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Technological, Nutritional and Organoleptic Characteristics of Six Formulations of Composite Flours Based on Sorghum Added or Not With Moringa Leaves Powder

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Abstract: Improving the nutritional status of the rural population requires the optimum use of available food. The objective of this study was to develop 06 formulations of composites flours based on sorghum, legumes (groundnut, *voandzou*, cowpea) added or not with moringa leaves powder used in the preparation of local food in rural households. To do this, the raw materials were cleaned, washed and dried before being ground. The groundnut and voandzou were specifically roasted and the cowpea was dehulled. Three formulations of composites flours composed of 65% of sorghum flour and 35% of legumes and three other formulations of composites flours composed of 70% of sorghum flour, 20% of legumes and 10% of moringa leaves powder were produced. The mixtures were ground, sieved and used to make "*tô*". The technological properties and the nutritional characteristics of the composites flours were determined using AOAC methods. The sensory analysis of *tô* was carried out by two panels composed of 60 researchers and students, men and women of the DTA/IRSAT. From the results, it was appeared that the mean values of the absorption capacity, the swelling capacity and the solubility index of the composites flours varied significantly ($P<0.05$) from 100.42% to 136.47%, from 6.01% to 12.97% and from 15.70% to 23.85% respectively. The contents of humidity, crude fat, crude proteins, total carbohydrates, ash and energy values varied significantly ($P<0.05$) from 5.32 to 7.43%, from 2.71 to 17.66g/100g DM, from 15.90 to 18.16/100g DM, from 65.49 to 79.87g/100g DM, from 1.25 to 2.55% g/100g DM and from 400.16 to 476.22Kcal/100g DM, respectively. All of the composites flours were accepted by the tasters.

Keywords: Composites Flours, Technological Ability, Nutritional Value, Sensorial

1. Introduction

Burkina Faso's diet is mainly composed of cereals and legume, which contribute to a protein intake of 41.4% and 23.5% respectively, and a food energy availability of 56.6% and 11.4% [1]. White sorghum, cowpea, voandzou and groundnut are among the most widely used crops in Burkina Faso and their production amounts were 467,998 tonnes, 707,994 tonnes, 58,435 tonnes and 396,129 tonnes respectively. They are generally processed into flour (semi-finished products) before used to produce traditional main food. Several uses of cereal flours in the form of food have been identified in the literature. These are dough (to) the research [2], porridges (*benkida*, *bensaalga* and other infant porridges) [7, 39], roasted products (*mougoudougou*) [3], steamed products (couscous, *bassi*, *déguè*), products cooked in water (*fourra*) [4], fried products (fritters) [2] and drinks (*zomkom*)

[5]. Legumes are eaten in the form of stews and food associated with cereals [6]. Most of the food prepared in households with simple cereal flour and consumed are low in protein [7]. Indeed, local cereals are poor in proteins, particularly in amino acids such as lysine [8]. The consumption of these kinds of foods is one of the causes of stunting observed in households in Burkina Faso. According to nutritional surveys in Burkina Faso, one child in four suffers from stunted growth (24.9%), with the highest prevalence in the Sahel (43.1%), Centre-North (29.8%) and North (28.9%) regions [9]. Several studies have evaluated the nutritional potential of cereal grains [10-12]. Sorghum carbohydrates represent 80% of the grain dry matter. It contains 7 to 16% protein, 3-4% lipids, 1.5 to 3% mineral content of the dry matter [13]. Whole cowpea grain contains 23-32% protein, 50-60% carbohydrates and less than 1% fat [14-15]. For whole grains of voandzou varieties, a study in Côte d'Ivoire found that the biochemical composition of 7 voandzou cultivars contains 14.61 to 20.74% protein, 54.05 to 64.50% carbohydrates, 7.22 to 8.55% lipids and 2.55 to 2.98% ash [16]. The whole fresh groundnut seed contains 44 to 56 g/100 g lipids [17], 15 g/100 g of carbohydrates [18-19], which can reach up to 27 g/100 g in some cultivars depending on the growing conditions [20], about 24 g/100 g total protein (N*5.46) [21]. The combination of cereals and legumes allows them to compensate each other's for amino acid and mineral deficiencies [22]. Many studies have shown that flours composed of grains and legumes have a high nutritional quality protein [23- 35]. The addition of a mineral source could balance the levels of certain minerals. A study in South Africa found that dried leaves contained a 30.3% of crude protein content, 19 amino acids and it was rich in calcium (3.65%), phosphorus (0.3%), magnesium (0.5%), potassium (1.5%), sodium (0.164%), sulfur (0.63%), zinc (13.03 mg/kg), copper (8.25%), manganese (86.8 mg/kg), iron (490 mg/kg), and selenium (363 mg/kg) [25]. The use of composite flours will contribute to improving the nutritional status of the population. The objective of the study was to determine the technological, nutritional and organoleptic characteristics of 6 formulations of composite flours that will be used in households for the preparation of local food.

2. Material and Methods

2.1. Vegetal Material

The cereal and legumes were obtained from the seed suppliers of the Association Minim-Song-Paaga (AMSP) of Kaya (Burkina Faso). The sorghum variety (*Sorghum bicolor* L) used, was the Kapelga variety. The groundnut (*Arachis hypogea* L.) and cowpea (*Vigna unguiculata* L) varieties are QH243C and KVX442C, respectively. As for voandzou, the local white variety was used.

2.2. Production of Composites Flours and tô

The flours were produced at the pilot workshop of the Food Technology Department of the Research institute in Applied Sciences and Technologies (IRSAT).

2.2.1. Pre-Treatment of Raw Materials

The sorghum grains were washed with potable water, dried and milled to flour. The flour was sifted. The groundnut seeds were sorted and then roasted and de-shelled. The voandzou seeds were sorted and roasted. They were finely ground into flour. Cowpea seeds were sorted, dehulled, washed and dried. They were finely ground into flour.

2.2.2. Formulation of Composite Flours

Six formulations of composite flours were developed following the FAO/WHO 2006 recommendations to cover the nutritional needs for protein, iron and zinc of young children from 3 to 12 years old and using the nutritional values of sorghum, cowpea, groundnut, and voanzdou extracted from the West Africa Composition Table in 2019. Thus, a good nutritional quality infant flour should contain at least 400 Kcal of energy, 15g of protein, 68g of carbohydrate, 8g of fat, 8.5mg of iron, 3.7mg of zinc, 2.9g of ash per 100g of dry matter. An estimate of 65% sorghum flour and 35% legume or 70% sorghum flour, 30% legume and 10% moringa was made to cover the total protein and energy requirements. After the different formulations, each mixture was ground and sieved. Table 1 shows the theoretical nutritional values of the different formulations.

Table 1. *Theoretical biochemical composition of the different formulations for 100g of dry matter of flours.*

Flour (100g DM)	Energy Kcal	Protein (g)	Lipids (g)	Carbo hydrates (g)	Iron (mg)	Zinc (mg)	Ash (g)
nutritional objective	400	15	8	68	8,5	3,7	2,9
sorghum	395,72	11,72	1,92	80,27	3,95	2,01	0,90
sorghum 65% groundnut 35%	477,45	17,02	19,04	57,63	5,19	2,60	1,47
sorghum 65% voandzou 35%	384,52	15,22	3,72	65,74	3,82	2,21	1,76
sorghum 65% cowpea 35%	385,82	16,52	1,78	71,66	4,07	2,26	1,63
sorghum 70% groundnut 20% moringa 10%	437,12	17,29	12,89	62,67	8,52	2,68	2,16
sorghum 70% voadzou 20% moringa 10%	382,28	15,92	3,33	65,75	7,62	2,41	2,27
sorghum 70% cowpea 20% moringa 10%	383,02	16,66	2,22	69,13	7,76	2,43	1,47

2.2.3. Preparation of the «Tô»

The preparation of the *tô* was carried out according to the description of Icard-Vernière and *al.* [2]. To prepare the *tô*, water is heated in a pot, usually made of metal, until it boils, with or without the addition of tamarind. A small part of the flour (about 1/3) is suspended in cold water to give a "flour milk". This flour milk is added to the boiling water while stirring until a light porridge of homogeneous consistency is obtained.

After cooking for about 10 minutes, part of the porridge is taken from the pot and put into a container. The remaining 2/3 of the flour is then added by dispersion to the slurry in the pot. The whole is mixed vigorously for about 15 minutes until it thickens. The slurry contained in the container is added progressively while continuing to mix and cook for about 15 to 30 minutes. When the dough becomes homogeneous and very thick, the tô is served in a dish with a wooden ladle.

2.3. Evaluation of the Technological Aptitude of Composite Flours

The technological analyses carried out consisted in the determination of the granulometry, the capacity of water absorption, the power of swelling and the index of solubility.

2.3.1. Granulometric Characterization

The particle size examination of a flour consists of determining the size of its particles and their respective weight proportions. It provides information on how the grain has been processed at the mill and essential on the extraction rate of the flour. The granulometry consisted in separating with a set of sieves the different granulometric fractions of the compound flours and to determine their proportions.

2.3.2. Water Absorption Capacity

The water absorption capacity (WAC) of flours was determined by the method modified by Phillips and *al.* [44]. The principle of the method is to show the amount of water in grams retained by 100 g of flour after saturation and centrifugation.

The swelling rate is determined gravimetrically as described in the protocol of Corke and Li [45].

2.3.3. The Solubility Index

It was determined according to the method of Corke and Li [45]. The solubility index is obtained by gravimetry.

2.4. Evaluation of the Physico-Chemical Characteristics of the Composites Flours

The physicochemical analysis of the composites flours consisted of the determination of the moisture, lipid, protein, carbohydrate, ash, energy value and mineral composition of the flours. The moisture, protein, lipid, carbohydrate, ash, and energy content of the composite flours were determined according to the AOAC (1990) method [46] in three trials.

2.4.1. Water Content

The water content of the samples was determined by differential weighing before and after oven drying at 130°C for 2 hours according to the French standard NF V 03-707: 2000 [26].

2.4.2. Fatty Acidity

The acidity of cereals is the quantity of free fatty acids extractable by 95% ethanol. It was determined according to the international standard ISO 7305 1998 [47].

2.4.3. Lipid Contents

The lipid contents of the samples were determined by the Soxhlet extraction method according to the international standard ISO 659: 1998[27] with hexane as solvent.

2.4.4. Total Protein Content

The total protein content was determined by the Kjeldahl method according to the French standard NF V03-050: 1970 [28].

2.4.5. Total Ash Contents

Ash contents were determined by incineration in a muffle furnace (Nabertherm®) at 550°C for 4 hours according to the international standard ISO 2171: 2007 [29].

2.4.6. Total Carbohydrate Contents

Total carbohydrate contents were determined by difference using the method of Egan and *al.* [30] according to the formula:

Total carbohydrate content (%) = 100-[water content (%) + protein content (%) + fat content (%) + ash content (%)].

2.4.7. Energy Values

The energy values of the supplementary feeds were calculated using the coefficients of Atwater and Benedict [31] according to the following formula:

Energy value (Kcal/100g) = carbohydrate content (%) × 4 (Kcal) + protein content (%) × 4 (Kcal) + fat content (%) × 9 (Kcal)

2.4.8. Determination of Iron and Zinc Content

Iron and zinc contents were determined by flame atomic absorption spectrometry according to the AOAC (2012) method [43]. Approximately 3 g of flour is weighed calcined at 550 °C for 10 hours in a muffle furnace. The ash is recovered and dissolved with concentrated hydrochloric acid and supplemented with deionized water.

2.5. Sensory Analysis

The sensory analysis was conducted at IRSAT/DTA (Ouagadougou, Burkina Faso) by two panels of 60 researchers and students. The control *tô* and the three sorghum and legume-based to were tasted by panel 1 on day 1. The control sample (*tô*) and the sorghum, legume and moringa tô were tasted by panel 2 on day 2. The characteristics of the two panels are presented in Table 2 below.

Table 2. *Socio-demographics of the tasting panels.*

Factors	variable	panel 1	panel 2
	effectif	30	30
sex	female	63,3	70
	male	36,7	30
Age	15 -30 years	73,3	83,3
	31 -40 years	16,7	13,3
	over 40 years	10	3,3
function	student	70	80
	researcher	30	20
religion	Christian	50,0	70,0
	Muslim	50,0	30,0

Three sensory tests were performed: the sensory profile, the hedonic test and the classification test. A tray composed of 4 bowls of different formulations of toddy with water was presented to the taster. A form was given to the taster to fill out. The coded samples were presented simultaneously to each panelist in a randomized order. The sensory profile of each sample was based on the appearance (color), taste (flavor), smell (aroma), consistency and hedonic test using a five-point hedonic scale (AFNOR, 2000).

2.6. Statistical Data Processing

The data was collected with Excel 2016. The variance analysis (ANOVA) was carried out with the XLSTAT 2016 software. The Turkey tests at the 5% threshold were performed for comparison of means when variance analysis revealed significant differences.

3. Results and Discussion

3.1. Technological Parameters of the Formulated Flours

Table 3 shows the Granulometry of flours.

Table 3. *Granulometry (%) of flours.*

Flours	710-1000 µm	500 µm	355 µm	250 µm	180 µm	125 µm	<125 µm
Sorghum 65% Voandzou 35%	100	98,2 ±0,28^{a}	46,4± 0,28^{d}	28,6± 0,00^{d}	26,6± 0,00^{b}	9,0 ±0,28^{a}	3,8± 0,28^{a}
sorghum 65% groundnut 35%	100	94,6± 0,28^{c}	49,8± 0,28^{c}	39,6± 0,28^{a}	21,8± 0,28^{c}	4,8± 0,57^{d}	2,8± 0,57^{b}
sorghum	100	98,8± 0,00^{a}	58,2± 0,00^{a}	39,4 ±0,28^{a}	15,6± 0,28^{d}	3,4± 0,28^{e}	2,2± 0,28^{c}
sorghum 70% voandzou 20% moringa 10%	100	93,6± 0,00^{d}	52,2± 0,00^{b}	36,6± 0,28^{c}	21,4± 0,28^{c}	7,8± 0,28^{b}	2,8 ±0,28^{b}
sorghum 65% cowpea 35%	100	95,6 ±0,57^{b}	44,0± 0,57^{e}	37,4± 0,57^{b}	29,4± 0,57^{a}	3,2 ±0,28^{e}	2,6 ±0,28^{bc}
sorghum 70% cowpea 20% moringa 10%	100	94,2± 0,28^{cd}	53,0± 0,28^{b}	23,4± 0,28^{f}	25,8± 0,28^{b}	4,6 ±0,28^{d}	2,6± 0,28^{bc}
sorghum 70% groundnut 20% moringa 10%	100	94,6± 0,28^{c}	43,6± 0,28^{e}	26,6± 0,57^{e}	13,8± 0,57^{e}	5,8± 0,28^{c}	2,2 ±0,28^{c}

The mean values of the same column with the same superscript letters are not significantly different at the 0.05 probability level

For a size of 500 µm, nearly 93 to 98% of the formulated flours passed through the mesh. The formulated flours therefore have a diameter of less than 0.5 mm. The comparison of the percentages of the sieves of less than 500 µm showed significant variations at the 5% threshold. Comparison of the sieve means of whole sorghum flour and voandzou -sorghum flour with those of sorghum 65% groundnut 35% and sorghum 70% groundnut 20% moringa 10% showed that the particle sizes were not significant at the 5% level. The particles of sorghum flour and Sorghum 65% Voandzou 35% composite flour had the same size and were smaller than the particles size of *sorghum 65% groundnut 35%* flour, sorghum groundnut moringa flour and sorghum cowpea moringa flour. There is a similarity in particle size between cowpea moringa and voandzou moringa sorghum flours. The granulometry of the flours being lower or equal to 0.5 corresponds to the Burkinabé standard on the infantile flours. According to the standard, a good flour requires a grain size between 1 mm and 0.5 mm in diameter.

Table 4 presents the technological characteristics of the different flours.

Table 4. *Technological parameters of flours.*

	WAC (%)	WSI (%)	SR (%)	FA (%)
sorghum 70% cowpea 20% moringa 10%	127,49±0,21^{b}	21,82±0,12^{bc}	11,41±0,01^{b}	0,34± 0,01b
sorghum 65% cowpea 35%	136,47 ±0,61^{a}	22,50±0,05^{b}	12,97±0,01^{a}	0,26± 0,00d
Sorghum 65% Voandzou 35%	124,37±0,00^{bc}	21,80±0,09^{bc}	11,55±0,06^{b}	0,26± 0,00d
sorghum 70% voadzou 20% moringa 10%	111,79±0,16^{d}	23,85±0,16^{a}	10,08±0,10^{c}	0,29± 0,00c
sorghum 70% groundnut 20% moringa 10%	100,42±0,02^{f}	15,70±0,28^{e}	6,01±0,01^{e}	0,40± 0,01a
sorghum 65% groundnut 35%	102,55±0,41^{e}	21,52±0,40^{c}	6,04±0,01^{e}	0,18± 0,00^{e}
sorghum	99,26±0,10^{e}	12,42±0,10^{f}	6,64±0,02^{e}	0,33± 0,00b

The mean values of the same column with the same superscript letters are not significantly different at the 0.05 probability level

WAC: Water Absorption Capacity; SR: Swelling Rate; WSI: Water Solubility Index, FA: Fatty Acidity

The water absorption capacity of the composite flours ranged from 100.42 to 136.47%. The highest water absorption capacity was observed in the *sorghum 65% cowpea 35%* flour and the lowest in the whole sorghum flour. The solubility index of the composite flours ranged from 15.70 to 23.85%. The high solubility index was observed in *sorghum 70% voadzou 20% moringa 10%* flour and the lowest in the whole sorghum flour. The water absorption capacities of the compound flours and the water solubility index being high and higher than that of the whole sorghum flour gives the flours the ability to be easily handled. Legumes and moringa increased the WAC. The WAC and WSI of the formulations were approximately equal to those found by Diallo [32] on wheat flours substituted by Voandzou flour from 5% to 20%. The water absorption capacity (WAC) of these flours ranged from 96.95% to 116.78%). As for the water solubility index (WSI), it ranged from 28.10% to 34.23 [32]. The physicochemical characteristics of the flours revealed that the titratable acidity measured varied from 0.18 to 0.34%. It was appeared from previously studies that the acidity of flours allowed to preserve flours against the attacks of microorganisms [33]. Thus, sorghum flours enriched with legume could be stored for a long time without risk of microbial alterations. The swelling rate of the composite flours was between 6.04 and 12.97%. The highest swelling rate was observed in the *sorghum 65% cowpea 35%* flour and the lowest in the *sorghum 65% groundnut 35%* flour. The fat acidity of the composite flours ranged from 0.18 to 0.34%. The highest fat acidity was observed in the *sorghum 70% cowpea 20% moringa 10%* composite flour and the lowest in the *sorghum 65% groundnut 35%* flour. Comparisons of water absorption capacities, solubility indices, swelling rates and fatty acidities showed significant variations (P<0.05) of the flours in each parameter.

However, the comparison between the different averages revealed that there is no significant difference between the water absorption capacity of whole sorghum flour and *sorghum 65% groundnut 35%* flour. Also 'there is no significant difference between the swelling rate of whole sorghum flour, *sorghum 65% groundnut 35%* flour and *sorghum 70% groundnut 20% moringa 10%* flour. As for fat acidity, there is no significant difference between *sorghum 65% cowpea 35%* flour and *Sorghum 65% Voandzou 35%* flour and also *sorghum 70% cowpea 20% moringa 10%* flour and sorghum whole flour.

3.2. Nutritional Characteristics of Compound Flours

Table 5 presents the content of the nutritional characteristics of flours.

Table 5. *Nutritional characteristics of flours.*

Composite flours	Humidity (%)	Ash (g/100g DM)	Lipid (g/100g DM)	Glucid (g/100g DM)	Protein (g/100g DM)	VAE (Kcal/100g DM)	Iron (mg/100g DM)	Zn (mg/100g DM)
sorghum 70% cowpea 20% moringa 10%	5.94± 0.19^{d}	1.34 ±0.04^{c}	5.27± 0.08^{d}	77.84 ±0.13^{c}	16.89± 0.05^{b}	430.63± 0.26^{d}	7.61±0.11^{a}	3.42±0.09^{b}
sorghum 65% cowpea 35%	6.63± 0.21^{c}	1.25 ±0.12^{c}	3.70± 0.01^{e}	79.87 ±0.21^{b}	16.44± 0.20^{b}	423.16± 0.26^{e}	2.54±0.06^{g}	3.92±0.03^{a}
Sorghum 65% Voandzou 35%	6.82 ±0.20^{bc}	1.19 ±0.00^{c}	5.96± 0.01^{c}	78.14± 0.19^{c}	15.90± 0.18^{c}	434.47± 0.24^{c}	1.98±0.15^{h}	2.55±0.02^{f}
sorghum 70% voadzou 20% moringa 10%	5.86± 0.17^{d}	2.36 ±0.28^{a}	4.72± 0.08^{d}	79.36± 0.16^{b}	15.92± 0.08^{c}	427.55± 0.29^{d}	6.59±0.20^{b}	2.58±0.02^{f}
sorghum 70% groundnut 20% moringa 10%	6.80 ±0.23^{bc}	2.48 ±0.23^{a}	14.21± 0.00^{b}	68.05± 0.13^{e}	17.75± 0.12^{a}	476.22± 0.13^{b}	5.91±0.08^{c}	3.03±0.02^{d}
sorghum 65% groundnut 35%	5.32± 0.06^{e}	1.78 ±0.15^{b}	17.66± 0.07^{a}	65.49± 0.23^{f}	16.85± 0.17^{b}	492.08± 0.32^{a}	5.55±0.09^{d}	4.03±0.01^{a}
sorghum	7.29± 0.08^{a}	1.48 ±0.07^{bc}	2.11± 0.76^{g}	87.24 ±1.21^{a}	10.65± 0.45^{d}	413.90± 4.00^{f}	4.12±0.06^{e}	2.61±0.02^{f}
FAO standards (FAO, 2006)	< 8	2.9	8	68	15	400	8.5	3.7

The mean values of the same column with the same superscript letters are not significantly different at the 0.05 probability level

The humidity of the composite flours varied significantly (P<0.05 from 5.32 to 6.82%. The highest moisture content was observed in the whole sorghum flour and the lowest in the *sorghum 65% groundnut 35%* flour. The moisture content of all the composite flours was satisfying. The Burkinabe standard indicating a moisture content of less than 8% for the flours. This rate allows a good conservation of the flours because it is lower than the limit value favorable to the development of micro-organisms on the food products (12%), in particular the development of moulds directly related to the moisture of the product [40]. In addition, the low moisture content of the flours increases their shelf life. These contents were similar to those found by the research [34]. On flours composed of rice, cowpea, soybean and groundnut. The water content of the latter of the flours ranged from 5.6% to 11.

The protein, lipid, carbohydrate and ash contents of the composite flours varied significantly (P<0.05) and ranged from 15.90 to 17.75 g/100gDM, from 3.70 to 17.66 g/100gDM, from 65.49 to 79.87 g/100gDM, and from 1.19 to 2.48 g/100gDM respectively. The highest protein contents were observed in *sorghum 70% groundnut 20 =% moringa 10%* flour, *sorghum 70% cowpea 20% moringa 10%* flour, *sorghum 65% groundnut 35%* flour and *sorghum 65% cowpea 35%* flour. The protein content of the flours is in accordance with the WHO recommendation to cover the needs of children and adults in the household. The incorporation of the legume resulted in at least 15.90 g/100gDM of protein. This finding is similar to that found by other studies on the formulation of composite flours in improving the nutritional quality of foods [34-36]. The protein content of flours used in households can have a positive impact on tissue repair and muscle building. They are therefore extremely important during the growth of children, pregnancy and the maintenance of adult cells. The highest lipid content was observed in the *sorghum 70% groundnut 20% moringa 10%* flour and the *sorghum 65% groundnut 35%* flour. The lowest protein and lipid content was observed in the control flour. The lipid content of the sorghum flours increased significantly with the addition of the legume and especially with the groundnut. It increased from 2.11 to 3.70, from 5.96 to 17.66 g/100gDM for cowpea, voandzou and groundnut respectively. The flours obtained with cowpea and voandzou presented a fat content below the FAO standards (8%) [41] and that obtained with groundnut is higher. This could be explained by the fact that cowpea and voandzou are not rich enough in lipid while groundnut has a high lipid content. These results corroborate those of [34] who showed that the lipid content of composites flours of rice-cowpea was less than 8%, while that composed of rice flour with groundnut and soybean was higher than the 8% standard recommended by codex alimentarius 2013. This high value was also obtained by Tounkara and collaborator who found that the flour composed of millet with cowpea and groundnut presented a lipid high content of 10.83±0.03 g/100gMS [36].

The highest ash content was observed in the *sorghum 70% groundnut 20% moringa 10%* flour and the *sorghum 70% voadzou 20% moringa 10%* flour. The lowest ash content was observed in the *Sorghum 65% Voandzou 35%* flour. Ash content is an indication of the mineral content in a food. The addition of moringa powder to sorghum and legume flour resulted in an increase in the ash content of the composites flours. These results corroborated those of Shiriki et collaborator in corn, soybean and groundnut flour fortified with Moringa oleifera [42]. As for carbohydrates, the highest levels were observed in whole sorghum flour and *sorghum 65% cowpea 35%* flour. The lowest carbohydrate content was observed in *sorghum 65% groundnut 35%* flour. The comparison of the lipid averages between the different flours reveals that there is no significant difference between the *sorghum 70% voadzou 20% moringa 10%* and *sorghum 70% cowpea 20% moringa 10%* flours. The comparison of carbohydrates contents between the different flours showed that there is no significant difference between *Sorghum 65% Voandzou 35%* flour and *sorghum 70% cowpea 20% moringa 10%* flours on the one hand and between *sorghum cowpea* flour and *sorghum 70% voadzou 20% moringa 10%* flour on the other hand. The comparison of proteins contents between the different flours revealed that there was no significant difference between *sorghum 65% cowpea 35%* flour, *sorghum 65% groundnut 35%* flour and *sorghum 70% cowpea 20% moringa 10%* flour on the one hand and between *sorghum 65% voandzou 35%* flour and *sorghum 70% voadzou 20% moringa 10%* flour on the other hand. The energy values of the composite flours varied significantly ($P<0.05$) between 423.16 and 422.08Kcal/100g DM. The highest energy value was found in *sorghum 65% groundnut 35%* flour and the lowest was found in whole sorghum flour. However, there is no significant difference between *sorghum 70% voadzou 20% moringa 10%* and *sorghum 70% cowpea 20%* moringa 10% flours.

The energy values of the composite flours cover the requirements recommended by the FAO for flours. These results are in agreement with those of [37] in maize (*Zea mays*) and safou *(Dacryodes edulis*) based composite flours produced in Côte d'Ivoire.

The iron and zinc contents of the flours were significantly different ($P<0.05$) and ranged from 1.98 to 7.61 mg/100g DM. The highest iron content was observed in *Sorghum 70% Groundnut 20%* moringa 10% flour, *sorghum 70% cowpea 20% moringa 10%* flour and *sorghum 70% voadzou 20% moringa 10%* flour and the lowest content was observed in *Sorghum 65% Voandzou 35%* flour. The Zn content ranged from 2.55 to 4.031 mg/100g DM. The highest zinc content was found in *sorghum 65% groundnut 35%* flour and *sorghum 65% cowpea 35%* flour, and the lowest in *Sorghum 65% Voandzou 35%* flour.

The iron and zinc contents of the flours enriched with legume and moringa were high, showing that the addition of moringa improved the iron and zinc contents. The presence of iron in composite flours is beneficial because iron is involved in the constitution of hemoglobin, myoglobin and many enzymes and limits the anemia of children and pregnant women [38]. These levels are similar to those found by [34, 36] on flours based on cereal, cowpea and groundnut. Zinc represents, with iron, one of the most concentrated minerals in the brain. Therefore, it is essential to cover the zinc needs of infants where brain growth is still important. Zinc is also involved in immunity because it reduces the incidence and severity of diarrhea in children [38]. Zinc limits children diarrheal diseases, the development of the body and in the growth of the child and could limit the occurrence of nutritional deficiencies.

3.3. Organoleptic Characteristics of the Flours

3.3.1. Sensory Profile of the Tô

The Figure 1 shows the sensory profiles of sorghum flour-based tô and sorghum -legume-based flours.

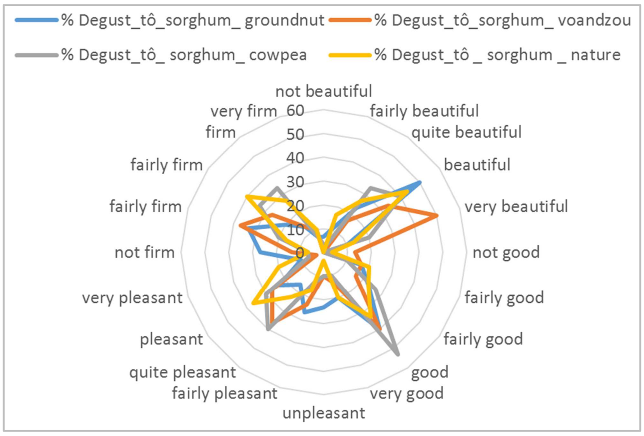

Figure 1. *Sensory profile of sorghum -legume based tô.*

% Degust_tô_sorghum_nature represents the% of tasters who appreciated tô prepared the natural sorghum *flour*
% Degust_tô_sorghum_groundnut represents the% of tasters who appreciated tô prepared from sorghum 65% groundnut 35% flour
% Degust_tô_sorghum_voandzou represents the% of tasters who appreciated tô prepared from sorghum 65% voandzou 35% flour
% Degust_tô_sorghum_cowpea represents the% of tasters who appreciated tô prepared from sorghum 65% cowpea 35% flour

The majority of the tasters found that the groundnut sorghum noodle presented a beautiful color, good aroma, pleasant taste and fairly firm texture by the majority of tasters. It was also found that the sorghum cowpea *tô* had a good color, good aroma, pleasant taste and firm texture.

The sorghum voandzou *tô* presented a very nice color, a good aroma, a pleasant taste and a fairly firm texture. The natural sorghum noodle has a beautiful color, a good aroma, a pleasant taste and a fairly firm texture. The Figure 2 presents the sensory profiles of sorghum flour-based tô and sorghum -legume-moringa composites flours.

The majority of the tasters judged: The sorghum -arachid-moringa tô had a beautiful color, good aroma, pleasant enough taste and fairly firm texture by the majority of tasters.

The sorghum -cowpea -moringa tô is of good color, good aroma, pleasant taste and fairly firm texture.

The sorghum -vandzou-moringa tô with a good color, good aroma, pleasant taste and firm texture.

Sorghum -nature toast with a very nice color, good aroma, pleasant taste and firm texture.

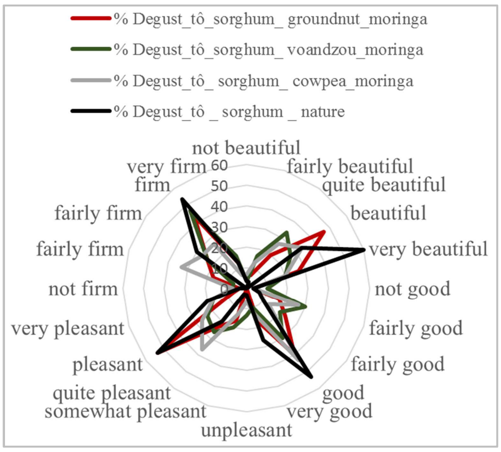

Figure 2. *Sensory profile of Sorghum - legume-moringa based tô.*

% Degust_tô_sorghum _nature represents the% of tasters who appreciated tô prepared the natural sorghum *flour*

% Degust_tô_sorghum _groundnut _moringa represents the% of tasters who appreciated tô prepared from sorghum 70% groundnut 20% moringa 10% flour

% Degust_tô_sorghum _voandzou _moringa represents the% of tasters who appreciated tô prepared from sorghum 70% voandzou 20% moringa 10% flour

% Degust_tô_sorghum _cowpea _moringa represents the% of tasters who appreciated tô prepared from sorghum 70% cowpea 20% moringa 10% flour

3.3.2. Hedonic Preference and the Ranking of the Tô of Compound Flours

Figure 3 presents the hedonic appreciations and classification of sorghum flour-based and sorghum -legume-based to.

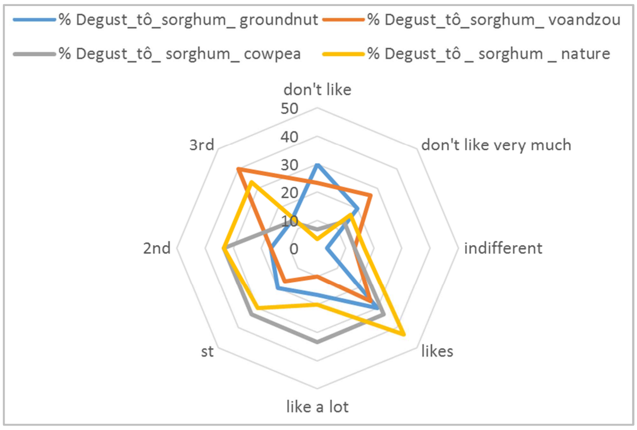

Figure 3. *Preference and classification of sorghum -legume based tô.*

It was found that the majority of tasters liked all the tô. The cowpea sorghum tô was ranked 1st, the whole sorghum tô was ranked 2nd, the voandzou sorghum tô was ranked 3rd, and the sorghum groundnut tô was ranked 4th.

Figure 4 illustrates the tasters' preference results for sorghum -legume-moringa -based tô.

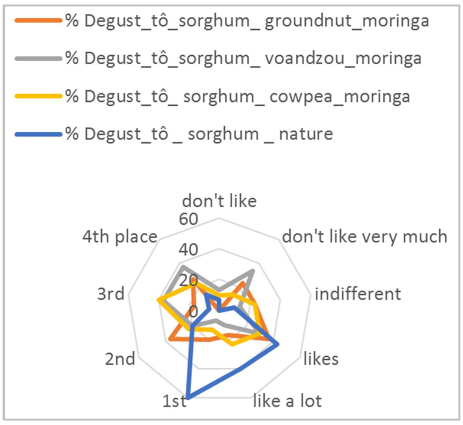

Figure 4. *Preference and classification of sorghum -legume-moringa based tô.*

It was found that the majority of tasters liked all the tô. The whole sorghum tô was ranked 1st, the groundnut moringa tô was ranked 2nd, the cowpea moringa tô was ranked 3rd and the voandzou moringa tô was ranked 4th.

A change in sensory profile is felt. The addition of legumes with or without moringa negatively modified the appreciation of the texture and color of the tô samples. These results corroborate those of Hama et al. on the acceptability of couscous made with three composites flours formulations enriched with soybean (Glycine max) and moringa (Moringa oleifera), who found that color tests performed on cooked couscous revealed a preference for the control couscous [35].

4. Conclusion

Composites flours fully cover the protein and carbohydrate needs of children aged 3 to 12 years. Moringa has contributed to increase significantly the iron and zinc content in the flours and cover more than ¾ of the iron and zinc needs. The addition of legumes to improves the taste of the composites flours. Moringa and groundnut changed the color and texture of sorghum flour. Promotion of the use of these flours could be done in households or among processors to increase the use of these flours in order to balance the rations in households that consume highly cereal-based foods.

The authors have declared that there are no conflicts of interest in the manuscript.

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