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RESEARCH ARTICLE

ASSESSMENT OF AMINO ACID, VITAMIN, FUNCTIONAL AND ANTIOXIDANT PROPERTIES IN A LEGUME-CEREAL BASED COMPLEMENTARY BLEND

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Abstract

This study assessed the nutritional quality of flour made from roasted corn, roasted soybeans and roasted groundnuts. Functional, antioxidant properties, vitamin and amino acids profiles were assessed. This composite roasted corn flour is an important source of vitamins with vitamins B9 (39.91 ± 0.87 μg), C (30.86 ± 0.01 $\text{mg}/100\text{g}$) and E (27.82 ± 0.01 $\text{mg}/100\text{g}$) recording the higher content. Likewise, the analysis reveals the presence of essential amino acids with high content in lysine (26.32 ± 0.29 $\text{g}/100$ g), tryptophan (17.22 ± 0.29 $\text{g}/100$ g) and leucine (20.17 ± 0.01 $\text{g}/100$ g). In addition, this composite roasted corn flour exhibited interesting polyphenol (198.04 ± 3.31 $\text{mg EGA}/100$ g) and flavonoid (55.29 ± 0.37 $\text{mg EQ}/100$ g) contents and an antioxidant activity (DPPH) of 62.36 ± 2.50 %. Finally, the studied corn flour recorded interesting functional properties such as water absorption capacity (295.61 ± 3.15 %), water solubility index (35.63 ± 0.50 %), apparent density (0.71 ± 0.02 g/mL), porosity (40.30 ± 0.52 %) and wettability (4.10 ± 0.1 %) respectively. Flour made from roasted corn could be used to produce nutritious food for infant in complement of breastmilk.

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Introduction:-

Access to safe, nutritious and sufficient food must be considered a human right. According to FAO, (2015) malnutrition is an abnormal physiological condition due to inadequate and unbalanced intake by excess or deficiency of nutrients. These nutrients, divided into macronutrients (carbohydrates, proteins and fats) and micronutrients (vitamins and minerals), provide energy and are essential for physical, cognitive growth and development of body. FAO's report on food security and nutrition indicates that the number of undernourished people in the world is steadily increasing from 804 million (2014) to 821 million in 2017 (FAO, 2018). Malnutrition is therefore a public health problem worldwide and particularly in developing countries (Tou, 2007). Africa remains the continent with the highest prevalence of undernourishment, affecting almost 21 % of the population, more than 256 million people (FAO, 2018).

Children under five and pregnant women are the most affected group of the population by this scourge because of their great susceptibility to vitamin and mineral deficiency due to growth demand and reproduction, respectively. Indeed, malnutrition contributes to 35 % of deaths of children under five in West and Center Africa (FAO, 2015). Malnutrition usually appears during the period corresponding to the introduction of complementary food in infants (Dewey and Brown, 2003). This largely interferes with the growth, physiology development of infant according

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to FAO, (2018). The causes are multiples but the main one is related to the poverty of the populations of these developing countries. Due to this high level of poverty, many families cannot afford to buy commercial complementary foods, so children are weaned with starchy, macro- and micronutrient-poor foods that induce a critical nutritional state at the weaning stage.

In Côte d'Ivoire, most complementary foods are prepared from local foods, including starchy products such as cereals and tubers, which are clearly insufficient from a nutritional point of view for some macro and micronutrients (Nnam, 2001). This leads to the implementation of complementary foods and adequate feeding practices that are essential for the body's growth and development (FAO, 2018). Indeed, complementary foods are the combination of different nutritional and functional foods rich mainly in proteins, fats, vitamins and minerals obtained from cereals and other source products (Obasi et al., 2018).

Previous work on nutritional assessment of a 5-5% soybean and peanut fortified corn meal in young Wistar rats has shown a good nutritional status and improved growth. No anomalies in the regulatory bodies were observed. In the biometric study, no abnormalities were observed in the regulatory organs, namely the kidneys, liver, heart and spleen, compared to the control regime (Rougbo et al., 2018). Furthermore, a comparative study between this improved roasted meal and its traditional roasted corn flour counterpart highlighted its great richness in basic nutrients compounds such as carbohydrates, lipids, proteins, minerals and its low content in anti-nutrient compounds (Rougbo et al., 2019).

Protein quality of corn can be improved by blending it with legumes especially soybean and groundnut (Ajanaku et al., 2012). They are one of the few plants which provide high quality protein with minimum saturated fat. Soybean helps people feel better and live longer with an enhanced quality of life. Soybean provides all the essential amino acids in sufficient quantity for human health. Almost 40 per cent of the calories from soybean are derived from protein. The 1991's FAO/WHO protein evaluation committee classify soy protein on par with egg and milk protein and ahead of beef protein. Several published reports have centred on improving the nutritional values of corn food through enrichment most especially with protein rich substances to boost limiting amino acids (Ajanaku et al., 2012), vitaminic profile and functional property. Thereby, in-depth studies should be carried out on the intrinsic qualities of this blended food to ensure that this enriched formulation with protein rich substances boost limiting amino in corn, improves vitamin profile, functional and antioxidant properties necessary for a balanced diet and maintaining the health of the consumer. The purpose of this study is to highlight the nutritional potential of this formulation through evaluation of dependent variables such as amino acid, vitamin profiles, functional and antioxidant properties.

Materials and Methods:-

Procurement of raw materials:

Corn kernels (*Zea mays*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea* L.) used in this study were procured from the wholesale market of Adjamé (5°29'17" north, 4°01'56" west), a local market of Abidjan (Côte d'Ivoire).

Preparation of the different flours:

Preparation of roasted corn flour:

Corn kernels were cleaned and sorted by hand before being grilled at 120 °C for 20 min in a MEMMERT ventilated oven. The roasted corn kernels were milled in a heavy duty speed blender. The powder obtained (ground) was screened with a 250 µm mesh sizes to obtain a fine flour of roasted corn. The flour produced was stored at 4 °C, in hermetically sealed boxes, for the further use (Figure 1).

Preparation of roasted soy flour:

The Roasted soy flour was obtained from soya beans, previously cleaned and sorted by hand, then roasted at 120 °C for 20 min, in a ventilated MEMMERT oven. The beans were milled using a heavy duty speed blender, the ground product obtained was then sieved with a 250 µm mesh sizes. The flour produced was stored at 4 °C, in hermetically sealed boxes, for further use (Figure 1).

Preparation of roasted groundnut flour:

The roasted groundnut flour was obtained from the peanut seeds previously stripped and then dried in a ventilated oven type MEMMERT at 80 °C for 24 h. The grains were removed from the oven and crushed in a heavy duty

speed blender. The ground material obtained was then screened with a 250 μm mesh sizes sieves. The flour produced was stored at 4 °C, in hermetically sealed boxes, for further use (Figure 1).

Formulation of composite roasted corn flour:

The 100-5-5% corn-soya-peanut flour formulation retained after an hedonic test (data not shown) was used to prepare the composite flour from the previously prepared flours. Composite flour samples were blended properly, packed in sealed bags and stored till further analysis (Figure 1).

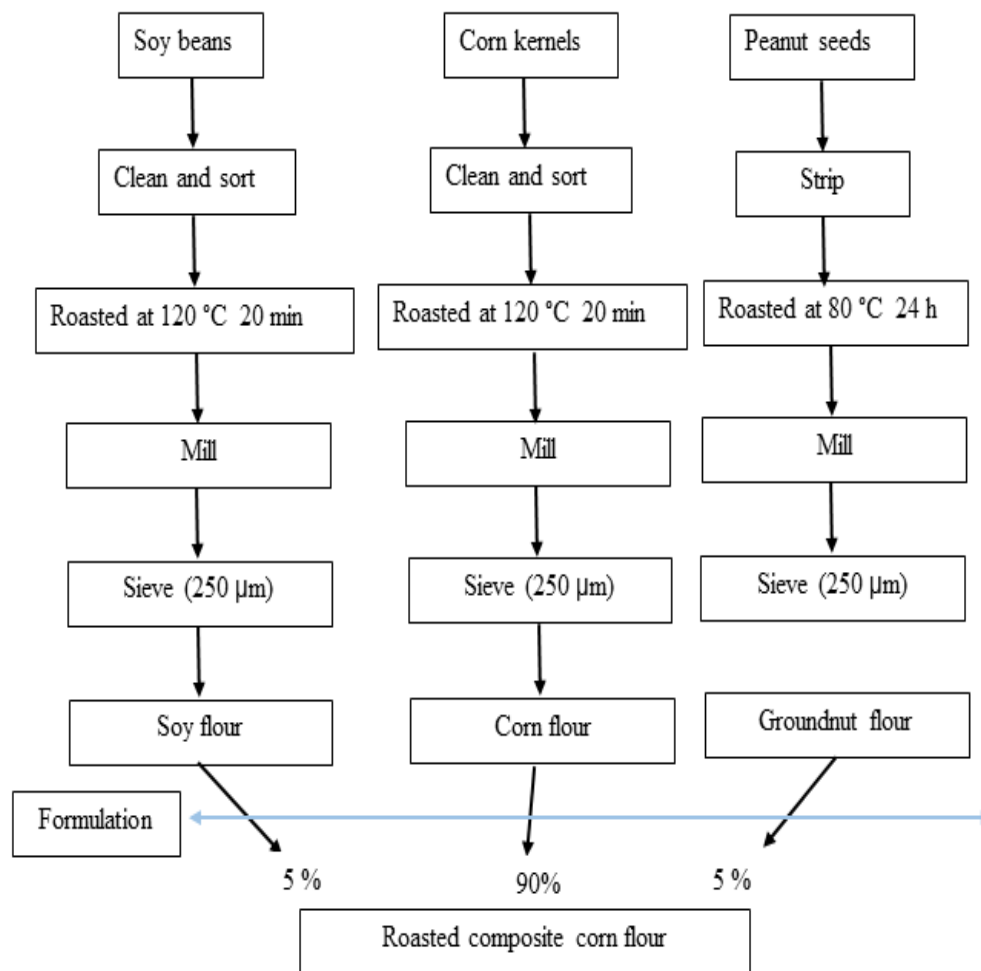


Figure 1:- Process flowchart on the preparation of flours.

Nutritional profile:

Determination of Vitamin content:

Vitamin determination was performed using a SHIMADZU SPD 20A model with a PAD detector, a C18 ODS Column, 250 x 4.6 from Cluzeau France with isocratic mode (Acetonitrile: 55 mL, tetrahydrofuran 37 mL and water: 8 mL); mobile phase flow (1.5 mL); wavelength and detection (325 nm).

One (1g) of sample was weighed and transferred into a 100 mL beaker protected from light with aluminum foil. 20 mL of methanol are then added and the resulting solution was stirred with a bar magnet for 2 h 30 min at room temperature. The methanol was extracted by filtration and quantitatively placed in a 25 mL flask to form the test solutions. Standard solution of 0.01 $\mu\text{g} / \mu\text{L}$ of vitamin A; 0.05 $\mu\text{g} / \mu\text{L}$, 0.1 $\mu\text{g} / \mu\text{L}$ of thiamine; 0.144 $\mu\text{g} / \mu\text{L}$ of riboflavin; 0.151 $\mu\text{g} / \mu\text{L}$ of pyridoxine and 0.072 $\mu\text{g} / \mu\text{L}$ of folic acid were immediately prepared by simple dilution in methanol to constitute the control solution.

Determination of amino acid profile:

The amino acid composition of the sample was determined according to the method of Kaga et al., (2002). This analysis was performed using the High Performance Liquid Chromatography (Water Alliance model e2695) with an automatic 48-sample collection system and a p2895 pump system.

5 g of sample were added in 10 mL of 0.2N sodium citrate buffer, pH 2.3. Then 10 mL of 6N hydrochloric acid was added to the whole and the mixture was heated at 110 °C for 24 h to hydrolyze the sample proteins. After evaporation of the hydrochloric acid, 10 mL of 70 % ethanol was added to the sample and the mixture was filtered before injection on the HPLC. Enfin, 5 to 10 µL of the filtrat was loaded into the cartridge of HPLC. Detection of amino acids was done using a Waters 247 spectrofluorometer, at the wavelength of 340 nm and the signals were magnified and traced on a two pen recorder using a linear chart to develop a chromatograph. The area under the peak was calculated as the concentration of each amino acid.

Functional properties:**Determination of wettability:**

The method described by Onwuka (2005) was adopted. One (1g) of roasted corn flour was placed in a 25 mL measuring cylinder with a diameter of 1 cm. The cylinder was inverted at 10 cm above the water contained in 600 mL beaker. The finger was used to close the cylinder disallowing the flour sample from falling. By removing the finger and giving the cylinder a gentle tap, the flour sample was discharged into the water surface. Remove finger and pour contents into beaker. The time taken by the sample to get completely wet was recorded as the time of wettability.

Determination of water absorption capacity (WAC) and water solubility index (WSI):

Water absorption capacity is the ability of flour to absorb and retain water. Water absorption capacity (WAC) and water solubility index were determined using the method described by Phillips et al., (1988). One (1) g of flour (M0) was weighed and dissolved in 10 mL of distilled water contained in a centrifuge tube. The mixture was stirred for 30 min by a stirrer and held in a water bath at 37 °C for 30 min. Then, the mixture was centrifuge at 4200 rpm for 12 min (Ditton LAB centrifuge, UK). The resulting sediment (M1) was weighed and then dried at 105 °C to constant weight (M2).

The WAC was then calculated as follows: $WAC (\%) = (M2-M1) / M2 \times 100$

While the WSI was calculated using the following equation: $WSI (\%) = (M0-M1) / M0 \times 100$

Determination of oil absorption capacity (OAC):

For the oil absorption capacity, the method described by Eke and Akobundu, (1993) was used. One (1) g of flour (M0) is weighed and dissolved in 10 mL of oil. The mixture was then stirred for 30 min at room temperature using a magnetic stirrer and centrifuged at 4000 rpm for 10 min. The pellet was recovered and the mass was recorded (M1). The experience has been repeated for different qualities of oils.

$OAC (\%) = (M1-M0) / M0 \times 100$

Determination of emulsion capacity:

The emulsion (EC) capacity of the compound flours was determined according to the slightly modified Beuchat (1977) method. Two (2) g of flour were dispersed in 50 mL of distilled water contained in an Erlenmeyer. The mixture was homogenized with a magnetic stirrer for twenty (20) min. The suspension was transferred to a centrifuge tube and 10 mL of oil (V0) was added. This mixture has been stirred continuously for 5 min, then heated in a water bath for 15 min at 85 °C. The tube is removed and cooled at room temperature (25 °C) for 5 min and centrifuged at 4500 rpm until the volume of oil (V1) separated from the emulsion (V2) becomes constant. The results are expressed as a percentage of emulsified oil / gram of composite corn flour used.

$EC (\%) = VE \times 100 / V \times W$

Where: W = weight of sample

VE = Volume of emulsion layer E

V = Total volume of mixture

Bulk density (BD) and Porosity (P) Measurement:

Bulk density and Porosity were determined using the method described by Narayana and Narasinga (1982). Fifty (50) g sample (ME) were weighed and placed in a 100 mL volumetric cylinder and the sample on the the cylinder

was holding on a vortex vibrator for 1 min to obtain a constant volume of the sample. The bulk density value was calculated as the ratio of mass of the flour and the volume occupied in the cylinder (Vt).

$$BD \text{ (g/mL)} = ME / Vt$$

Porosity was calculated as the ratio between the difference on the initial volume (V0) and the final volume (Vt) and the initial volume (V0) $P = (V0 - Vt) / V0$

Anti-oxdyant properties:

Preparation of methanolic extracts:

Phenolic compounds were extracted with methanol by the Singleton et al. (1999) method.

One gram (1) g of flour of this composed roasted corn was homogenized in 10 mL of 70 % methanol. The resulting mixture was centrifuged at 1000 rpm for 10 min. The pellet was recovered in 10 mL of 70 % methanol and centrifuged again under the same conditions. The supernatants were collected in a 50 mL vial and adjusted with distilled water to the mark. The resulting solution is called methanolic extract.

Determination of total phenols content (TPC):

TPC was determined by the method of Singleton et al., 1999, with slight modifications. Methanolic extract previously obtain (1 mL) was mixed with 1 mL of Folin-ciocalteus reagent (1 mol). The tube was left to stand for 3 min then the mixed was neutralised with 1 mL of 20% (w/v) saturated sodium carbonate solution. The tube was then filled to 10 mL with distilled water and placed in the dark for 30 min. The optical density reading was taken at 725 nm against a control. A standard range established from a gallic acid stock solution (1mg/mL), under the same conditions as the test determined the amount of polyphenol in the sample. TPC was expressed as gallic acid equivalents (mg GAE/g dry weight).

Determination of flavonoids content (FC):

The determination of flavonoids content was performed according to the method described by Meda et al. (2005). The methanolic extract (0.5 mL) previously obtain was added to a test tube. Then 0.5 mL aluminum chloride (10% w/v), 0.5 mL of sodium acetate (1M) and 2 mL of distilled water were added successively to the sample extract. The mixture was left to stand for thirty (30) min in the dark and the spectrophotometer absorbance reading was taken at 415 nm against the control. A calibration range was performed from a 0.1 mg/mL quercetin stock solution.

Evaluation of the ability to trap the DPPH radical:

This activity was determined using the method of Mensor et al. (2001). Two (2) mL of the methanolic extract or standard (ascorbic acid and α -tocopherol) at a concentration of 2 mg / mL were added to 1 mL of DPPH methanolic solution (0.3 mM). The mixture was shaken and kept at room temperature (30 ± 1 °C), away from light for 30 min. The blank of each solution was prepared by combining 2 mL methanolic extract and 1 mL methanol without DPPH. However, 1 mL methanolic DPPH and 2 mL methanol are used as controls. The absorbances of the solutions obtained were measured at 517 nm, using a spectrophotometer. The percentage inhibition of DPPH was calculated according to the equation:

$$DDPH \text{ radical (\%)} = [(1 - \text{sample absorbance} / \text{absorbance of check})] \times 100$$

Evaluation of flour reducing properties:

The reducing power of flour was determined according to the Oyaizu (1986) method.

A volume (0.3 mL) of the methanolic extract from the sample, potassium ferrocyanide (1 %) and sodium phosphate buffer (pH 7; 0.20 M) were carefully mixed. Then the mixture was incubated at 50 °C for 20 min, then 0.3 mL trichloroacetic acid (10%) was added. The mixture was centrifuged at 6000 rpm at 4 °C for 10 min. 0.6 mL of the supernatant was mixed with 0.12 mL iron chloride III hexahydrate (0.1%) and 0.6 mL deionized water. After 10 min, the absorbance of the mixture was measured at 700 nm. A high level of absorbance of the mixture would indicate greater reducing activity.

Data Analysis:

Data collected for functional property particularly Oil absorption capacity were subjected to one way Analysis of variance (ANOVA $p < 0.05$) using SPSS 11.0 software. Means with significant differences were separated by Turkey test

Results and Discussion:-**Nutritional profile:**

Development and use of nutritious complementary foods from available and affordable food commodities, is one approach that is being encouraged as part of effort to reduce morbidity and mortality in children. Preparation and use of home-based foods have been observed to be deficient in some essential nutrients (Ladeji et al., 2000). Analysis of the composite roasted corn flour afforded to determine both in qualitative and quantitative terms, the adequacy of the blend to meet the recommended dietary requirement for essential amino acids and vitamins in infants and young children.

The quantity and quality of protein is an important consideration in infant and child nutrition as both are required for optimal growth and development. The mean essential amino acids of the studied roasted composite corn flour (Figure 2) detected are lysine, Tryptophane, Phenylamine, Threonine, Isoleucine, Valine and Leucine.

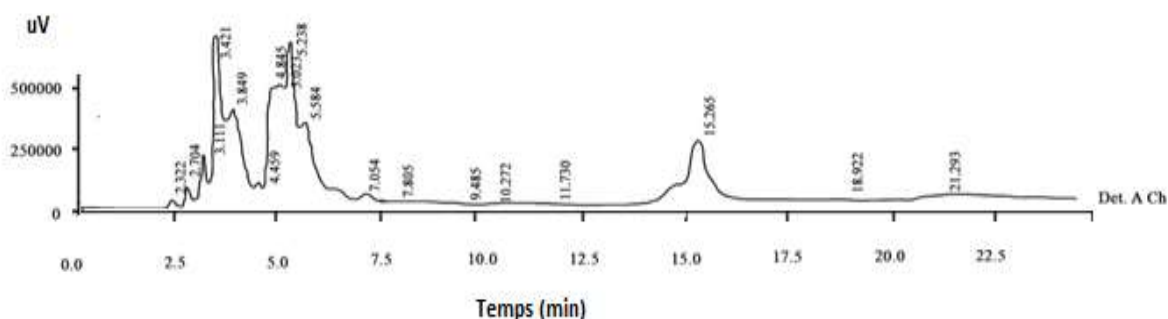


Figure 2:- Chromatogram profile of amino acids of the composite roasted corn flour.

Retention time of the main essential amino acids (min.): 2.322: Threonine; 2.704: Valine; 3.421: isoleucine; 5.023: phenylalanine; 15.265: Leucine; 21.293: Lysine; 5.584: Tryptophane

The presence of lysine and tryptophan shows the interest of this formulation insofar as these two essential amino acids are absent in corn (FAO, 1993). This fact is explained by the specificity of amino acid composition of each component (corn, soy and groundnut). Corn proteins are deficient in lysine and tryptophan but contain fairly large amounts of other amino acids such as sulfur amino acids. In contrast, legume proteins are relatively rich in lysine and tryptophan but poor in sulfur amino acids (Bressani and Elías, 1974).

As for protein quantity, Rougbo et al., 2019 shown that the composite roasted corn flour exhibit higher level of protein (19.66%) compared to its traditional roasted corn flour counterpart ($10.00 \pm 0.02\%$). Protein quantity is a function of the amino acids presents. Essential amino acids which can only be provided in the diet must be adequate for normal protein turn over. Data given in Table 1 compares the amount of essential amino acids previously detected to “WHO Ideals” amino acids content.

These essential amino acids (71.23%) represent the largest part of amino acids contained in the studied composite roasted corn flour. In addition they compared favorably with the “WHO Ideal protein” for children for all the essential amino acids identified.

Table 1:- Amino acid content of the composite roasted corn flour compared to “WHO Ideal protein”

Amino acids	roasted Composite corn flour	“WHO Ideal protein” □
	(g/100 g Protein)	(g/100 g Protein)
Lysine	14.74±0.29	5.8
Tryptophane	10.19±0.09	1.1
Phenylalanine	03.51±0.11	3.5
Threonine	09.35±0.01	3.4

Isoleucine	11.93±0.16	2.8
Valine	11.54±0.03	3.3
Leucine	09.97±0.01	6.6
Total	71.23	

□: WHO, 1985 “WHO Ideal protein” for children under five. The values are the mean ± standard deviation of three measurements (n = 3).

The results tend to agree with the assertion that high protein content of legume increases the protein content of cereal-based complementary foods and supplement the deficient amino acid. From this point of view, this flour would be suitable for home made complementary food

Vitamins are indispensable micronutrients with numerous important roles and regulate many biochemical functions in the body. Unlike lipid soluble vitamins that can be stored in the body, water soluble vitamins can not be stored and therefore required a daily supply. As they are either not or synthesized in inadequate amount, vitamins are therefore required from the diet (Fellows, 2009).

Vitamins profile of the composite roasted corn flour is depicted in Figure 3. This profile indicates that the studied flour consist mainly of vitamins A, B (B1, B2, B6, B9 and B12), C and E. This blend makes it possible to offer a wide range of vitamins to children to meet the needs of their organism according to their age and their development.

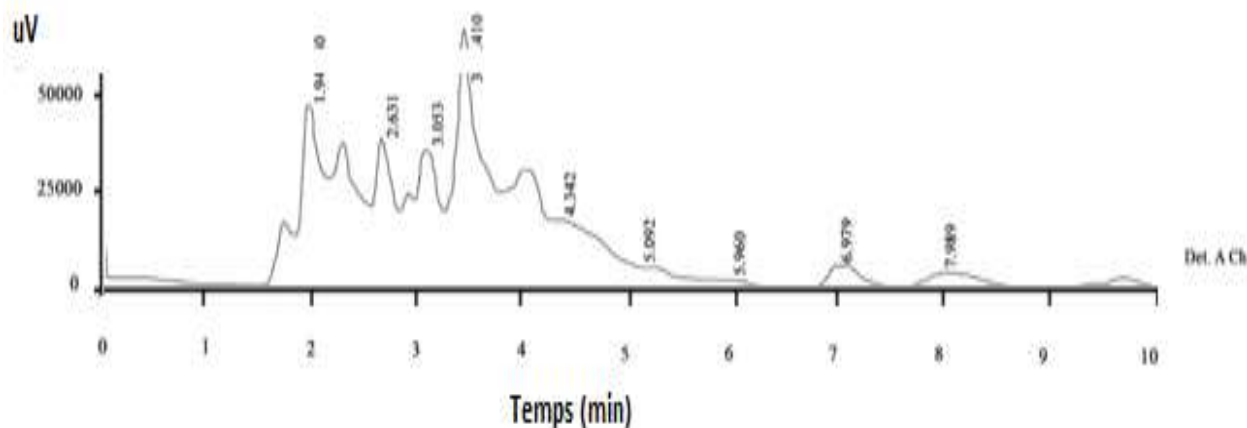


Figure 3:- Chromatogram profile of vitamins in the composite roasted corn flour.

Retention time (min.): Vitamin B6 :1.940; Vitamin B9 : 2.631; Vitamin B2: 3.05 ; Vitamin B1 : 3.410; vitamin C: 4.342 ; Vitamin E : 5.960 ; Vitamin B12: 6.979 ; Vitamin A: 7.989.

Vitamins contents of the studied flour are shown on table 2. Analysis of this table reveals that the three vitamins A ($34 \pm 0.04 \mu\text{g}/100 \text{ g}$), C ($30.86 \pm 0.01 \text{ mg}/100 \text{ g}$) and E ($27.82 \pm 0.01 \text{ mg}/100 \text{ g}$) account for more than 98 % of all vitamins present in the studied flour. When compared with yellow corn, we noted that the formulation 5-5-90 (soy-groundnut-corn) make it possible to considerably increase the contents in vitamin thus improving the nutritional potential of this flour (CIQUAL, 2017). Indeed, when we refer to the recommended nutritional intake, we noted that these vitamins contents are sufficient to cover the needs of children from 6 to 11 months receiving a minimum of two meals a day (OMS, 2011) except for vitamin A (Table 2).

Table 2:- Vitamin content of the composite roasted corn flour compared to the recommended nutrient intake.

Vitamin	Roasted composite corn flour (/100 g)	RNI (/day) □ □ 6 to 11 months
A	$34.00 \pm 0.04 \mu\text{g}$	$350 \mu\text{g}$ (RE)
B ₁	$00.17 \pm 0.01 \text{ mg}$	0.2 mg
B ₂	$00.26 \pm 0.04 \text{ mg}$	0.4 mg
B ₆	$01.16 \pm 0.01 \text{ mg}$	0.2 mg
B ₉	$0,39 \pm 0.07 \text{ mg}$	50 μg

B ₁₂	0.016±0.01 mg	0.4 mg	
C	30.86±0.01 mg	25 mg	
E	27.82±0.01 mg	4 mg	
□ □RNI: Recommended nutrient intake/day (OMS, 2011).The values are the mean ± standard deviation of three measurements (n = 3)			

Dietary deficiency of vitamin A is not recommended. In infants and children, vitamin A is essential for rapid growth and to fight infections. Insufficient vitamin A intake can cause deficiency leading to night blindness and increase the risk of morbidity and mortality from childhood infections such as measles and diarrheal diseases (Fellows, 2009).

In this regard, supplementation of household complementary foods with vitamin-dense foodstuff have been suggested like fruit pulps which are rich in protein, iron, calcium and β -carotene (vitamin A precursor)(Obizoba et al., 1994). However, since complementary foods are tend to supplement breast milk, it is hoped that the deficient vitamins in the blend would probably be met by mother's milk. This is why it is recommended to continue breastfeeding after 6 months. Thus, this composite roasted corn flour is a food that can solve vitamin deficiency problems in developing countries

Functional properties:

Functional properties are very important insofar as they represent the parameters to be taken into account in the development of food products because of their effects on the texture, the sensation in the mouth and on the consistency of the product(Bhat and Yahya, 2014). Understanding some of the intrinsic behaviours of flour helps to define the manufacturing parameters of the different products.

Thus, these properties were determined in the studied composite flour and results are shown in table 3. The bulk density about 0.71±0.02 g/mL exhibited by the composite roasted corn flour is comparable to those obtained byYeboah-Awudz et al., 2018in their formulation of 9-91% peanut/rice flour and 18-82% Bambara peanut/rice flour with 0.78 and 0.74 g/mL respectively. But this value is higher than that of 0.56 and 0.62 g/ mL reported by Eltayeb et al. (2011) for Bambara groundnut flour. Nutritionally, low bulk density promotes easy digestibility of food products, particularly among children with weak digestive system. This is important in complementary foods because high bulk limits the caloric and nutrient intake per feed per child and infants are sometimes unable to consume enough to satisfy their energy and nutrientsrequirements. Apart from dietary bulk of the gruel made from complementary diets, the bulk density is also important in the packaging requirement and material handling (Kaletunc and Breslauer, 2003).

The water absorption capacity (WAC) is an essential functional property of protein which depend on pore size and charges on the protein molecules. WAC characterizes the ability of flour to rehydration which is the first step of its conversion into dough. The obtained value (295.61 g/100 g) was lower than the findings (311.43 %) of Olaposi andal. (2018) for Bambara groundnut flour. But the same authors reported water absorption capacity of 108.67 % for wheat flour. This suggests that the studied flours are moderately hydrophilic and will have a moderate water absorption and binding capacity which is desirable for making thinner gruels with high caloric density per unit volume. This moderate WAC of the studied flour will thus limit the microbial activities of food products (Giami and Bekeham, 1992) and extend the shelf-life of such product.

As same as WAC, Porosity and water solubility index are index of the maximum of water that a food product would absorb and retain (Marero et al., 1988). These parameters depend on intrinsic factors such as amino acid composition, protein conformation and surface polarity.

Table 3:- Functional properties of the composite roasted corn flour.

Parameters	Values
Emulsion capacity (%)	5,26 ± 0,1
Emulsion Stabibility (%)	2,50 ± 0,15
Wettability (s)	4,10 ± 0,1
Bulk density(g/mL)	0,71 ± 0,02
Hydrated density (g/mL)	0,5 ± 0,1
Porosity (%)	40,30 ± 0,52
Water absorption capacity (%)	295,61 ± 3,15

water solubility index (%)		35,63 ± 0,05
Oil absorption capacity (OAC)(%)	Aya	192,98 ± 1,05
	Olive	178,67 ± 0,43
	Palmer	199,48 ± 0,03
	Sunflower	168,19 ± 0,17

*The values are the mean ± standard deviation of three measurements (n = 3).

As regards wettability, data shown that the studied flours wet very quickly (about 4.10 s). This wettability value is very low than those previously found (about 25 s) for flours from purple corn flour (Akafou et al., 2019) and (92.66 – 99.5 s) for flours from edible mushrooms *Volvariella volvacea* and *Armillaria mellea* (Dué et al., 2016). This reflects the rapidity of this phenomenon and allows better dispersibility of the flour to produce aqueous beverages and batters.

The emulsifying properties are usually related to the volume of oil that can be emulsified by protein before collapse of emulsion occurs and thus express the ability of flour to emulsify oil. Food emulsions are thermodynamically unstable mixtures of immiscible liquids. The formation (EC) and stability (ES) of emulsion is very important in food systems (Fekria et al., 2012). As shown in Table 3, values obtained (5.26 % and 2.5 %) by both emulsion capacity and stability are less similar to those obtained by Adegunwa et al. (2017) which are respectively 26.11 and 2.55 % in a 60-40 % of plantain/ tiger nut flour formulation. The capacity of proteins to enhance the formation and stabilization of emulsion is important for many applications in cakes, frozen desserts and gruel. In these products particularly in formulated complementary diets, emulsifying and stabilizing capacities are required to keep the mixture more homogenous and ensure its stability over time (Fekria et al., 2012).

The ability to absorb oil helps to preserve the flavour of food in the mouth and increases calorie intake during food development (Kinsella 1976). The oil absorption capacity (OAC) of the studied composite roasted corn flour was investigated in the presence of the most consumed oils such as Aya, olive, palmer and sunflower oils (Table 4). The composite roasted corn flour displayed higher value of oil absorption capacity (192.98±1.05 g/100 g and 199.48±0.03 g/100 g, respectively) with Aya and palmer oils while the lower value of OAC (168.19±0.17 g/100 g) was exhibited with sunflower oil (Table 3). Also, these OAC were greater than those of maize (107 %) and wheat (72.50 %) flours from Pakistan (Shad et al., 2013).

OAC has been attributed to be due to physical entrapment of oil and binding of fat to the polar chains of proteins. Kinsella (1976) reported that more hydrophobic proteins show superior binding of lipids, this implies that non-polar amino acids side chains bind the paraffin chains of fats. Based on this report, the low OAC of the formulated blend with sunflower oil reflects the low entrapment of this oil causing a weak bond of fat to the polar chains of proteins. On the contrary, the high OAC displayed with Aya and palmer oils reflects the high physical trapping practiced on these oils, which increases the binding of fats to the polar chains of proteins. This study reveals that the composite roasted corn flour is more hydrophobic to saturated (Aya and palmer oils) oils than unsaturated (sunflower oil) and will be able to retain more flavour and probably have a better mouthfeel with these oils. In addition, this OAC shows that composite roasted corn flour exhibit a higher content of hydrophobic amino acids capable of physically trapping the oil in the protein (Lawal and Adebowale 2004). This protein's ability makes the flour more useful in food systems where optimal oil absorption is desired.

Antioxidant properties:

The main antioxidant compounds of the composite roasted corn flour have been evaluated (Table 4). The study revealed that the composite roasted corn flour exhibit value of 198.04±3.31 mg of galic acid equivalent per 100 g of dry matter for total polyphenol content (TPC), and 5.29±0.37 mg of quercetine equivalent per 100g of dry matter for flavonoids contents (FC) with an antioxidant power of 62.36±2.50 % and a reducing power of Iron of 21.53±0.08 % (Table 4). As concern the TPC, the value observed was greater than those of commercial wheat flours which ranged from 116 to 155 mg GAE/ 100 g of dry matter (Yu et al., 2013).

Table 4:- Principal antioxidant compounds and anti-oxidant capacity and reducing power of iron of the composite roasted corn flour.

Studied parameters	Content (/ 100g)
Total polyphenol (mg EAG/100 g dm)	198.04±3.31

Flavonoid (mg EQ/100g dm)	5.29±0.37
Antioxidant activity (DPPH %)	62.36±2.50
Reducing power of iron (mg/100g dm)	21.53±0.08

The values are the mean ± standard deviation of three measurements (n = 3). dm: dry mater, EAG: Galic acid equivalents; EQ: Quercetine equivalents

The high content of total polyphenol and the antioxidant capacity induce the studied flour to protect the cellular constituents against oxydation and limit the risk of various degenerative diseases associated with oxidative stress. High levels of total polyphenol and antioxidant capacity are believed to be due to the roasting process of soybean, groundnut and corn grains used to make the composite roasted corn flour. Talcott et al., (2005) also reported that heat treatment can release phenolic compounds contained in cellular components. This could be due to the maillard reaction during roasting. This reaction induces the formation of melanoidine which has been declared to have antioxidant activity. Significant correlations ($P < 0.05$) were observed by Chograni et al., (2012) between the total polyphenol or flavonoid content and the antioxidant activity estimated by the iron reducing power and free radical scavenging activity, indicating that most phenols and flavonoids contribute significantly to antioxidant capacity.

Conclusion:-

This in-depth study highlights the intrinsic qualities of the enriched formulation of roasted corn flour with 5-5 soybean/peanut. This formulation boosts the essential amino acids content, vitamin profile, antioxidant and functional properties. These ideal qualities make the studied formulation interesting for balanced diet of infant in complement with breast milk and for maintaining the health of the consumer.

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Conflicts of Interest:

The authors declare no conflict of interest.

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