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Nutritional Evaluation and Sensory Description of Five Porridges Formulated from Certain Local Commodities for Use as Supplementary Foods for Children in Côte d'Ivoire

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Abstract **Original Research Article**

The aim of this work was to evaluate the nutritional, vitamin and sensory potential of porridges for infant feeding. Endeed, malnutrition in weaning infants and young children is a major public health and social problem in developing countries. It is therefore essential to develop appropriate complementary food formulations to address this problem. In this context, different flours have been developed from local raw materials (cereals and pulses) in combination with other ingredients. Five porridges, B1F, B2F, B3F, B4F and B5F were prepared from five flours formulated with several ingredients according to the PNN method. Biochemical, fonctional and nutritional analyses were carried out on the porridges obtained as well as hedonic tests. Results showed that these porridges are rich in proteins (15.93-22.36%) and lipids (19.93-26.80%), with an energy density above the recommended limit for porridges used as complementary foods. Due to their high viscosity (1.90 Pa/s), B1F and B5F porridges would be more suitable for young children. Porridges B1F, B2F and B3F were the most popular due to their sweet, milky flavour. Porridges B4F 449.4 ± 0.07µg/100g and B5F (628,00 ±1,00 µg/100g stand out for their high vitamin A content, while B2F (30.20) and B3F (34.10 mg/100g) have the highest vitamin E content.

Keywords: Malnutrition, Porridge, Complementary Foods, Maize, Soya, Peanut, Palm Oil.

INTRODUCTION

Child malnutrition is a major public health and social welfare problem in developing countries **(Gbogouri *et al.*, 2019**). It can result from over- or under-nutrition, leading to states of malnutrition or undernutrition such as acute malnutrition or wasting, chronic malnutrition or stunting, low body weight and micronutrient deficiencies (**Bengaly, 2010**). Women, children and adolescents are particularly vulnerable. In 2020, 149 millions children under the age of 5 will be stunted, while 45 millions will be wasted. This form of protein-energy malnutrition occurs mainly during the diversification phase of the diet. It is associated with the death of 50 % of children under 5 (**WHO, 2022**). After 6 months of age, the composition and quantity of breast milk are no longer adequate to meet the growing nutritional needs of infants (**Marcel *et al.*, 2022**). Therefore, it is essential to introduce new liquid or semi-liquid foods to supplement the diet provided by breast milk. This stage is crucial for infant growth, as inadequate introduction of complementary foods can lead to malnutrition, a major challenge in child health (**Victora *et al.*, (2016); Demmer *et al.*, (2018**) In developing countries, mothers mainly use traditional porridges made from simple or fermented local cereal flours (**Oumarou *et al.*, 2012**) to initiate the introduction of complementary foods at weaning. These products are characterized by high starch viscosity and apparent density but low quality protein and micronutrient content (**Doué *et al.*, 2021; Eke-Ejiofor *et al.*, 2021**). In Côte d'Ivoire, researchers have studied this issue and proposed a variety of safe and appropriate food combinations. As part of this initiative, various flours value characterised by high levels of protein and high energy value have been developed. These flours, made from basic raw materials (cereals and pulses) and combined with other ingredients, are intended to be used in the preparation of porridges with high nutritional and energy value. The aim is to diversify the product range by offering a wide range of products that meet the specific needs of these children. However, the porridges in these different formulations have not yet been characterised to determine their nutritional potential. It therefore seems appropriate to analyse the porridges based on the flours formulated, in order to highlight the nutritional potential of these semi-liquid preparations and to identify the appropriate composition of the mixtures to be prepared for an effective diversification of the food supply for infants and young children. The general objective of this work is therefore to evaluate the nutritional and sensory potential of five porridges prepared from formulated flours.

MATERIALS

The food material consisted of flours supplied by the Biotechnology Laboratory of the Félix Houphouët Boigny University, Côte d'Ivoire. The different flours used to prepare the porridges were formulated by combining the different ingredients in the proportions indicated in the table 1. These ingredients are made from widely available local raw materials, including two types of germinated cereals (maize and millet), two types of legumes (soya and peanuts), crude palm oil, and manufactured products as brown sugar, refined palm edible oil enriched with vitamin A, and whole milk powder purchased from a shopping center in the Abidjan district.

Table 1: Formulation model for the different flours used to make porridges

Ingredients (For 100g of food)	Food formulas				
	1F	**2F**	**3F**	**4F**	**5F**
Sprouted maize flour (g)	---	20	25	20	---
Sprouted millet flour (g)	30	10	---	---	25
Soybeans flour (g)	30	30	30	30	30
Peanuts paste (g)	---	---	--	15	10
Whole milk powder (g)	15	15	15	15	15
RPO (g)	18	15	20	---	---
UPO (g)	---	---	---	10	10
Sugar (g)	7	10	10	10	10

RPO: refined edible palm oil enriched with vitamin A; UPO: unrefined palm oil

METHODS

Procedure for Preparing Infant Porridges from Formulated Flours

To prepare each porridge, 50 g of each type of pre-formulated flour were mixed with 200 mL of drinking water and boiled for 5 minutes. After cooking, the indicated amounts of sugar, milk and oil were added.

Determination of the Biochemical and Nutritional Properties of the Different Porridges

Lipids were extracted by the Soxhlet method as described by **AFNOR (1986).** Proteins were quantified by the Kjeldahl method and dry matter and water content were determined by the **AOAC (1990)** method. The energy density of the porridges was calculated using the method described by **Laurent (1996)** by multiplying the dry matter content of the porridges by a factor of 4.25 kcal/100 mL of porridge.

Determination of the Vitamin Content

The levels of vitamins B1, A, D and E were determined according to the methods described by **Abidi (2000)**, using reversed-phase HPLC (Shimadzu SPD 20A) and UV detection.

The fat-soluble vitamins (A, E and D) were extracted according to the method described by **Jedlicka *et al*., (1992)** using a 10% KOH solution and ascorbic acid.

Determination of Mineral Content of the Different Porridges

The mineral content (calcium, potassium, magnesium, sodium, iron and zinc) was determined by atomic absorption spectrophotometry according to **AOAC 2016**.

Determination of the Viscosity of the Different Porridges

A BROO FIELD model DV-II + viscometer was used to determine the viscosity. The method consisted of inserting the No. 2 needle of the viscometer as a rod into each gruel and then shaking at a speed of 20 rpm for 10 min. After a stabilisation time of 5 min, the viscosity was read in CP (Centi Poise).

Determination of the Descriptive and Hedonic Characteristics of the Porridges

The descriptive and hedonic tests were carried out using the method described by Mohammad *et al*., (2014).

Statistical Analysis

Analyses were performed in triplicate and results are presented as mean ± standard deviation. Analysis of variance (ANOVA) was performed using SPSS version 20.0 software with Duncan's tests. Tables were generated with Windows Excel 2013. Principal Component Analysis (PCA) and Hierarchical Ascending Classification (HAC) were used to determine the differences between the different porridges.

RESULTS

Table 2 shows the biochemical and functional properties of the porridges. Statistical analysis reveals a significant difference in the various parameters studied for all the porridges prepared.

Regarding the moisture content, porridge B4F obtained the lowest value (73.45 ± 0.30%) and porridge B2F the highest (78.73 ± 0.22%). The dry matter content ranged from 21.27 ± 0.33% to 26.55 ± 0.90% for porridges B3F and B4F. The same trend was observed for the fat content, with the lowest content for porridge B2F (19.93 ± 0.11%) and the highest for porridge B4F (26.80 ± 0.00%). Porridge B4F had the highest protein content (22.36 ± 0.30%), the best energy density (106.18 ± 1.14%) and the lowest viscosity (0.5 ± 0.00 Pa/s). B1F had the lowest protein content (15.93 ± 0.35%) and the lowest energy density (84.54 ± 1.32%). B1F and B5F had the highest viscosities of about 1.9 Pa.s.

Table 2: Biochemical and functional properties of porridges

	B1F	B2F	B3F	B4F	B5F
Humidity %	77.53 ±0.10^{c}	78.73 ±0.22^{d}	78.53 ±0.39^{d}	73.45 ±0.30^{a}	74.91 ±0.06^{b}
Dry Matter %	22.47 ±0.10^{b}	21.27 ±0.22^{a}	21.47 ±0.33^{a}	26.55 ±0.90^{d}	25.09 ±0.06 ^{c}
Fat %	20.96 ±0.32^{a}	19.93 ±0.11^{a}	26.00 ±1.73^{b}	26.80 ±0.00^{c}	25.20 ±0.00^{b}
Protein %	15.93 ±0.35^{a}	19.94 ±0.48^{b}	16.10 ±0.2^{a}	22.36 ±0.30^{c}	20.06 ±0.11^{b}
E.D. (Kcal)	89.85 ±0.42^{b}	85.05 ±0.89^{a}	84.54 ±1.32^{a}	106.18 ±1.14^{d}	100.36 ±0.24^{c}
Viscosity (Pa/s)	1.90±0.01^{d}	0.70 ±0.01^{c}	0.60 ±0.00^{b}	0.50 ±0.00^{a}	1.90 ±0.06^{e}

E.D. : Energy Density The values shown in the table are the means ± standard deviations of trials carried out in triplicate. Within the same row, values with the same exponent do not differ significantly (P > 0.05).

Vitamin Levels in the Porridges

The levels of vitamins A, E, D and B1 in the porridges are shown in **Table 3**. Statistical analysis revealed a significant difference in the vitamin A content of the different porridges. It ranged from 197.7 ± 2 µg/100g (B2F) to 628.00 ± 1.00 µg/100g (B5F). Vitamin E levels were high in all porridges, ranging from 26.56 ± 0.51 mg/100g to 34.10 ± 0.6 mg/100g for porridges B5F and B3F respectively. With the exception of porridge B5F, all the others showed no significant difference in vitamin D content. The B2F porridge (1.00 ± 0.10 µg/100g) had the highest level, while B5F (0.70 ± 0.10 µg/100) had the lowest. As for the vitamin B1 levels in the porridges, the lowest content was observed in the B4F porridge (0.46 ± 0.01 mg/100 g) and the highest in the B5F porridge (0.78 ± 0.01 mg/100 g).

Table 3: Vitamins content of porridges

	B1F	B2F	B3F	B4F	B5F
Vit A (µg/100g)	235.93 ±1.46^{b}	197.7 ±2.00^{a}	245.06 ±0.75^{c}	449.4 ±0.07^{d}	628,00 ±1,00^{e}
Vit E (mg/100 g)	29.46 ±0.68^{b,c}	30.20 ±0.30^{c}	34.10 ± 0.6^{d}	26.7 ±0.85^{a}	26.56 ±0.51^{a}
Vit D (µg/100g)	0.86 ±0.05^{b}	1.00 ±0.10^{b}	0.96 ±0.05^{b}	0.86 ±0.15^{b}	0.70 ±0.10^{a}
Vit B1 (mg/100 g)	0.66 ±0.02^{d}	0.57 ±0.01^{c}	0.51 ±0.01^{b}	0.46 ±0.01^{a}	0.78 ±0.01^{e}

The values shown in the table are the means ± standard deviations of trials carried out in triplicate. Within the same row, values with the same exponent do not differ significantly (P > 0.05).

Mineral Content of the Different Porridges

A significant difference was observed in the mineral composition of the different porridges (table 4). Potassium is the micro-element most present in the porridges. Its content varied from 557.60 ± 0.6 mg/100 g to 779.9 ± 0.85 mg/100 g. Potassium is followed by calcium, whose concentration varies from 214.3 ±0.2 to 251.3 ±0.03 mg/100g. Magnesium comes third with B5F (219.8 ±0.10mg/100g) having the highest concentration, while B2F has the lowest (200.1 ±0.10bmg/100g). The total concentration of trace elements such as zinc and iron in the porridges studied ranged from 1.76±0.4 to 2±0.1mg/100g and from 5.06±0.3 to 6.56±0.1 respectively.

Table 4: Mineral content of porridges (mg/100g)

	B1F	B2F	B3F	B4F	B5F
Calcium	238.9 ±0.2^{d}	219.6 ±0.40^{b}	214.3 ±0.2^{a}	23.2 ±0.07^{c}	251.3 ±0.03^{e}
Potassium	668.3 ±0.68^{c}	606.20±0.30^{b}	557.60 ± 0.6^{a}	779.9 ±0.85^{e}	758.6 ±0.51^{d}
Magnésium	208.6 ±0.05^{b}	200.1 ±0.10^{b}	201.8 ±0.05^{b}	204.7 ±0.15^{b}	219.8 ±0.10^{a}
Sodium	4.2±0.3^{b}	3.86±0.2^{a}	5.9±0.1^{c}	33.06±0.3^{e}	31.3±0.05^{d}
iron	6.56±0.1^{e}	5.83±0.1^{c}	5.13±00^{b}	5.06±0.3^{a}	6.1±0.1^{d}
Zinc	1.8±0.2^{b}	1.76±0.4^{a}	2±0.1^{e}	1.83±0.02	1.93±0.05^{d}

The values shown in the table are the means ± standard deviations of trials carried out in triplicate. Within the same row, values with the same exponent do not differ significantly (P > 0.05).

Sensory Profile of the Different Porridges

The results of the sensory profile study of the different porridges are presented in Figure 1.

The porridge with the most pronounced colour was the one prepared from 2F flours (6.1). It also had the highest homogeneity score (7), while the B4F and B5F porridges had the best lipidity (6.3 and 6.4), granularity (5.6) and viscosity (7.1 and 6.3). The peanut flavour was well perceived in the B5F porridge (6.1) and the milk flavour in the B2F porridge (6.1). For oil, porridges made from 4F and 5F flours received the highest scores of 5.8 and 6.1 respectively. The B1F porridge was perceived as salty by the panelists, while the B4F porridge had a more pronounced sweet flavour. In terms of mouthfeel, B1F, B2F and B3F had the best scores, ranging from 5.0 ± 1.9 to 6.0 ± 1.8.

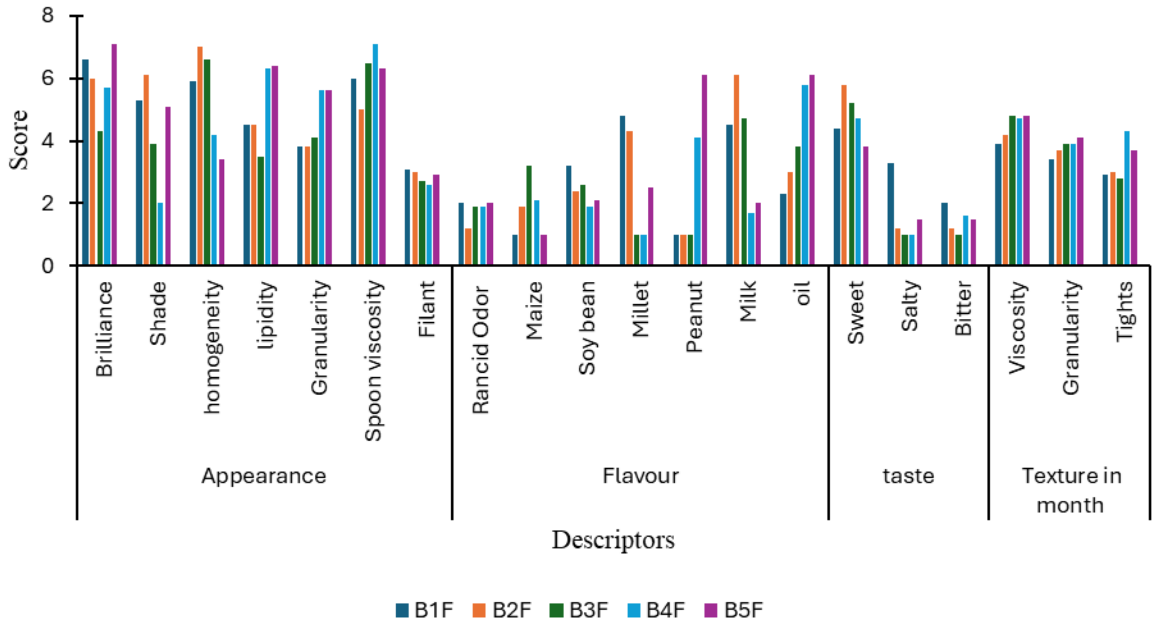

Figure 1: Sensory profile of porridges

The hedonic test scores for the porridges are shown in Table 4. The statistical analysis reveals a significant difference at the level of the different porridges ($P<0.05$) with respect to the defined descriptors. In general, all the sensory characteristics for each porridge were above 2.00. However, porridge B3F (porridge made with 3F flour) had higher organoleptic scores. It was followed by B2F and B1F porridges.

Table 4: Hedonic test results for porridges

Descriptors	B1F	B2F	B3F	B4F	B5F
Appearance	5.0 ± 1.8^{de}	$6.4 \pm 1.8^{f,g}$	6.9 ± 1.6^{g}	4.2 ± 1.9^{bcd}	3.6 ± 1.6^{bc}
Flavour	$4.9 \pm 1.8^{c,d}$	5.6 ± 2^{cd}	5.8 ± 2.2^{d}	3.5 ± 1.9^{b}	$3.4 \pm 1.5^{a,b}$
Taste	$5.2 \pm 1.8^{c,d}$	6.1 ± 1.6^{d}	6.1 ± 2^{d}	3.3 ± 1.7^{b}	3.1 ± 1.3^{b}
Texture in mouth	$5.0 \pm 1.9^{d,e}$	5.9 ± 1.6^{e}	6.0 ± 1.8^{e}	$3.5 \pm 1.8^{b,c}$	$3.6 \pm 1.8^{b,c}$
Acceptability Générale	5.5 ± 1.8^{c}	5.9 ± 1.8^{c}	6.4 ± 1.8^{c}	3.7 ± 2^{b}	3.8 ± 1.9^{b}

Principal component analysis revealed that the F1 axis accounted for 57.25% of the variation and enabled the B1F, B2F and B3F porridges to be distinguished from the B4F and B5F porridges. Axis F2, which accounts for 25.80% of the variation, was used to separate porridges B3F and B4F from porridges B1F, B2F and B5F. The B5F porridge is characterised by its iron, Ca, Mg and vitamin B1 content and its viscosity, while the B4F porridge is characterised by its vitamin A, protein, lipid, potassium and sodium content and its energy density.

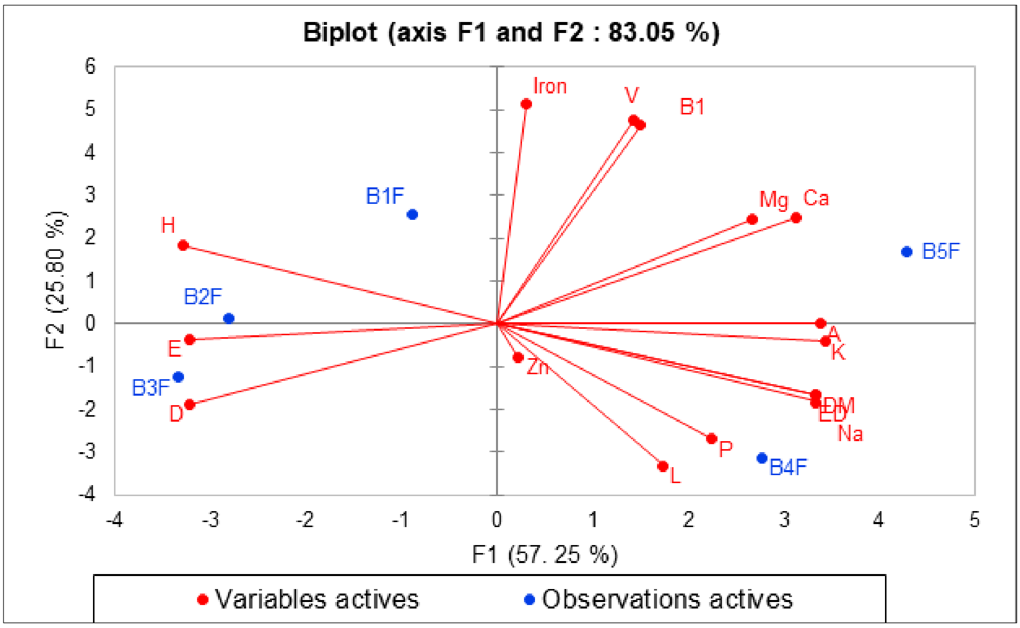

Figure 2

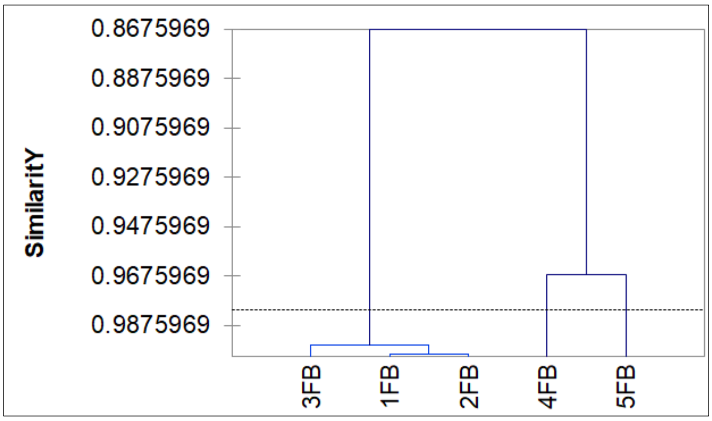

Figure 3

DISCUSSION

It is well known that porridges for infants must contain adequate quantities and quality of macronutrients and micronutrients, which are essential for balanced development. However, the proportions of these different components vary considerably depending on the ingredients used. The fat content of the mashes analysed is higher, due to the addition of refined and unrefined palm oil as an additional source of fat in the various preparations. These values are also higher than those found by **Gbogouri *et al.*, (2019)** for germinated maize-based baby flours enriched with soya or fish oil, and in line with the value recommended by **Codex (1991)** for complementary food preparations. excepted to the B2F porridge, all other porridges had a fat content higher than the RDA (Recommended Dietary Allowance of Vitamins and Other Nutrients) values (20 and 21.54%) (**Mamy *et al.*, (2020)**). Porridges made from formulated flours could be an effective means of nutritional rehabilitation for people suffering from protein-energy malnutrition. Lipids are a major contributor to improving energy value. They also provide essential fatty acids, promote the absorption of fat-soluble vitamins and improve the sensory quality of foods (**Nnam 2000**). The porridges obtained had high protein contents. They are higher than those (8.55 -16.12 g / 100 g) found by **Mayo *et al.*, (2022)** for porridges formulated from amaranth and locust flour. This high protein content could be explained by the inclusion of 30 g of soya flour in the different formulations. In fact, soya flour was used as the main source of protein in the present study due to its high protein content (around 40% according to **Synder *et al.*, 1987**) with good biological value, containing all essential amino acids as well as vitamins and minerals (**Artigot 2012**). Taking into account the protein intake recommended by the **Codex Alimentarius (1991)** (6-15% of total energy intake), the protein content of all the formulations is more than sufficient to cover the protein needs of the population, especially children and pregnant and lactating women (**OFSP, 2011**). These porridges could therefore offer additional benefits in the nutritional management of children diagnosed with moderate or even severe acute malnutrition. They could also lead to more rapid nutritional treatment. The porridges produced have high dry matter content and energy density with low viscosity. Similar energy density values were obtained by **Mamy *et al*., (2020)** for porridges based on composite flours. These high dry matter and energy densities combined with the low viscosity of the porridges could be explained by the use of germinated cereals in the production of the different porridge flours. During germination, the seeds release amylases that break down the starch (dextrinisation), thereby reducing the viscosity of the product and increasing its energy density (**Gnahé *et al*., 2009**). The work of **Kayode *et al*., (2007)** and **Elenga (2012)** reported that the incorporation of malt led to an increase in the dry matter and energy density of porridges. The same phenomenon was observed by **Zannou *et al*., (2011),** who used germinated maize flour as a source of alpha-amylase to increase the energy density of cassava and attiéké-based weaning porridges. According to **Trèche (1995),** porridges should have a viscosity of less than 1.5 Pa.s to be well tolerated by young children. However, it should be noted that B1F and B5F porridges have a viscosity of more than 1.5 Pa.s, while B2F, B3F and B4F have lower viscosities. These formulas are therefore more suitable for infants between 6 and 12 months and for infants over 12 months who are still bottle-fed. Furthermore, according to **Eyanga *et al*., (2018)**, porridges used to supplement breast milk should have an energy density greater than 60 Kcal/100 mL. Our porridges meet this recommendation well, as they all have an energy density greater than 60 Kcal/100 mL, with the highest values for B4F and B5F porridges. They are therefore good sources of energy for children and can compensate for deficiencies in the family diet. In addition, the amounts of vitamins E and B1 in the porridges would be sufficient to meet the daily requirement, estimated at 5 µg/d for vitamin E and 0.5 µg/d for vitamin B1 (**FAO/WHO, 2004**). This richness in vitamins E and B1 is beneficial for the body's well-being. Vitamin E plays an important role in the production of red blood cells, while vitamin B1 is crucial for the activity of enzymes involved in the synthesis of metabolic energy and contributes to the optimal functioning of the nervous system and blood production (**Elie, 2022**). For vitamin A, the B1F, B2F, B3F and especially B4F and B5F porridges could be used as a dietary supplement, as they can cover more than 60% of the daily requirement. Nutritional rehabilitation with these porridges would therefore be more beneficial, as they could help to correct the still-reversible damage caused by vitamin A deficiency and prevent it from reaching irreversible levels. The high vitamin content is thought to be due to the addition of vitamin-rich oil. Like all oils, crude and refined palm oil contains almost 100 % lipids in the form of triglycerides, and crude palm oil (red oil) is said to be the highest source of natural carotenoids (500 to 2000 mg/kg of crude oil) (**Lefèvre, 2015**). This crude oil contains 15 times more carotenoids than carrots and 300 times more than tomatoes. Among these carotenoids is β-carotene. This is converted into vitamin A in the body, making crude palm oil an excellent source of vitamin A (**Lecerf, 2012**). According to the United Nations regular consumption of crude palm oil limits blindness caused by vitamin A deficiency. It is also rich in vitamin E, with tocopherols (150 to 200 mg/kg of crude oil) and tocotrienols (up to 500 mg/kg of crude oil). These molecules are natural antioxidants because they limit the formation of free radicals (**Lecerf, 2012**). With regard to minerals, the porridges studied revealed higher levels of calcium, magnesium, potassium, sodium, iron and zinc than those reported by **Doué *et al*., (2021)** for tiger nut-based porridges consumed in the Bassam region. Overall, the mineral concentrations obtained were within the levels recommended by **FAO (2006).** These minerals are essential micronutrients because they play a crucial role in the optimal functioning of the body, actively participating in physiological and metabolic processes. They are even involved in the development of the body and the growth of children. They must be provided in very small amounts in the diet to stimulate cell growth and metabolism (**Oyewole and Asagbra, 2003).**

Principal Component Analysis (PCA) Analysis

At the level of the different porridges, the PCA test shows a better expression of vitamin A and proteins in the porridges made from 4F and 5F composite flours. This result is consistent with the different levels observed. The B4F and B5F porridges are therefore richer in protein and vitamin A. For the B1F, B3F and B2F porridges, their position in the factorial plane (close to the centre) does not allow an objective analysis of the possible relationships with the different parameters. Nevertheless, the bottom-up classification allowed all the porridges to be grouped according to their similarities. Thus, B1F, B2F and B3F porridges are closer to the standard data and would therefore be better adapted to the nutritional needs of people with moderate acute malnutrition.

Sensory Analysis

The descriptive test carried out on the porridges made with the improved flours made it possible to establish the sensory profile of each porridge. The B1F and B2F porridges are characterised by a very shiny and unctuous appearance, a dark beige, homogeneous and oily colour, a fairly intense milky and milky flavour and a sweet and slightly viscous taste in the mouth. B3F porridge is characterised by a fairly intense milky flavour, less pronounced oil, corn and soy flavours, a sweet taste and a homogeneous texture with a granular appearance. B4F porridge is characterised by a lacklustre, fatty, granular and viscous appearance, a smooth, granular and not very sticky texture in the mouth, a low sugar content and an intense oil and peanut flavour. B5F porridge is also characterised by an intense oil and peanut flavour, a rather granular and unctuous texture with little stickiness in the mouth, and a glossy, dark beige, fatty, granular and viscous appearance. The B1F, B2F and B3F porridges obtained the highest average scores and were statistically identical, which means that they were more appreciated by the tasters.

These averages are between 5.5 and 6.4, which corresponds to the pleasant level. These values are higher than those obtained by **Fogny *et al*., (2017)** for porridges made from fonio enriched with local food resources for supplementary feeding of young children in Benin (4.4-4.48). The tasters' preference for these porridges could be attributed to their sweet flavour and rather intense milky taste for 2F flours, but also to their low viscosity in the mouth. These flours are therefore more likely to be appreciated by children.

CONCLUSION

The aim of our study was to assess the nutritional, vitamin and sensory potential of porridges made from formulated flours produced in the laboratory, in order to determine their suitability for use as food supplements. Analysis of the results showed that the five porridges were rich in protein and lipids. They also had good energy density and were rich in micronutrients, vitamins (A, B1, D and E) and minerals (Na, K, Mg, Iron and Zn). Two porridges, B1F and B5F, have viscosities higher than 1.5 and are therefore more suitable for young children. Formulations B1F, B2F and B3F were the most appreciated during the sensory analysis due to their sweet and milky taste. B2F, B3F and B4F porridges are suitable for infants. The porridges obtained meet the recommended standards for food supplement porridges designed to fight against malnutrition.

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