consisted of plantain, groundnut and maize collected in the survey areas (Abengourou, Agnibilekro, Bondoukou and Bouna).

2.2 METHODS

2.2.1 METHOD FOR FORMULATING INSTANT INFANT FORMULA

The incorporation rates of the raw materials used to formulate instant flours are determined by simple calculations taking into account the nutritional values per 100 grams of raw materials. The material balance and overall material balance equations presented below, assisted by Excel software, were used to formulate the feeds [13], [14].

$$\begin{cases} a_{11}X_1+a_{12}X_2+\ldots\ldots\ldots\ldots a_{1n}X_n=b_1 \\ a_{21}X_1+a_{22}X_2+\ldots\ldots\ldots\ldots a_{2n}X_n=b_2 \\ a_{n1}X_1+a_{n2}X_2+\ldots\ldots\ldots\ldots a_{nn}X_n=b_n \end{cases}$$

With : a= Nutrient contents (carbohydrates, proteins, lipids, ash, fiber, moisture).
X= Proportions of ingredients to be mixed; b= Requirements to be met

2.2.2 INSTANT INFANT FORMULA MANUFACTURING METHOD

2.2.2.1 PRELIMINARY OPERATIONS

2.2.2.1.1 PRODUCTION OF PLANTAIN FLOUR

Ripe plantains (stage 5) of the horn 1 variety were used for the manufacture of banana flour. Five kilograms of plantain fingers were washed with water and blanched with the skin in boiling water containing citric acid (0.5 g / L) for 10 minutes. After blanching, the fingers were peeled and soaked in a citric acid solution (1 g / L) for 30 minutes. The pulps were thinly sliced to a thickness of two to four millimeters and dried at 45 °C in an oven for 48 hours. The drying was done in a ventilated oven where the hot air comes in direct contact with the product. The fruit slices are placed evenly on the racks and must not touch each other as this would slow down the evaporation of the water. They are continuously brazed to ensure uniform drying. When they come out of the oven, the plantains are crushed in a Moulinex and then sifted through 250 µm diameter meshes to obtain the flour, which is stored in polyethylene bags at 4 °C until use.

2.2.2.1.2 PRODUCTION OF SPROUTED CORN FLOUR

Five kilograms of sorted, washed corn seeds are soaked in water for six hours. After soaking, the seeds were well spread on wet cloth for three days to allow them to germinate, the medium was moistened from time to time (every two hours) to prevent the seeds from drying out and stopping to germinate. Then, the germinated seeds were dried in the sun for 48 hours, degerminated, de-peeled, ground in a Moulinex and then sieved through 250 µm diameter meshes to obtain the flour, which is stored in polyethylene bags at 4 °C until use.

2.2.2.1.3 PRODUCTION OF UNGERMINATED CORN FLOUR

Five kilograms of sorted, washed corn seeds were soaked in water for six hours. After soaking, the seeds were well spread out in the sun for 48 hours, de-peeled, ground in a Moulinex and then sieved in 250 µm diameter meshes to obtain the flour, which is stored in polyethylene bags at 4 °C until use.

2.2.2.1.4 Production Of Peanut Flour

Two kilograms of sorted, washed peanut seeds are soaked in water for two hours. After soaking, the drained seeds are roasted for 5 minutes at 100 °C to be de-peeled, crushed in a Moulinex and then sieved in 250 µm diameter mesh to obtain the flour, which is stored in polyethylene bags at 4 °C until use.

2.2.3 Instant Composite Flour Manufacturing Technology

2.2.3.1 Different Formulations And Their Abbreviations

F1: 45 % ripe banana flour (stage 5), 40 % peanut flour and 15 % germinated maize flour.

F2: 45 % ripe banana flour (stage 5), 40 % peanut flour and 15 % unsprouted maize flour.

2.2.3.2 Production Of F1 And F2 Composite Flours

After weighing, the ripe plantain flour (stage 5), peanut flour and amylase source (germinated maize for F1 and ungerminated maize for F2) were mixed in water (w / v, 1/2) containing 0.5 g / L citric acid and 0.3 g / L dissodium dihydrogen pyrophosphate for baking. Cooking time was 20 minutes, with stirring, after the water / flour premix had reached a temperature of 100 °C. Once cooking was complete, the resulting paste was rolled out to a thickness of 0.5 cm, then placed in an oven (45 °C / 24 h) to dry. The resulting product was ground and sieved through a 250 µm sieve to produce the baked composite flour, which was stored in polyethylene bags at 4 °C until use.

2.2.3.2.1 Physicochemical Characterization Of The Flours

The chemical analysis of the flours consisted in the determination of moisture, lipids, protein, carbohydrates, fiber, ash, viscosity, energy value were determined according to the method [15] in triplicate.

Moisture content was determined by placing 5g of flour in the oven (Biobase BOV-D70, China) at 105 °C for 24 h [15].

The protein content was determined by the Keldjahl method and the percentage nitrogen atom (% N) obtained was used to calculate the percentage crude protein (% P) using the following relationship:

% P = % Nitrogen × 6.25. The lipid content was determined using hexane extraction in a Soxhlet type extractor [15].

The ash content was determined by incinerating the samples in a muffle furnace (Nabertherm GmbH, Germany) at 600 °C. The ash was cooled in a desiccator and weighed. For the crude fibers, 1 g of flour sample is digested with 1.25 N sulfuric acid and 1.25 N sodium hydroxide solution. The insoluble residue obtained is washed with hot water and dried in an oven at 105 °C for 24 hours. The dried residue is then incinerated in an oven at 600 °C for 6 hours and weighed for the determination of the crude fiber content [15].

The carbohydrate content (in % dry matter) is estimated by differential calculation from the formula proposed by [16]:

% Carbohydrate = 100 - (% Moisture + % Ash + % Protein + % Fat)

The energy value was determined from the lipid, carbohydrate and protein content of the flours using Atwater's conversion factors: 4 Kcal / g for protein, 9 Kcal / g for lipids and 4 Kcal / g for carbohydrates [15]. The energy value in Kcal / 100 g MS was calculated from the following formula:

EV = 4 × (%) Protein + 9 × (%) Fat + 4 × (%) Carbohydrate

The viscosity of the slurries was measured using a Brookfield rotational viscometer (Model LVDVE, USA) [17].

The determination of mineral fractions was done by atomic absorption spectrophotometer determination of ash [15].

The energy density is determined by calculation and expressed in kilocalories per 100 ml of slurry by estimating that 1 g of flour provides 4 Kcal of energy [18].

Energy density = (Mass of flour x 4 Kcal) / Mass of slurry

Amino acids were determined by reverse-phase high-performance liquid chromatography (the HPLC apparatus used consists of a pico-Tag system (Waters, Milford, Mass, U.S.A.), a UV detector (Shimadzu SPDS-6A UV Spectrophotometric detector) and an integrator (Shimadzu C-R-6A UV Chromatopac). Total acid extraction was performed according to the modified method [19]. The content of each amino acid was calculated using the following expression expressed in mg/100g dry matter:

C (mg / 100 g) = A x CS x Volume extrait x 1000 / As x Sample weight

A: Peak area of the amino acid in the sample

As: Peak area of the standard for a given amino acid

Cs: Concentration of the standard for a given amino acid

C: Concentration of identified amino acid.

2.2.3.3 Sensory Analysis Of Composite Flours

2.2.3.3.1 Preparation Of Porridges

Porridge preparation was based on the energy density of around 120 Kcal / 100 g recommended for children aged 6 to 24 months [20]. The F1 (ripe banana + peanut + sprouted maize) and F2 (ripe banana + peanut + unsprouted maize) porridges were prepared by mixing 70 g of flour with 130 g of boiled tap water. The porridges were cooled to around 40 °C before serving.

2.2.3.3.2 Hedonic Test

Sensory evaluation took place at the Biocatalysis and Bioprocess Laboratory of Nangui Abrogoua University. The panel was made up of 45 untrained people recruited on the basis of their availability. Three-digit coded slurry samples were presented monadically to each panelist in randomized order. Sensory attributes such as color, flavor, odor, appearance and overall acceptability were evaluated (Appendix 2). The degree of appreciation of each descriptor was scored on a 9-point unipolar scale ranging from 1 (extremely unappreciated) to 9 (extremely appreciated) [21].

2.2.3.3.3 Statistical Processing Of Data

Analyses were carried out on two samples with three replicates for each sample.

Statistical analyses of hedonic data were carried out using "Statistica" software version 7.1. Comparisons between dependent variables were determined using analysis of variance (ANOVA) and the Student test at the 5 % threshold.

3 Results

3.1 Chemical Composition Of Banana, Peanut, Corn And Germinated Corn Flours

The flours (banana, sprouted corn, unsprouted corn and peanut) show significant differences ($P \leq 0.05$) in the various characteristics studied. In terms of protein, the protein content of sprouted cereals was significantly higher than that of unsprouted cereals, while peanuts were richer in protein, followed by sprouted corn, unsprouted corn and banana. Flour moisture levels are significantly different, with sprouted cereals having lower moisture levels than unsprouted cereals. Peanut flour is the richest source of lipids, while the lipid content of sprouted cereals is significantly lower than that of unsprouted flours. Statistically, these flours are different: peanut flour has the lowest carbohydrate content, while banana flour has the highest, followed by ungerminated corn flour and germinated corn flour. Ash levels are significantly different at the 5 % threshold, with sprouted corn flour recording a higher level than unsprouted corn flour. In conclusion, none of these flours on its own can meet standard norms, hence the need to formulate composite flours in which certain raw materials are used as carbohydrate, lipid, mineralogical and enzymatic sources.

Table 1. Chemical composition of flours

Characteristics	Banana flour	Sprouted corn flour	Unsprouted corn flour	Peanut flour
Moisture (g / 100 g)	6,17 ± 0,03 c	4,75 ± 0,09 b	5,54 ± 0,06 e	4,13 ± 0,04 a
Lipid (g / 100 g)	0,24 ± 0,02 a	2,75 ± 0,09 b	3,76 ± 0,28 c	45,19 ± 0,02 d
Protein (g / 100 g)	0,82 ± 0,06 a	12,06 ± 0,12 e	9,44 ± 0,10 f	28,74 ± 0,05 g
Ash (g / 100 g)	1,88 ± 0,07 c	1,79 ± 0,03 a	1,59 ± 0,02 d	2,28 ± 0,03 e
Fiber (g / 100 g)	3,62 ± 0,04 a	4,19 ± 0,07 d	5,13 ± 0,05 e	5,37 ± 0,03 f
Carbohydrate (g / 100 g)	87,26 ± 0,07 b	74,45 ± 0,32 a	74,55 ± 0,25 a	14,29 ± 0,02 f

Means ± standard deviations followed by the same lower-case letter on a line are not significantly different at the 5 % threshold according to Duncan's test.

3.2 PHYSICO-CHEMICAL COMPOSITION OF INSTANT FLOURS

In general, all flours incorporated from sprouted cereals have lower moisture, lipid, carbohydrate and fiber contents than flours incorporated from unsprouted cereals. The lipid levels of flours incorporated from sprouted cereals are lower than flours incorporated from unsprouted cereals. However, it should be noted that these two formulated flours have moisture, lipid, fiber and ash levels that comply with standards. F1 flour incorporated with sprouted cereals has a higher reducing sugar content than F2 flour. The energy content of flour made from sprouted cereals is lower than that of flour made from unsprouted cereals. F1 flour incorporated with sprouted cereals has a higher energy density than F2 flour. F1 flour's energy density is in line with standards, enabling it to cover children's daily requirements in two meals. F1 flour has a viscosity in line with standards, and can be used to make high-energy density porridges. Flour incorporating sprouted cereals has a higher vitamin C content. F1 and F2 flours have an acid pH (5 and 6), It should be noted, however, that flour incorporated from sprouted cereals is more acidic than flour incorporated from unsprouted cereals. Flour incorporated from sprouted cereals also has a higher titratable acidity than flour incorporated from unsprouted cereals.

Table 2. Physico-chemical composition of instant flours

Characteristics	F1	F2
Moisture (g / 100 g MS)	5,45 ± 0,02 a	5,60 ± 0,07 b
Fat (g / 100 g MS)	19,57 ± 0,04 a	19,86 ± 0,11 b
Protein (g / 100 g MS)	14,54 ± 0,08 a	13,49 ± 0,03 b
Ash (g / 100 g MS)	2,17 ± 0,06 a	2,12 ± 0,04 a
Fiber (g / 100 g MS)	4,56 ± 0,05 a	4,89 ± 0,09 b
Carbohydrates (g / 100 g MS)	59,15 ± 0,09 a	59,65 ± 0,04 b
Energy (Kcal / 100 g MS)	470,96 ± 0,28 a	471,26 ± 0,84 b
Viscosity Pa s	1,34 ± 0,06 a	4,42 ± 0,07 b
Energy density (Kcal / 100 g MS)	141,29 ± 0,08 a	70,69 ± 0,13 b
pH [MS]	5,68 ± 0,02 a	5,91 ± 0,03 b
Starches (g / 100 g MS)	1,77 ± 0,50 a	8,35 ± 0,15 b

F1: ripe banana + peanut + germinated maize; F2: ripe banana + peanut + unsprouted maize
Means ± standard deviations followed by the same lower-case letter on a line are not significantly different at the 5 % threshold according to Student's t test.

3.3 MINERAL COMPOSITION OF INSTANT FLOURS

F1 flour made up partly of germinated maize has significantly higher proportions of minerals than F2 flour made up partly of ungerminated maize.

Table 3. Mineral composition of composite flours

Minerals	F1	F2
Iron (mg / 100 g MS)	21,80 ± 0,64 a	18,95 ± 0,64 b
Zinc (mg / 100 g MS)	4,69 ± 0,08 a	4,17 ± 0,09 b
Calcium (mg / 100 g MS)	740,18 ± 7,89 a	581,60 ± 4,01 b
Phosphorus (mg / 100g MS)	417,82 ± 8,12 a	286,34 ± 2,71 b
Potassium (mg / 100 g MS)	889,85 ± 5,80 a	506,72 ± 18,38 b
Magnesium (mg / 100 g MS)	170,54 ± 2,49 a	143,38 ± 5,31 b
Sodium (mg / 100 g MS)	79,91 ± 2,12 a	57,21 ± 1,40 b
Iodine (µg / 100 g MS)	26,35 ± 0,40 a	24,06 ± 0,38 b
Selenium (mg / 100 g MS)	5,53 ± 0,08 a	5,19 ± 0,04 b
Manganese (mg / 100 g MS)	20,65 ± 0,44 a	17,64 ± 0,39 b
Copper (µg / 100 g MS)	203,19 ± 3,20 a	179,49 ± 1,50 b
Chlorine (mg / 100 g MS)	173,41 ± 6,00 a	159,72 ± 2,41 b

F1: ripe banana + peanut + germinated maize; F2: ripe banana + peanut + unsprouted maize
Means ± standard deviations followed by the same lower-case letter on a line are not significantly different at the 5 % threshold according to Student's t test.

3.4 AMINO ACID COMPOSITION OF INSTANT FLOURS

Incorporated sprouted corn flour successively records higher levels of histidine, leucine, lysine, sulfur amino acid, threonine and tyrosine than incorporated non-germinated cereal flour. Similarly, the levels of isoleucine, tryptophan, valine, arginine and cystine in incorporated germinated corn flour were significantly higher than in incorporated non-germinated corn flour.

Table 4. Amino acid composition of instant flours

Amino acids (mg / 100 g MS)	F1	F2
Histidine	69,63 ± 1,19 a	54,80 ± 1,70 b
Isoleucine	266,70 ± 4,75 a	260,76 ± 1,33 a
Leucine	800,97 ± 3,45 a	791,38 ± 1,11 b
Lysine	427,69 ± 2,43 a	408,41 ± 4,34 b
A.A. Sulphur	188,04 ± 2,65 a	170,35 ± 2,25 b
Tryptophan	46,53 ± 1,02 a	45,68 ± 1,12 a
Threonine	487,46 ± 3,74 a	463,35 ± 2,11 b
Valine	505,72 ± 7,79 a	443,78 ± 0,81 b
Arginine	23,51 ± 1,49 a	17,25 ± 0,14 b
Cystine	2,32 ± 0,03 a	2,26 ± 0,03 a
Tyrosine	148,75 ± 1,60 a	143,23 ± 1,11 b
Phenylalanine	498,75 ± 1,13 a	442,40 ± 1,70 b

F1: ripe banana + peanut + germinated maize; F2: ripe banana + peanut + unsprouted maize
Means ± standard deviations followed by the same lower-case letter on a line are not significantly different at the 5 % threshold according to Student's t test.

3.5 HEDONIC TESTING OF INSTANT FLOURS

The sensory characteristics of the porridges are presented in Table 1. In terms of color, there were significant differences between porridges at the 5 % level. The F1 slurry (8.18 ± 0.70) was more appreciated than the F2 slurry (7.15 ± 1,16). With mean scores of 8.23 ± 0.95 and 8.07 ± 0.94, no significant difference difference was observed between the taste of F1 and F2 slurries. As for odour, there was no significant difference between the F1 and F2 slurries. Statistical analysis revealed significant differences at the 5 % threshold concerning appearance. F1 slurry (8.13 ± 0.89) was rated better than F2 (7.25 ± 1,76). In terms of general acceptability, with an average score of 8.07 ± 0.99, F1 spray liquid was more popular than F2, which recorded an average score of 7.20 ± 1.54.

Table 5. Comparison of sensory characteristics of slurries

Characteristics	Color	Taste	Odor	Aspect	General acceptability
F1	8,18 ± 0,70 a	8,23 ± 0,95 c	7,07 ± 1,44 d	8,13 ± 0,89 e	8,07 ± 0,99 g
F2	7,15 ± 1,16 b	8,07 ± 0,94 c	7,17 ± 0,92 d	7,25 ± 1,76 f	7,20 ± 1,54 h

F1: ripe banana + peanut + germinated maize; F2: ripe banana + peanut + unsprouted maize
Means ± standard deviations followed by the same lower-case letter in a column are not significantly different at the 5 % threshold according to Student's t test.

4 Discussion

4.1 Chemical Composition Of Banana, Peanut, Ungerminated Maize And Germinated Maize Flours

The flours (banana, peanut, sprouted and unsprouted maize) show significant differences ($P \leq 0.05$) in the characteristics studied. In terms of moisture, fiber and lipid content, germinated corn flour has significantly lower values than non-germinated corn flour. The increase in dry matter content during germination leads to a drop in flour moisture content [22]. The decrease in lipid content could also be explained by the biochemical and physiological changes that occur in germinated grains [23]. Indeed, lipase activity increases during germination, with the aim of producing the sugars required for the growth of the young seedling before the establishment of its photosynthetic apparatus [24]. This reduction in the fiber content of germinated flour is partly due to enzymatic hydrolysis followed by solubilization. The ash content of germinated corn flour is significantly higher than that of ungerminated corn flour at the 5 % threshold. The increase in ash content during germination could be due to the water used to soak, rinse and sprinkle the kernels during germination [25]. This increase in the protein content of germinated corn flour could be due to the fact that, during germination, metabolic enzymes such as proteinases are activated. Their hydrolytic action led to the release of certain amino acids and peptides, whose synthesis or utilization led to the formation of new proteins [26], [27].

4.2 Physico-Chemical Composition Of Instant Flours

The difference between the two formulations is whether the corn is sprouted or unsprouted. Between the parameters studied. For example, flour made from germinated corn significantly lower levels of moisture, lipids, fiber and carbohydrates than the and carbohydrates than the unsprouted corn flour. Corn flour F1 and F2 flours have their moisture content below 10, which explains why these flours can be kept longer shelf life. Similarly, [28] have reported that flour with a moisture content less than or equal to 10 % is ideal for long-term storage period. The fiber content of flour incorporated from F1 germinated maize is significantly lower than that of flour incorporated from F2 ungerminated maize, due in part to enzymatic hydrolysis followed by solubilization [29]. The lower percentage of fiber in flours during germination is thought to increase their digestibility. This is due to the hydrolytic action of alpha amylases, which break down large starch molecules into smaller molecules (maltodextrins) with reduced swelling capacity. The energy provided by flour incorporated with sprouted cereals is lower than the energy provided by flour incorporated with unsprouted cereals. The energy value of the flour decreased with germination. The change in the content of chemical constituents (proteins, lipids and carbohydrates) affects the energy value [12]. Thus, the decrease in energy value during germination would be due to the breakdown of lipids to meet the energy requirements of the growing germ [30]. On the other hand, flour incorporated from germinated maize has a significantly higher energy density than flour incorporated from non-germinated maize, in line with standards. The viscosity of incorporated sprouted corn flour is also in line with standards. The titratable acidity of sprouted corn flour is significantly higher than that of unsprouted corn flour. The increase in flour acidity during germination is probably due to the hydrolysis of certain macromolecules [27]. According to [31], carbohydrate metabolism during germination is a consequence of the accumulation of organic acids, hence the increase in titratable acidity, which is in fact a measure of the quantity of organic acids [32].

4.3 Mineral Composition Of Instant Flours

In general, F1 flour incorporated with sprouted maize has significantly higher mineral content than F2 flour incorporated with unsprouted maize. The mineral composition of the flour is much higher when the cereals used are sprouted. Potassium, the most abundant mineral in these sprouted cereal flours, plays a protective role against increased blood pressure and other cardiovascular risks. It is also involved in amino acid and protein synthesis [33], [34]. Calcium is involved in many biological processes, including a variety of enzymatic reactions. In association with phosphorus, it plays an important role in the diets of both children and adults. Indeed, it is involved in bone fortification and tooth development [35]. Sodium, whose concentration is higher in flours made from sprouted cereals, plays a part in controlling the osmotic pressure that develops between blood and cells as a result of unequal ionic concentrations [36]. Along with calcium, phosphorus is involved in tooth formation and bone development in children [32]. Magnesium helps regulate the body's acid-base balance and maintain normal muscle and nerve function [37]. It reduces blood triglyceride and cholesterol levels, and plays a part in the body's defense mechanisms against microbial and viral infections [34]. Magnesium levels were improved during germination. Iron can act as an antioxidant, helping to prevent cardiomyopathy and stunted growth. It also facilitates the oxidation of carbohydrates, proteins and lipids [38]. Iron deficiency leads to a drop in haemoglobin levels, resulting in anaemia [39]. However, iron levels have been shown to increase in sprouted grain flours. This result is an advantage for these flours in the preparation of infant porridges. Zinc can prevent cardiomyopathy and stunted growth. Zinc deficiency can lead to poor appetite, a weakened immune system, diarrhoea, delayed sexual maturation and eye and skin lesions [40]. Zinc levels increased during germination. These flours are ideal for infant nutrition, as according to [41], the role of Fe and Zn in a child's development is of great interest due to the detrimental effects of their deficiencies on a child's development. Daily intake is estimated by [42] at 6 mg/day. The increase in copper levels in flour incorporated with sprouted cereals is thought to be due to the activation of enzymes during these processes. Copper plays an essential role in several enzyme systems, including cytochrome oxidase and tyrosinase [43]. Ascorbic acid is directly involved in the modulation of plant growth, including early embryo germination [29].

4.4 Amino Acid Composition Of Instant Flours

The amino acid profile shows that formulated flours contain appreciable quantities of both non-essential and essential amino acids. Sprouted cereal flour generally has significantly higher amino acid levels than non-germinated maize flour. All essential amino acids are present, with high levels of phenylalanine, arginine, leucine and lysine, which may facilitate protein synthesis and the assimilation of other amino acids [44]. Incorporated sprouted maize flour has high levels of arginine, which [45] suggests is essential for children's growth. The sulphur amino acid content (methionine and cysteine) of incorporated sprouted maize flour is significantly higher than that of non-germinated maize flour, so it is essential to take account of essential amino acids in balanced proportions. Thus, [46] have shown that an excess of leucine in food interferes with the utilization of isoleucine, just as an excess of leucine would interfere with the utilization of lysine. [47] have shown that a leucine/lysine ratio of less than 4.6 is considered nutritionally correct. In this study, the ratio was below 4.6. It could therefore be concluded that the proteins in formulated flours have favorable leucine/isoleucine and leucine/lysine ratios and would not present any problem of essential amino acid imbalance.

4.5 Hedonic Testing Of Instant Flours

The F1 porridge was accepted by panelists on the basis of its thinner consistency than the F2 porridge. Indeed, in order to be swallowed by infants, porridges must have a viscosity not exceeding 1600 Centipoises [48]. The thinner consistency of F1 porridge compared with F2 could be explained by the hydrolytic action of alpha amylases from sprouted cereals. These enzymes hydrolyze the starch molecules into simple elements such as glucose, fructose and sucrose, which give porridges their sweet taste and make them less thick, enabling them to be prepared at sufficient energy densities [49], [50]. These results are in line with those of [51], who present cereal germination as a traditional means of improving the nutritional and organoleptic quality of infant foods. The work of [52] confirms this hypothesis by showing an increase in the activity of β amylase, an enzyme that hydrolyzes large starch molecules into smaller molecules (maltodextrins) whose swelling capacity is reduced, thus increasing the fluidity of the porridges. Also, the F1 slurry was more appreciated than the F2 slurry in terms of coloration. In fact, germination tends to further increase the vitamin (ascorbic acid, riboflavin, niacin, tocopherols and thiamine) and polyphenol content of seeds [53]. These antioxidants play a very important role in preserving foodstuffs from effects such as rancidity of taste and preventing changes in texture and color [54].

5 Conclusion

The local manufacture of instant infant flour is a way of adding value to little-exploited agricultural resources, and turning them into high value-added products, while also reducing post-harvest losses. With this in mind, we set ourselves the goal of developing supplementary foods rich in essential nutrients for improved infant health and growth. The use of locally available products such as plantain, peanut and corn, and technological processes such as soaking and germination, have enabled us to produce flours with high energy density, good fluidity and rich nutritional content that meet standard norms. Among these flours, the panelists were most appreciative of the slurry incorporated from germinated maize (F1). The panelists' acceptance of F1 porridge over F2 porridge for their children was mainly due to its fluidity. Composite flour incorporating sprouted maize (F1) could be recommended for infants, helping to combat infant malnutrition.

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