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Formulation of Instant Atadjon (Mixed Tiger Nut and Rice) Flours Enriched with Legumes for Children of Weaning Age

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Authors' contributions

This work was carried out in collaboration among all authors. Author GGD designed and supervised the study. Author MC and GGD managed and performed the experimental and statistical analysis. AuthorTLC and MC wrote the protocol and wrote the first draft of the manuscipt. Authors RMM and TLC managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: Formulate instant infant flours based on a mixture of Tigernut-rice enriched with legumes, maize and peanuts.
Study Design: Original research.
Place and Duration of Study: This study took place at the Laboratory of Biotechnology, Agriculture and Valorization of Biological Resources, Félix Houphouët-Boigny University between March and July 2022.
Methodology: The ingredient doses of the three instant flour recipes (F1, F2 and F3) were combined using the Pearson square according to the dietary recommendations. For this purpose, three compositions were prepared that achieved a protein content of 13%. These were compound flour F1 (47.10% tigernut-rice+42.90% voandzou+5 % maize + 5% groundnut paste), compound flour F2 (52.54% tigernut-rice+37.46% cowpea+5% maize+5% groundnut paste) and compound flour F3 (51.20% tigernut-rice+38.80% common bean+5% maize+5% groundnut paste). The nutritional content, the amino acid composition of these flours as well as the organoleptic properties

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of their porridges were determined according to standard methods.
Results: The results revealed that atadjon instant flours produced at 13% protein with maize, groundnut and mainly legumes voandzou (F1), cowpea (F2) and common bean(F3) are rich in complete proteins with all nine essential amino acids. However, the formulation based on F1 exhibited the highest content of these essential amino acids. Energy and carbohydrate values of the three formulations reached a satisfactory rate over 100% compared to the nutritional norms. The respective lipid (9.54; 6.18; 7.18%) and ash (1.87; 1.67; 1.67%) contents of the three instant atadjon flours were within the range of recommended values. Finally, the anti-nutritional factors are almost negligible since the fibre contents of 2.56% (F1), 3.45% (F2) and 3% (F3) are below the limits recommended by the standards, as are those of tannins and oxalates. the porridges prepared from these flours were appreciated by the tasters. However, the porridge prepared from atadjon flour F1 was the most appreciated for its colour, aroma and taste.
Conclusion: These good quality and nutritious intant flours, prepared from locally available and accessible ingredients, could therefore be recommended for infant feeding.

Keywords: Infant flour; weaning; legume; nutritional quality; sensoriel quality; formulation.

1. INTRODUCTION

Malnutrition remains a major public health and economic problem in sub-Saharan Africa, with the region having some of the most nutritionally insecure people in the world. The undernourishment rate is estimated at 22% (235 million people), which is the highest in the world [1]. In the same region, 1 in 3 children under the age of 5 suffer from chronic malnutrition or stunting [2]. This form of protein-energy malnutrition affects children under five mainly during the period of supplementary feeding. In Côte d'Ivoire, the prevalence rate of stunting is estimated at 21.6% according to the latest data from the national Multiple Indicator Cluster Survey [3]. This chronic malnutrition, which is mainly due to a diet of limited quantity, quality and diversity, generally appears during the weaning period. During this period, which extends from 6 months to 2 years, breast milk alone is no longer sufficient to cover the nutritional needs of the growing child. It is therefore important to supplement with a diversified and nutrient-dense "complementary" diet to meet the needs of infants and young children, which are particularly high relative to their size [4]. This period is a high-risk phase in an infant's life, and can lead to malnutrition if poorly managed. It is therefore important to have infant formula of good nutritional quality to cover the child's needs.

However, in sub-Saharan Africa, mothers feed their children with traditional porridges prepared from simple or compound flours from starchy cereals or tubers and generally characterised by their low macro- and micronutrient content [5]. The over-reliance on these starchy foods (maize, rice, cassava etc.) to meet all nutritional needs results in inadequate protein and/or calorie intake very often accompanied by widespread dietary micronutrient deficiency [6]. All this has a detrimental effect on the growth and development of children. The necessity of satisfying the nutritional requirements of the child during weaning of has therefore been the subject of many studies and recommendations by WHO, leading to the manufacture of various types of infant formula with a view to offering children products of good nutritional and health quality [7,8].

In Africa, good quality infant formula is available on the market, but it is an imported and expensive industrial product. Therefore, they are not accessible to all budgets. However, the formulation of supplementary foods based on local raw materials enriched with legumes, local foods rich in protein and available, will make it possible to meet nutritional and health recommendations. Indeed, legumes such as cowpea, voandzou and common bean, in addition to their easily digested nutritional content after various technological treatments (roasting, cooking, germination, etc.), are characterised by high levels of complete protein equivalent to that of animal proteins (milk, eggs and meat) [9,10]. Thus, their incorporation into local infant formula could constitute a sustainable and effective alternative to industrial flours, which are generally made from imported products, not always available and expensive [7]. The recent study conducted by [11] on "Atadjon" complementary porridges highlighted the low protein content (5.37 g/100g) of the 2/3-1/3 mixed flour formulation of Tiger Nut and Rice despite its appreciation by the tasting panel and its low content of anti-nutritional factors. The production of protein-enriched instant infant flours from these local ingredients will make it possible to develop realistic and affordable formulations. The aim of this study is to develop, using the Pearson square method, formulations of instant infant flours based on mixed tigernut-rice flour enriched with proteins from local legumes (cowpea, voandzou, cowpea and common bean) to improve its nutritional value.

2. MATERIALS AND METHODS

2.1 Biological Material

The plant material used in this study consists of common bean (*Phaseolus vulgaris*), cowpea (V*igna unguiculata*), voandzou (*Vigna subteranea*) seeds, groundnut (*Arachis hypogaea*), rice (*Oryza sativa*) and maize (*Zea mays*) and Tiger Nut (*Cyperus esculentus*) tubers purchased at the forum market in adjamé (5°29′17″ north, 4°01′56″ west) in Côte d'Ivoire.

2.2 Preparation of the Different Flours

2.2.1 Preparation of the atadjon flour (mixed 2/3 Tiger Nut-1/3 Rice)

A mass of 500 g of previously cleaned tiger nuts (manual sorting to remove impurities and defective grains and washing two or three times with tap water) was crushed using a mechanical grinder. The crushed material was dried at 50°c for 24 h in a ventilated oven (memert, france) and then finely ground in a mixer (moulinex, france). The powder was sieved using a 250 µm mesh sieve and the fine flour obtained was packed in sterile glass jars and stored at 4°c.

A mass of 500 g of previously cleaned rice grains (manually sorted to remove impurities and defective grains and washed with tap water) was cooked in water for 25-30 min at low heat. After cooking, the cooled rice grains were dried at 50 °c in a ventilated oven (memmert, france) for 24 h. After grinding in a blender and sieving with a 250 µm mesh sieve, the fine flour obtained was packaged in sterile glass jars and stored at 4°c.

The tigernut and rice flours previously produced are introduced in the proportions of 2/3 (tigernut) and 1/3 (rice) into an electric flour blender and then rigorously mixed for 5 min in order to make the mixture homogeneous. The resulting mixed flour (atadjon flour) is then packed in sterile glass jars and stored at 4°c.

2.2.2 Preparation of the flour of the different legumes

A mass of 500 g of legumes seeds (common bean, cowpea and voandzou), previously cleaned (manual sorting to remove impurities and defective grains and washing with tap water), was put to soak in distilled water (v/v, 1/3) overnight at room temperature and then depelleted. These beans were then cooked in boiling water over low heat for 30 min (common bean and cowpea) and 1 h (voandzou). After cooking, the cooled beans were dried at 50°C for 24 h in a ventilated oven (Memmert, France) and then finely ground using a mixer (Moulinex, France). The powder resulting from this grinding was sieved with a 250 µm mesh sieve and the fine flour of the different legumes was packaged in sterile glass jars and stored at 4°C.

2.2.3 Preparation of the roasted maize flour

250 g of previously cleaned maize kernels (hand sorted to remove impurities and defective kernels and washed with tap water) were roasted at 120°C for 20 min in an electric oven. The roasted maize kernels were then coarsely crushed using a mechanical grinder and finely ground in a blender (Moulinex, France) and the powder sieved through a 250 µm mesh sieve. The resulting fine roasted maize flour was packed in sterile glass jars and stored at 4°C.

2.2.4 Preparation of the peanut paste

200 g of previously cleaned peanut kernels (hand sorted to remove impurities and defective kernels and washed with tap water) were roasted at 120°C for 20 min in an electric oven. The roasted peanuts were then crushed using a mechanical grinder and finely ground in a mixer (Moulinex, France). The resulting peanut paste was also packaged in sterile glass jars and stored at 4°C.

2.3 Formulation of Atadjon Flours Enriched with Legumes

2.3.1 Pearson square method

The Pearson square method (Fig. 1, Table 1) was used to determine the proportions of the two main ingredients of the feed, which are the mixed starch-rice flour (2/3-1/3) and the flour of the different legumes (common bean, cowpea and voandzou) in order to reach a protein content of 13% in the final mixture (Table 1).

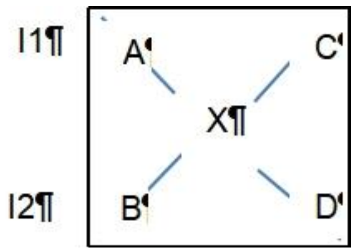

Fig. 1. Pearson Square diagram

X: represents the amount of protein required; A and B represent the protein contents of the starch-rice mixture (I1) and the legume meal (I2) to obtain the required protein; C (absolute value of the difference between B and X): share of the rice-stem mix in the mixture; D (absolute value of the difference between A and X): share of the legume in the mixture; Proportion of stump-rice mixture (I1) = C/(C+D) × 90; Proportion of the legume (I2) = D/(C+D) × 90

Table 1. Pearson square factors and formulation of atadjon/legume composite flours

	Pearson Square Factors				Proportion of ingredients in the formulation (g/ 100 g)				
	A (%)*	**B (%)***	**C**	**D**	**I.1 (%)**	**I.2 (%)**	**I.3 (%)**	**I.4 (%)**	**Total**
F1	5,8	20,9	7,9	7,2	47,10	42,90	5	5	100
F2	5,8	23,1	10,1	7,2	52,54	37,46	5	5	100
F3	5,8	22,5	9,5	7,2	51,20	38,80	5	5	100

A (%): protein content of the tigernut-rice mix; B (%): protein content of the strain-rice mix; C: absolute value of the difference between B and X; D (absolute value of the difference between A and X); I.1: amount of mixed flour (S/R); I.2: amount of flour of the different legumes; I.3: amount of roasted maize flour; I.4: amount of peanut paste
** Source: West African food composition table 2019 [12]. F1: flour composed of Atadjon (mixed tigernut-rice), voandzou, maize and groundnut paste; F2: flour composed of Atadjon (mixed tigernut-rice, cowpea), maize and groundnut paste; F3: flour composed of Atadjon (mixed tigernut-rice), common bean, maize, and groundnut paste*

2.3.2 Mixing the ingredients

The atadjon flour enriched with various legumes was prepared by homogenising the different ingredients (the flours of the various legumes with the flour of the mixed tigernut-rice, roasted maize and groundnut paste) in the proportions indicated in Table I. Thus, according to the protein contents of the different ingredients, 100 g of legume-enriched atadjon flours were formulated by combining the ingredients in the required proportions (Table 1).

2.4 Preparation of the Instant Legume-enriched Atadjon Flours

The preparation of the instant flour consisted of gradually mixing an equivalent amount of legume-enriched atadjon flour and boiling water (100°C) until a homogeneous dough was obtained. The dough was then rolled out in a thin, even layer on a tray covered with baking paper and baked in an electric oven (Ilux, Turkey) at 130°C for 45 min. After cooling, the baked dough was pulverised in a mixer to obtain enriched instant atadjon flour.

2.5 Detrmination of the Biochemical Characteristics of Instant Atadjon Flours Enriched wiyh Legumes

2.5.1 Proximate analysis

The proximate analysis of the three instant flours of atadjon enriched with legumes consisted in the determination of the moisture content, lipids, carbohydrates, ash, crude fibres, energy value and amino acid composition of the flours.

The moisture, lipid and ash content of the composite flours were determined according to the [13] method in triplicate. The moisture content was determined by drying the samples in an oven (Memmert, Germany) at 105 °C for 24 h. The lipid content was determined using hexane extraction with Soxhlet (UnidTecator, Sweden). After evaporation of the solvent and drying of the capsule in an oven (Memmert, Germany) at 105°C for 30 min; the weight difference gave the lipid content of the samples. The percentage of ash (%) was determined by incinerating the composite meal samples in a muffle furnace (NaberthermGmbH, Germany) at 600°C for 6 h.

The ash was cooled in a desiccator and weighed. Total sugar content was determined by the phenol-sulfuric method as described by [14] after ethanosoluble extraction performed from the method described by [15]. The carbohydrate content (% DM) was estimated by differential calculation from the formula proposed by [16]: Carbohydrate content (% DM) = 100 - (Protein (% DM) + Fat (% DM) + Ash (% DM) + Fibre (% DM)).

The energy value was determined from the fat, carbohydrate and protein content of the composite flours using the Atwater conversion factors; 4 Kcal/g for protein, 9 Kcal/g for fat and 4 Kcal/ g for carbohydrate [13]. The energy value in Kcal/100g dry matter (DM) was calculated from the following formula: Energy value (Kcal/100g DM) = (% protein ×4) + (% carbohydrate ×4) + (% fat 9).

2.5.2 Amino acid evaluation

The amino acid contents of the flour samples were determined according to the method described by [17]. For the extraction of these amino acids, five (5) g of flour was dissolved in 20 mL of sodium citrate (0.2 N) at pH 2.3, then diluted in 10 mL of hydrochloric acid (6 N) after manual stirring for 25 min at room temperature (25°C). The mixture was heated to 110 °C for 24 h in the oven (Thitec 250, France). After evaporation of the acid, the sample was collected in 10 mL of ethanol (70%, v/v) and filtered with a 0.45 µm diameter Millipore filter (Sartorius AG, Germany). A 20 µL aliquot of this mixture was injected into an HPLC instrument (Waters Alliance, model e2695, USA), equipped with an automatic sampling system and a p2895 pump system. Amino acid separation was performed using two serial columns, lichrocart 125-4 cartridge containing a Lichrospher 100 RP18 column, each 12.5 cm long and 5 µm in diameter. Detection was performed using a Waters 2475 spectrofluorometer (Excitation 340 nm; emission at 450 nm). Elution was performed using two eluents A (mixture of 1.36 g sodium acetate trihydrate, 500 mL distilled water, 90 µL triethylamine and 1.5 mL tetrahydrofuran) and B (mixture of 1.36 g sodium trihydrate, 100 mL distilled water, 200 mL acetonitrile and 200 mL methanol, pH was adjusted to 7.2) and the chromatograms were recorded by computer with Borwin-type data processing software (JMBS, France). The areas of the peaks were automatically calculated from reference solutions of known content and the concentrations were expressed in mg/100 g MS.

2.5.3 Anti-nutritional factors determination

2.5.3.1 Crude fibre content

The fibre content was determined according to the method of [13]. Ten (10) grams of sample were homogenised in 50 mL of sulphuric acid (0.25 N) and boiled for 30 min under reflux refrigeration. Then 50 mL of 0.31 N sodium hydroxide was added to the contents of the flask and boiled once more for 30 min under reflux refrigeration. The extract obtained after boiling was filtered through Whatman No. 4 filter paper and the residue was washed several times with boiling water (100 °C) until complete removal of alkali. The residue was dried in an oven at 110°C for 8 h. It was cooled in a desiccator and then weighed. The residue obtained was incinerated in an oven at 550°C for 3 h, cooled in a desiccator, and the ash was weighed.

2.5.3.2 Tanin content

After extraction of the phenolic compounds with methanol according to the method of [18], the tanin content was evaluated in sulphuric acid medium with vanillin according to the method described by [19] using a standard curve established from a stock solution of tannic acid (2 mg/mL) under the same conditions as the test.

2.5.3.3 Oxalate content

The oxalate content was determined by the method described by [20]. 1 mg of each flour and 75 mL of 3.0 mol/L H_2SO_4 were thoroughly mixed for one hour and filtered (Wathman No. 1). 5 mL of filtrate was titrated against 0.1 mol. L-1 $KMnO_4$ until a slight pink colour appeared and persisted for at least 30 s.

2.6 Evaluation of the Organoleptic Quality of Porridges Prepared from Instan Atadjon Flours Enriched with Legumes

Infant porridges were prepared from the three enriched instant atadjon flours. 350 g of the different instant atadjon flours and the control FARINOR instant flour were dissolved and gradually mixed in 1500 mL of boiling water and stored in thermos flasks for taste testing.

A hedonic test for acceptability and ranking of porridges were performed according to [21]. An untrained panel of 60 people (young girls and boys, adult women and men) was recruited on the basis of their availability to perform a series of tests on the prepared porridges. Samples of four porridges prepared from the three Atadjon instant flours enriched with voandzou, cowpea and common bean and the control FARINOR instant flour coded (with 3 digits) were presented simultaneously to each panelist in a randomised order. The assessment of each porridge was based on colour, taste, aroma, consistency and overall acceptability of the porridges using a nine-point (9) hedonic scale. nine (9) point hedonic scale. Scores ranging from 9 (very good) to 1 (very bad) were assigned to the different modalities of the scale.

2.7 Statistical Analysis

Analysis of variance (ANOVA) was performed with the software SPSS version 20.0 to study the degree of difference between the variables. In case of significant difference between the studied parameters, the classification of the means (homogeneous groups) is carried out with the Duncan test. The significance level (α) is 0.05. Statistical differences with a probability value lower than 0.05 were considered significant.

3. RESULTS

3.1 Nutritive and Anti-nutritive Characteristics of Atadjon Instant Flours Enriched with Legumes

3.1.1 Nutrient content of atadjon instant flours enriched with legumes

3.1.1.1 Energy value and macronutrient content of atadjon instant flours enriched with legumes

Statistical analysis of the nutritional characteristics of three instant flours of atadjon enriched with legumes, namely voandzou (F1), cowpea (F2) and common bean (F3), shows that on the whole these instant flours differ from each other at the 5% threshold (Table 2). In the case of water, digestible carbohydrate and total sugar contents, the cowpea enriched atadjon instant flour (F2) recorded the highest contents of 2.99, 73.16 and 2.99 g/100 g, respectively, while for ash, lipid and energy, the voandzou enriched atadjon flour (F1) stood out with the highest contents of 1.87, 9.54% and 416.26 Kcal/100 g DM. On the other hand, the third formulation of atadjon enriched with common bean (F3) shows intermediate contents for all these parameters.

3.1.1.2 Amino acid density of Atadjon instant flours enriched with vegetables

The result for the types of amino acids and their content are depicted in Table 3. Statistical analysis of the average amino acid contents showed the existence of significant differences within the studied instant flours ($P < 0.05$).

Concerning the essential amino acids, it appears from the analysis of the three instant flours of atadjon enriched with legumes that the atadjon formulation enriched with voandzou (F1) recorded the highest values for eight of the nine identified amino acids, i.e. 4.89±0, 01 g/100 g protein (histidine), 8.60±0.3 g/100 g protein (isoleucine), 8.05±0.4 g/100 g protein (leucine), 6.13±0.11 g/100 g protein (methionine), 7.53±0, 21 g/100 g protein (phenylalanine), 7.95±0.11 g/100 g protein (threonine) 8.62±0.14 g/100 g protein (tryptophan) and 7.79±0.15 g/100 g protein (valine). Similarly, the cowpea enriched atadjon instant flour (F2) has the highest values of histidine (4.76±0.02 g/100 g protein), lysine (7.93±0.32 g/100 g protein) and tryptophan (8.60±0.21 g/100 g protein). On the other hand, the third formulation F3 (atadjon/ common bean) has the highest tryptophan content (8.62± 0.02 g/100 g protein) only.

Regarding non-essential amino acids, the voandzou enriched flour also recorded the highest values in the seven non-essential amino acids identified with contents of 0.94±0.02 (glutamic acid); 4.36±0.12 (arginine); 2.47±0.00 (proline), (alanine), 3.10±0.02 (serine), 3.89±0.04 (tyrosine) and 2.80±0.01 (cystine) in g/100 g protein. However, for glutamic acid (9.6±0.04 g/100 g protein) the formulation (F1) stands out with the highest value.

3.1.2 Anti-nutrient content of atadjon instant flours enriched with legumes

The analysis of variance carried out on the anti-nutritive properties of atadjon instant flours enriched with legumes reveals the existence of a significant difference at the 5% threshold for fibre and oxalate except for tannins.

Table 2. Macronutrient and energy density of native (atadjon) and composite (atadjon/legume) instant flours

	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	carbohydrate (%)	Energy (Kcal/100 g)	Total sugars (%)
F1	2.33±0.46[c]	**1.87±0.01[a]**	**9.54±0.46[a]**	***13±0.00[a]**	69.76±0.32[c]	**416.26±1.33[a]**	2.8±0.01[b]
F2	**2.99±0.23[a]**	1.67±0.01[b]	6.18±0.23[c]	***13±0.00[a]**	**73.16±0.23[a]**	400.20±2.23[c]	**2.99±0.02[a]**
F3	2.53±0.11[b]	1.67±0.02[b]	7.18±0.32[b]	***13±0.00[a]**	72.24±0.22[b]	409.12±2.03[b]	2.77±0.03[b]

*Note: *13%: Protein content of F1, F2 and F3 formulations determined from Pearson's square; high values are in bold and low values are underlined. Values in the same column with different alphabetical letters are significantly different (Duncan's test, 5%); those with the same letter are not. F1: composite instant flour atadjon/voandzou; F2: composite instant flour atadjon/ cowpea; F3: composite instant flour atadjon/ common bean*

Table 3. Amino acid composition (g/100 g protein) of instant atadjon flours enriched with voandzou, cowpea and common bean

		F1	F2	F3	*RDA
Essential Amino Acids (EAA)	Histidine	**4,89±0,01**[a]	**4,76±0,02**[a]	4,33±0,23[b]	2,0
	Isoleucine	**8,60±0,03[a]**	8,09±0,23[b]	4,62±0,12[c]	3,2
	Leucine	**8,05±0,04[a]**	6,14±0,12[c]	7, 01±0,13[b]	6,6
	Lysine	6,42±0,29[c]	**7,93±0,32[a]**	8,27±0,32[b]	5,7
	Méthionine	**6,13±0,11[a]**	5,84±0,01[b]	05,02±0,01[c]	2,7
	Phénylalanine	**7,53±0,21[a]**	6,39±0,00[b]	05,81±0,02[c]	5,2
	Thréonine	**7,95±0,11[a]**	7,34±0,02[b]	07,15±0,23[c]	3,1
	Tryptophan	08,62±0,14[a]	**08,64±0,21[a]**	**08,62±0,02[a]**	8,5
	Valine	**7,79±0,15[a]**	7,50±0,04[b]	07,07±0,22[c]	4,3
Non-Essential Amino acids (NEAA)	Glutamic Acid	**00,94±0,02[a]**	**0,96±0,04[a]**	00,78±0,00[c]	
	Arginine	**04,36±0,12[a]**	04,33±0,23[c]	03,04±0,02[d]	
	Proline	**02,47±0,00[a]**	02,07±0,24[b]	01,76±0,03[c]	
	Alanine	**03,10±0,02[a]**	01,65±0,41[b]	01,47±0,00[b]	
	Serine	**03,13±0,02[a]**	02,76±0,22[b]	02,49±0,03[c]	
	Tyrosine	**03,89±0,04[a]**	02,52±0,02[b]	02,02±0,01[c]	
	Cysteine	**02,80±0,01[a]**	02,12±0,01[b]	01,39±0,02[c]	
	Total EAA (%)	66,07	62,63	57,90	
	Total AA (%)	86,76	79,04	70,85	
	% RDA covered	159,97	151,65	140,19	41,3

** source: [22]. High values are in bold and low values are underlined. Values in the same column with different alphabetical letters are significantly different (Duncan test, 5%); those with the same letter are not. F1: atadjon instant flour enriched with voandzou; F2: atadjon instant flour enriched with cowpea; F3: atadjon instant flour enriched with common bean*

Table 4. Content in fibers, tanins and oxalates of the studied instant atadjon -legume enriched flours

	Fibers (g/100 g DM)	Tanins (mg/100 g DM)	Oxalates (mg/100 g DM)
F1(voandzou)	2.56±0.01[c]	**0.6±0.02[a]**	0.53±0.02[b]
F2 (cowpea)	**3.45±0.45[a]**	**0.7±0.01[a]**	0.54±0.02[b]
F3 (common bean)	3.00±0.04[b]	**0.8±0.00[a]**	**0.62±0.01[a]**

High values are in bold and low values are underlined. Values in the same column with different alphabetical letters are significantly different (Duncan test, 5%); those with the same letter are not. F1: atadjon instant flour enriched with voandzou; F2: atadjon instant flour enriched with cowpea; F3: atadjon instant flour enriched with common bean

For fibre, the values recorded vary between 2.56 (F1) and 3.45 % (F2). In the case of oxalates, the instant flours (F1 and F2) had the lowest average content of 0.53% in contrast to flour (F3) which has the highest value of 0.62%.

3.2 Sensory Characteristics of Atadjon Instant Flours Enriched with Legumes

The scores assigned by the amateur panelist for the different descriptors (appearance, aroma, taste and colour) as well as for the overall appreciation on a scale from 1 to 9 are recorded in Figs. 2 and 3, respectively. The analysis of the results revealed a significant variation ($p<0.05$) in the averages of the scores given by the panel.

For the aroma descriptor, the average scores for the studied porridges ranged from 4.82 to 6.00, with the highest aroma score given to the atadjon/common bean composite flour porridge (F3), while the lowest score was given to the control flour porridge (F4).

As for the scores given for the taste of the different composite instant flours and the commercial one (farinor), the average scores varied from 4.98 to 6.37 with the highest score (6.37) given to the F1 porridge (atadjon/voandzou) while the lowest score (4.98) was given to the control flour porridge.

For the colour descriptor, the average scores of the three instant composite flour porridges (atadjon/legume) and the commercial porridge (farinor) ranged from 6.26 to 6.85, with the highest colour score for the control porridge (farinor) and the lowest for the atadjon/voandzou porridge (F1).

Finally, the average appearance scores of the different composite slurries atadjon/voandzou F1 (5.89), atadjon/common bean F3 (5.97) and the control slurry (5.6) studied indicate a similar level of appreciation of the appearance of these porridges.

The analysis shows that the cowpea formulation F2 was the best appreciated for its appearance, aroma and taste, followed by the voandzou formulation F1, contrary to the common bean formulation F3 which comes after the FARINOR formulation (F4), whose colour was the best appreciated.

The overall assessment of the slurries and the panel's ranking are shown in Fig. 3.

Regarding the overall assessment, porridge from the F2 flour (6.69%) received the highest score, while porridge from the control flour (F4) received the lowest score (5.6%). The F2 (6.69%) and F3 (6.27%) porridgs scored in the middle at 6.69 and 6.27. This indicates that this panel prefers the F2 cowpea formulation first, then F1 (voandzou) and F3 (common bean) in second place before the control F4 (FARINOR).

Finally, in the ranking that results from these two levels of appreciation, it is the F1 (voandzou) formulation that is ranked first before the control formulation F4 (FARINOR), then come the other two formulations F3 (common bean) and F2 (cowpea) respectively

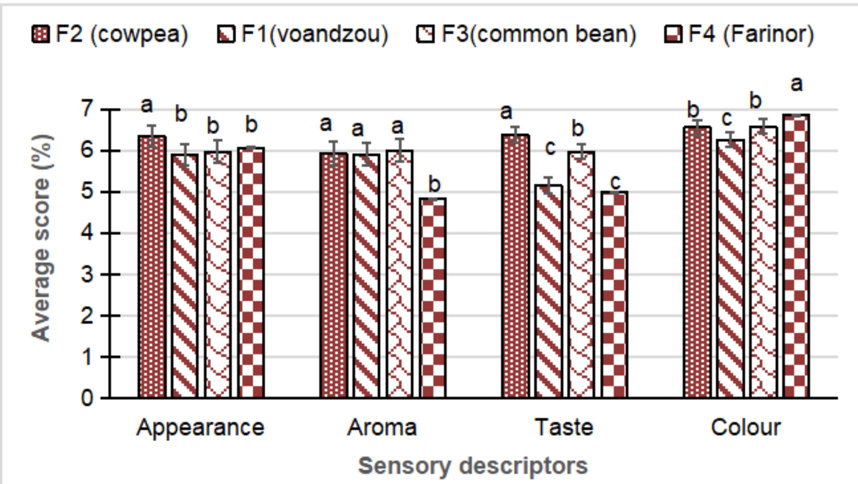

Fig. 2. Assessment of the descriptors (appearance, aroma, taste and colour) of the different porridges from commercial and enriched legume- atadjon flours by the tasters

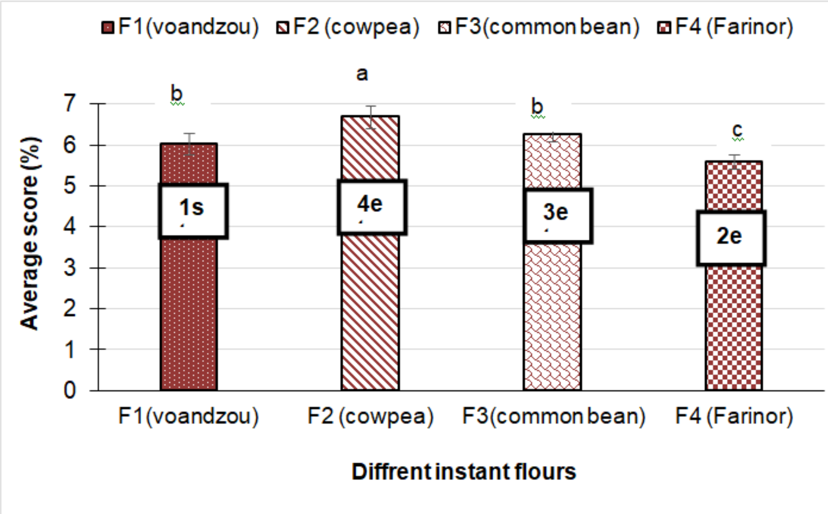

Fig. 3. Overall assessment of the various commercial and enriched legume-atadjon flours by the tasters and ranking

4. DISCUSSION

Flours prepared at home from local foods, generally starchy, are deficient in some essential nutrients [23]. In this context, local atadjon flours (a mixture of 2/3 Tiger Nut and 1/3 rice) whose porridges have a low protein density (05.37±0.04g/100g) and low energy density (95.70±0.12 Kcal/100g) [24] were enriched to 13% protein by adding maize, groundnut and mostly legume to formulate three instant flours enriched in voandzou (F1), cowpea (F2) and common bean (F3). The addition of roasted maize and groundnut paste to the different flours, as well as the pre-cooking of these flours, were carried out to significantly modify the viscosity of the porridges resulting from these formulations [25] and to contribute in terms of quality to the dietary diversity recommended for children aged 6 to 24 months.

The analysis of three instant atadjon flours enriched with voandzou F1, cowpea (F2) and common bean (F3) allowed to determine, both in qualitative and quantitative terms, the adequacy of the formulations to meet the recommended dietary needs in macronutrients, energy and essential amino acids in infants and young children.

Thus, the water content, which is an indicator of the flour's shelf life and possible microbial growth [24], was assessed. The moisture content of all samples of enriched atadjon instant flour was found to be within the Recommended Dietary Allowance (RDA) value (<5%) for infants and young children aged 6 months to 2 years [22]. Therefore, these instant flours of atadjon enriched with legumes would have a good conservation potential. It should also be noted that the low moisture content obtained is due to the combined drying (seed) and flour paste (oven) processes used to obtain these instant flours.

With regard to ash content (total minerals), the values of the three studied instant flours were in the range of the required dietary needs (less than 3%) for the recommended foods for children aged 6-24 months [22].

It has been widely demonstrated that sweetness is the most preferred flavour in infants and young children and that it positively stimulates their appetite [25]. Thus, the good sugar content of the three fortified atadjon formulations, especially the cowpea-fortified instant flour (F2), could modulate children's appetite by influencing their motivation to eat.

The fat content of the three atadjon enriched instant flours did not met the Recommended Daily Allowance for infants. However, they contribute 21% (F1), 19 (F3) and 18% (F2) of the total energy content of the flours.

With regard to energy value, the values recorded by three instant atadjon flours enriched with legumes were within the range of values required for the daily requirement recommended by [22] for infant foods (400-425 Kcal/100 g). The high energy level and protein content of the three instant atadjon flours enriched with legumes indicate that these flours are suitable as a complementary food for growing infants and young children. Several epidemiological surveys have shown that protein-energy malnutrition in children under 5 years of age is increasing in many developing countries due to poor complementary foods, which are low in energy, protein and vital micronutrients needed for normal growth and development of young children [26]. The adoption of these atadjon-enriched instant flours by Ivorian households could provide them with nutritionally sound infant flours.

The most significant effect of the legume fortification of the three native instant flours of atadjon was the improvement of the protein content to 13% as this indicates the good nutritional quality of these formulations [27]. They can therefore be used to prepare porridges in quantities that will provide children with sufficient energy and essential nutrients to complement milk. Thus, the three instant flours of atadjon enriched with voandzou (F1), cowpea (F2) and common bean (F3) could be recommended to mothers for the feeding of weaning-age children. Protein is a major source of amino acids and energy in times of energy deprivation. Adequate dietary protein intake is essential to maintain the function and integrity of cellular compartments and to normalise the health of infants and young children [28]. The adoption of these flours in the diet could therefore contribute to the prevention of protein-energy malnutrition, which is the most common form of malnutrition [28]. Especially since the ingredients are inexpensive, available and therefore accessible to all segments of the population.

Amino acid composition is one of the parameters for assessing the nutritional quality of a protein. The analysis of the amino acid profile of the three instant flours of Atadjon enriched with legumes has made it possible to highlight the presence of the nine essential amino acids (his, Ile, leu, lys, met, phe, thr, trp and val), thus underlining the good nutritional quality of the proteins in these formulations [29]. in fact, amino acids play a crucial role in the structure, the metabolism and physiology of the cells of all organisms, as constituents of proteins. As such, they constitute the bulk of the human body after water. Consequently, the presence of the nine amino acids that the organism of young children is unable to synthesise appears to be essential for the organism to achieve the desired nutritional balance [29]. In addition, the presence of lysine and tryptophan shows the interest of this formulation as these two essential amino acids are absent in cereals [30]. This fact is explained by the specificity of the amino acid composition of each component of the formulation (cereal, tuber, legume). Maize proteins are deficient in lysine and tryptophan but contain fairly large amounts of other amino acids such as sulphur amino acids. In contrast, legume proteins are relatively rich in lysine and tryptophan but poor in sulphur amino acids [31]. It should be noted that among the enriched instant atadjon flours studied, the voandzou-based F1 formulation has the highest content of eight of the nine essential amino acids detected; However, these three formulations have higher contents of these nine amino acids than the essential amino acids of the reference protein [22], thus meeting more than 100% of the recommended daily intake with a coverage of 159.97% for F1, 151.65% for F2 and 140.19% for F3. Therefore, these cereal- and legume-based infant flours, especially the voandzou-based one, could be used as an alternative source of protein and energy for infants.

Most cereals and legumes in the three atadjon formula enriched in voandzou (F1), cowpea (F2) and common bean (F3) naturally contain anti-nutritional factors, including fibre, tanins and oxalate that limit mineral bioavailability salt [32]. this is particularly worrying in young children, whose irreversible consequences may lead to stunting [33]. Therefore, the low tanin and oxalate contents compared to the contents observed in porridges from traditional atadjon preparations of 40.36 and 74.97 mg/100 g [11] would favour the integration of these enriched atadjon flours in the complementary diet of young children. Indeed, the low oxalate content is a major advantage because the uncomplexed bivalent elements will be bioavailable to these children. Similarly, low levels of tanins would limit the complexation of proteins, carbohydrates and other minerals, making them bioavailable [33].

Low fibre content in supplementary feeds is recommended to reduce gastric congestion and facilitate digestibility and absorption of nutrients. The low fibre content of these diets, below the limit of 5 g/100 g [22], would allow children to consume more food, giving them a greater chance of meeting their daily energy and other vital nutrient requirements. The low tannin, oxalate and fibre contents are due to the heat treatment during the production of the composite flour. Several authors have reported the value of treatments (physical, biochemical and thermal) to reduce and/or eliminate these anti-nutritional factors and to improve the digestibility of the feed [34]. Thus, these low levels of anti-nutritional factors recorded would prove the nutritional quality of the three composite flours studied.

In addition to the nutritional of infants' flours, their sensory quality was assassed, which is a necessary prerequisite for young children to receive food [35]. The overall acceptance of porridge indicated that the overall value of porridge varied. However, the instant porridge formulated with voandzou (F1) received the highest score for its smell end color.It should also be noted that observed differences in porridge appreciation may be significantly influenced by the degree of ingredient combinaison and product novelty.

5 CONCLUSION

This study made it possible to develop three instant flours based on tigernut/rice (atadjon) enriched with local food resources such as maize, groundnuts and, above all, legumes (voandzou, cowpeas and kidney beans). These instant flours with protein content of 13% meet WHO recommendations in terms of nutritional, anti-nutritional and organoleptic composition for the supplementation of infants. These three legume-enriched infant flours, with complete proteins including all nine essential amino acids, and endowed good lipid, carbohydrate contents and energy level, could therefore be recommended for infants in order to contribute to the reduction of child malnutrition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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