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Nutritional Composition and Functional Properties of a Fortified Ivorian Local Food ″BASSI″ of Maize

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Abstract: Six (6) formulations of ″BASSI″ based on a mixture of maize and soybeans have been developed. Soy flour was incorporated in amounts of 0, 10, 20, 30, 40 and 50%. The results showed that the nutritional value significantly increases with the incorporated soy rate, except the carbohydrate content which decreases. The water absorption capacity, oil absorption capacity and emulsifying activity also increased. As for the emulsion stability and the bulk density, the values decrease. The incorporation of soy improves the nutritional and functional properties of ″BASSI″.

Keywords*:* ″BASSI″, Cereal-Based Food, Chemical Composition, Functional Properties

1. Introduction

Dietary deficiencies are major scourges news. According to FAO, more than one billion people are affected by malnutrition in worldwide, most of which is in developing countries (FAO, 2009). The main causes are a protein-energy food deficit and a deficiency of certain key micronutrients such as calcium, iron and zinc (Soro et al., 2013). But we should add the unsustainable and inequitable access to food by the most vulnerable social strata and also the bad nutritional practices. Grains, including maize and millet are the staple food of many populations around the world. In Cote d'Ivoire, maize is the second cereal most cultivated and consumed after rice (Akanvou et al., 2006), while millet is the 3rd (Békoye and Akanvou, 2005). These food crops are used in the manufacture of many traditional dishes, including ″BASSI″. This multicultural food made from local product is consumed by the Ivorian population and several countries of the subregion. It is obtained after cooking cornmeal or millet and added sugar. But its nutritional value seems to be unbalanced because the main raw materials (maize and millet) for the manufacture of this commodity are rich in carbohydrates and low in proteins. The levels are 73% and 9.2% for maize and 67% and 11.8% for millet respectively (FAO, 1995). Generally, grains have low protein concentration and the quality of these proteins is limited by deficiencies in certain essential amino acids. Thus, it is necessary to incorporate a product with high nutritional density, and soy appears to meet this requirement. In most developing countries, soybean cultivation is encouraged. This legume is known for its seeds rich in protein (40%) and fat (20%), giving him the rank of first oleaginous-protein cultivated in the world (Duc et al., 2010). According to Zannou-Tchoko et al. (2011), soybean contains in balanced proportions proteins of good biological value with all essential amino acids. It also contains fatty acids such as omega (Demaison and Moreau, 2002). In addition to provide essential nutrients, it is used for its excellent functional properties in improving food processes (Wolf, 1970). Several formulations of ″BASSI″ from maize with soybeans incorporating were developed with the objective to determine the chemical composition of such mixtures; and assess their functional properties.

2. Materials and Methods

2.1. Materials

The plant material used was white maize (Zea mays) and yellow soybeans (Glycine max).

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2.2. Methods

2.2.1. Formulations of ″BASSI″ improved with soybean

Six formulations of ″BASSI″ containing soybean have been developed, six from maize. Soy flour was mixed with that of maize (AF) in the following proportions: 0% (AF0), 10% (AF1), 20% (AF2), 30% (AF3), 40% (AF4) and 50% (AF5). 25 g of sugar were added to 100 g of each mixture of flour. A specific volume of water was added to each mixture. The preparation process of ″BASSI″ is presented in figure 1.

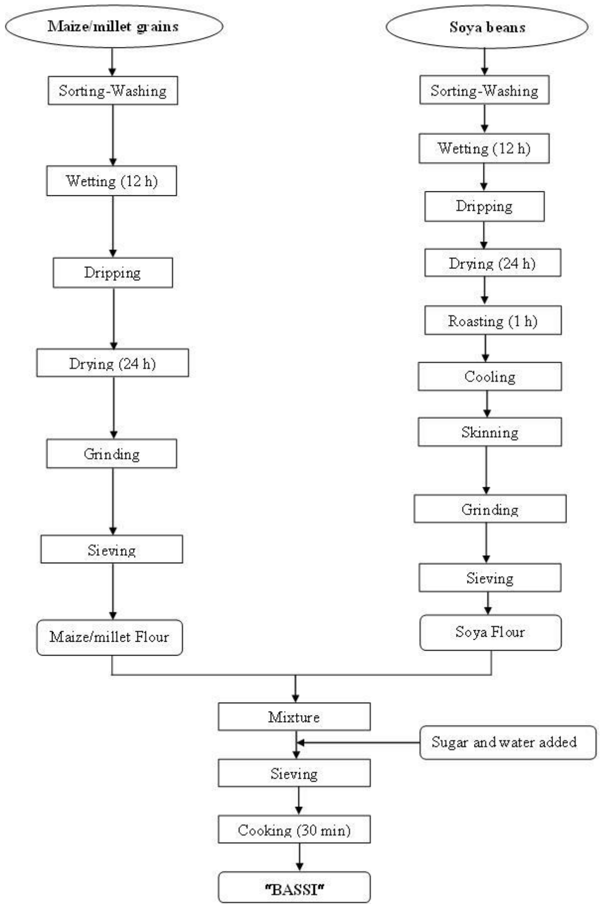

Figure 1: Scheme of ″BASSI″ manufacturing improved with soybean

Photocopy: ″BASSI″ improved with soybean

2.2.2. Chemical analysis of ″BASSI″ improved with soybean

Water content and ashes content were determined according to an official method (AOAC, 1990). Moisture was determined by drying in an oven at 105 °C for 24 hours and ash using a muffle furnace at 550 °C for 24 h. Proteins were quantified according to AOAC (1990) using the Kjeldahl method which taking place in three steps namely mineralization, distillation and acid-base quantification. Fat content was determined according to the method of Folch et al. (1957) using vacuum filtration and a solvent combination (chloroform and methanol) to extract the fat. Total carbohydrate was determined by difference of the total material to other biochemical compounds. Energy value corresponding to the available energy was calculated using the specific coefficients of Atwater and Benedict (1902) for proteins, lipids and carbohydrates. The pH and total acidity were determined according to AOAC (1990). For the last two parameters, each sample was diluted in 100 ml of distilled water, stirred for 30 min and the resulting mixture was filtered before analysis.

2.2.3. Functional properties of ″BASSI″

The water absorption capacity (WAC) was determined using the method of Phillips et al. (1988). The oil absorption capacity (OAC) was determined according to the method of Sosulski (1962). The hydrophilic-lipophilic index (HLI) as defined by Njintang et al. (2001) was calculated as the ratio of WAC/OAC. The emulsifying activity (EA) and emulsion stability (ES) were determined by the method of Yasumatsu et al. (1972). The bulk density (BD) was determined according to the method of Narayana and Narasimga (1982).

2.2.4. Statistical data processing

All measurements were performed in triplicate. Statistical differences were verified by ANOVA with SPSS 19.0 software. The comparison of means was carried out with the Duncan test for a significance level set at 5%.

3. Results and Discussion

3.1. Results

3.1.1. Chemical analysis of ″BASSI″ improved with soybean

3.1.1.1. Case of ″BASSI″ based maize

The nutritional composition of all formulations is presented in table 1. Water content is between 4.05 ± 0.01 and 4.74 ± 0.09 g/100 g of dry matter (DM). Protein, fat and ash increases with incorporated soy rate. Values are significantly different ($p < 0.05$) and range from 6.53 ± 0.01 to 22.33 ± 0.01 for proteins, 3.08 ± 0.02 to 9.23 ± 0 02 for fat and 0.62 ± 0.00 to 2.40 ± 0.01 for ashes. The mineral composition gradually increases with the incorporation of soy. Macro-minerals such as calcium, phosphorus, potassium, magnesium and sodium increase significantly ($p < 0.05$). Trace elements like manganese, iron, copper and zinc also significantly increase with incorporated soy rate ($p < 0.05$). On the other side, total carbohydrate content decreases ($p < 0.05$). Incorporation of soybean also improves the energy value of the formulations ($p < 0.05$). The results for the sugar content, pH and acidity are presented in table 2. Total sugar content decreases gradually as soybean increases. Values range between 16.75 ± 0.17 and 14.01 ± 0.91 mg/ml. pH and acidity changing inversely as soybean increases. The pH values are significantly different ($p < 0.05$). Acidity is statistically identical with 10 to 40% of incorporated soybean but different with 0 and 50% of incorporated soybean ($p < 0.05$).

Table 1: Nutritional value of ″BASSI″ based maize improved with soybean

Parameters	Content (g/100 g of dry matter)					
	AF0	AF1	AF2	AF3	AF4	AF5
Moisture	4.05^{a} ± 0.01	4.09^{ab} ± 0.02	4.12^{ab} ± 0.05	4.26^{c} ± 0.04	4.74^{d} ±0.09	4.16^{b} ± 0.05
Proteins	6.53^{a} ± 0.01	7.72^{b} ± 0.01	10.91^{c} ± 0.02	15.74^{d} ± 0.03	19.06^{e} ± 0.03	22.33^{f} ± 0.01
Fat	3.08^{a} ± 0.02	3.37^{b} ± 0.02	4.43^{c} ± 0.02	6.14^{d} ± 0.20	7.21^{e} ± 0.15	9.23^{f} ± 0.02
Ashes	0.62^{a} ± 0.00	1.09^{b} ± 0.01	1.43^{c} ± 0.01	1.81^{d} ± 0.00	2.13^{e} ± 0.01	2.40^{f} ± 0.01
Carbohydrates	85.72^{f} ± 0.03	83.61^{e} ± 0.19	79.14^{d} ± 0.07	72.06^{c} ± 0.19	66.86^{b} ± 0.12	61.88^{a} ± 0.08
Energetic value*	396.74^{a} ± 0.16	395.63^{a} ± 0.80	400.04^{b} ± 0.50	406.45^{c} ± 1.18	408.54^{d} ± 0.30	419.91^{e} ± 0.08
Minerals	**Content (mg/100 g of dry matter)**					
Calcium	18.30^{a} ± 0.00	26.07^{b} ± 0.14	29.59^{c} ± 0.17	33.84^{d} ± 0.13	41.56^{e} ± 0.17	51.47^{f} ± 0.30
Phosphorus	43.37^{a} ± 0.17	71.51^{b} ± 0.08	100.46^{c} ± 0.13	137.61^{d} ± 0.88	143.40^{e} ± 0.18	160.02^{f} ± 0.60
Potassium	1007.61^{a} ± 1.92	1312.15^{b} ± 0.05	1376.89^{c} ± 1.11	1398.61^{d} ± 0.35	1424.31^{e} ± 2.10	1475.31^{f} ± 0.64
Magnesium	28.06^{a} ± 0.21	43.52^{b} ± 0.90	49.27^{c} ± 1.03	65.73^{d} ± 0.85	79.22^{e} ± 0.26	112.00^{f} ± 0.40
Sodium	50.32^{a} ± 0.15	86.17^{b} ± 0.01	98.64^{c} ± 0.27	104.21^{d} ± 0.26	117.30^{e} ± 0.48	144.15^{f} ± 0.15
Manganese	0.28^{a} ± 0.00	0.49^{b} ± 0.01	0.72^{c} ± 0.02	1.08^{d} ± 0.05	1.44^{e} ± 0.10	1.57^{f} ± 0.01
Iron	3.12^{a} ± 0.10	3.16^{a} ± 0.05	3.67^{b} ± 0.01	3.85^{c} ± 0.03	5.74^{d} ± 0.09	8.30^{e} ± 0.09
Copper	0.06^{a} ± 0.00	0.18^{a} ± 0.02	0.40^{b} ± 0.07	0.68^{c} ± 0.09	1.31^{d} ± 0.14	1.83^{e} ± 0.06
Zinc	0.46^{a} ± 0.01	0.50^{a} ± 0.00	0.58^{b} ± 0.03	0.68^{c} ± 0.01	0.91^{d} ± 0.03	1.00^{e} ± 0.02

*Values followed by different letters in a line are statistically different (α = 0.05). Values represent the mean ± SD of three independent measurements (n = 3) * (Kcal/100 g of dry matter).*

Table 2: Total sugars, pH and acidity of ″BASSI″ based maize improved with soybean

Parameters	AF0	AF1	AF2	AF3	AF4	AF5
Total sugars*	$16.75^{c}\pm0.17$	$16.57^{bc}\pm0.23$	$15.70^{b}\pm0.62$	$15.72^{b}\pm0.25$	$14.69^{a}\pm0.28$	$14.01^{a}\pm0.91$
pH	$5.34^{a}\pm0,00$	$5.98^{b}\pm0,00$	$6.14^{c}\pm0.40$	$6.24^{d}\pm0.01$	$6.33^{e}\pm 0.01$	$6.42^{f}\pm 0.00$
Acidity**	$3.00^{b}\pm0.00$	$2.67^{ab}\pm0.57$	$2.33^{ab}\pm0.57$	$2.67^{ab}\pm0.57$	$2.33^{ab}\pm0.57$	$2.00^{a}\pm0.00$

Values followed by different letters in a line are statistically different (α = 0.05). Values represent the mean ± SD of three independent
*measurements (n = 3) * (mg/ml) ** (meq-g/100 g of dry matter).*

3.1.2. Functional properties of ″BASSI″ improved with soybean

3.1.2.1. Case of ″BASSI″ based maize

The results for functional properties are presented in table 3. The WAC, OAC and EA increase with incorporated soybean rate. Values are significantly different ($p < 0.05$). As for the ES, the values decrease, the formulations with 10 to 40% of soybean (AF1 to AF4) are statistically different from that of 0% (AF0) and 50% (AF5) ($p < 0.05$). The HLI (WAC/OAC report) range from 1.38 ± 0.01 to 1.42 ± 0.01. The values of HLI are significantly identical for the formulations at 0% (AF0), 10% (AF1) and 50% (AF5). The BD decreases gradually as soybean increases. Values are significantly different and range from 0.87 ± 0.00 to 0.67 ± 0.01 g/ml.

Tableau 3: Functional properties of ″BASSI″ based maize improved with soybean

Parameters	AF0	AF1	AF2	AF3	AF4	AF5
WAC*	$235.51^{a} \pm 1.13$	$239.87^{b} \pm 0.60$	$248.30^{c} \pm 0.50$	$252.88^{d} \pm 0.32$	$261.14^{e} \pm 2.26$	$268.41^{f} \pm 1.19$
OAC**	$168.45^{a} \pm 1.31$	$171.75^{b} \pm 2.55$	$175.57^{c} \pm 1.10$	$181.57^{d} \pm 0.42$	$189.09^{e} \pm 0.50$	$191.20^{f} \pm 0.72$
HLI	$1.40^{ab} \pm 0.00$	$1.40^{ab} \pm 0.02$	$1.42^{b} \pm 0.01$	$1.39^{a} \pm 0.00$	$1.38^{a} \pm 0.01$	$1.40^{ab} \pm 0.01$
EA (%)	$52.67^{a} \pm 1.01$	$54.06^{b} \pm 0.34$	$55.97^{c} \pm 0.62$	$56.60^{d} \pm 0.00$	$57.33^{e} \pm 0.62$	$59.36^{f} \pm 0.81$
ES (%)	$99.33^{c} \pm 1.15$	$96.77^{b} \pm 0.10$	$96.93^{b} \pm 0.14$	$96.77^{b} \pm 0.00$	$95.31^{b} \pm 1.77$	$89.09^{a} \pm 1.44$
BD (g/ml)	$0.87^{f} \pm 0.00$	$0.82^{e} \pm 0.00$	$0.79^{d} \pm 0.00$	$0.76^{c} \pm 0.01$	$0.72^{b} \pm 0.02$	$0.67^{a} \pm 0.01$

Values followed by different letters in a line are statistically different (α = 0.05). Values represent the mean ± SD of three independent
*measurements (n = 3) * (Kcal/100 g of dry matter).*

3.2. Discussion

3.2.1. Chemical analysis of ″BASSI″ improved with soybean

The protein content of the formulations increases with soybean incorporation. This result is in agreement with those of Akubor and Onimawo (2003) and Akusu and Wordu (2013) in their studies on the functional properties of local products. The protein content (10.91%) of AF2 formulation is lower than that found by Kalimbira et al. (2004) which obtained 14.15%. This difference could be related to the maize variety used. According to Sanogo (1994) *Codex Alimentarius* recommends a minimum of 13% protein for infant foods. AF3, AF4 and AF5 formulations are in compliance with Codex recommendations. The fat content also increases with soybean incorporation because soybean is rich in fat. Maize flours are naturally low in fat (3.08% for maize). Incorporation of soybean which is an oleaginous improves the fat content of the food. According to Demaison and Moreau (2002), the omega fats present in soybean are responsible for cardiovascular and immune balance. AF4 and AF5 formulations exceed the recommendations of the *Codex Alimentarius* (7%) for baby food (Sanogo, 1994). The ash content reflects the mineral composition of a food. That of our formulations increases with soybean rate. The formulations (AF4, AF5) exceed the recommendations of *Codex Alimentarius* (2%) for baby food (Sanogo, 1994). The results presented in tables 1 and 2 show that with the exception of calcium and copper (only for formulations containing millet), the mineral content of the formulations from 10 to 50% tend to satisfy the minimum desirable contents of an infantile flour (Mouquet et al., 1988). All formulations are excellent sources of carbohydrates. Formulations of 0 to 30% of soybean for both maize exceed the recommendations of the *Codex Alimentarius* (68%) for baby food (Sanogo, 1994). The energy value increases as soybean increases. This could be attributed to high levels of fat content (Kalimbira et al., 2004). All formulations have energy values similar to the recommendations of *Codex Alimentarius* (400 Kcal/100 g of DM) for baby food (Sanogo, 1994). The pH values are statistically different while those of acidity are identical. These acidic pH values are beneficial for food, especially in infant food (Soro et al., 2013) as most enzyme reactions are favored in acidic media.

3.2.2. Functional properties of ″BASSI″ improved with soybean

The oil absorption capacity (WAC) provides information on the maximum amount of water absorbed by food (Siddiq et al., 2010). WAC of formulations increases with soybean rate. These results are consistent with the work of Akubor and Badifu (2004) which showed that increasing the WAC could be explained by the increase in protein content (many hydrophilic residues). WAC values for the formulations from 20 to 50% (248.30 to 268.41% for maize) are superior to those obtained by Akubor and Onimawo (2003) (180-190 %). High values of WAC can also be assigned to cooking effect. Cooking would lead to dissociation and modification of protein molecules in monomeric subunits that can retain more water in the binding sites as suggested by Lin et al. (1974). A high value of WAC of flour is an important property in pastry flour (Wolf, 1970).

The oil absorption capacity (OAC) is important for the development of flavor and food preservation, because it would prevent the development of oxidative rancidity in reducing the availability of oil for oxygen in food (Siddiq et al., 2010). In our study, the OAC increases with soybean incorporation. This increase is attributed to their protein content and the cooking effect as suggested by an author (El-Adawy, 2000). The type of protein can also influence oil retention properties, because the oil is attached to the nonpolar side chains of proteins as mentioned by some authors (Siddiq et al., 2010) in their work on the physical and functional characteristics of beans flour. The ability of proteins to retain oil is an interesting property because it allows good retention of flavor in the food processes, improving palatability (Moure et al., 2006). The flours of this study could be good lipophilic constituents and therefore suitable for preparing soups and cakes as shown by some authors (Aremu et al., 2007).

The hydrophilic-lipophilic index (HLI) assesses the comparative flour affinity for water and oil. The values for the formulations based on maize (1.38 and 1.42) are superior to those reported by Njintang et al. (2001) for cowpea (about 1.12). More HLI approach to value 1, more the flour has good affinity for water as well as oil. All the values are greater than 1, this means that the flours have more affinity for water than oil.

The emulsifying activity (EA) is an important parameter in the development of formulations requiring mixtures of water and oil, such as baked goods (Shad et al., 2013). This parameter increases with soy incorporation. Improving the EA could be attributed to the increase in protein content as suggested by some authors (Moure et al., 2006). Soy protein helps the formation of emulsions and their stability during food processing. Our results agree with those of Siddiq et al. (2010) which reported in their study that the high stability of flour emulsion was due to the globular nature of the main soy proteins.

The bulk density (BD) is influenced by the size of the starch particles. The resulting values decrease as soybean increases. This could probably due to the fact that maize have higher densities than soybeans (Akubor and Onimawo, 2003). The same authors reported a similarity with the cookies made from soy flour and maize. This decrease may be also due to the small amount of starch in soya meal compared to maize. This property is important during mixing and packaging (Sakai, 1979).

4. Conclusion and perspectives

This study is a contribution for improving the nutritional quality and functional properties of ″BASSI″, a local product based on a mixture of maize and soybean. ″BASSI″ enrichment with soybean improves nutrient levels and functional properties of the formulations. ″BASSI″ consumption can reduce the risk of malnutrition among the population, particularly in children. The results for the functional properties provide useful data for their potential uses in food industry. In perspective, it would be interesting to determine the profiles of amino acids and fatty acids that are crucial for assessing the quality of protein and fat. In addition, the establishment of an extension policy is needed to bring the population to consume improved traditional dishes that meet the nutritional quality requirements.

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