Physicochemical, nutritional and techno-functional characterization of flours of millet (*Pennisetum glaucum*), maize (*Zea mays*) and soy (*Glycine max*) grown in the north of Ivory Coast.

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Abstract : *The present study aims to analyze physico-chemical, nutritional and rheological properties of the witness (100% wheat), soy, millet and maize flours and evaluate the impact of composite flours through the formulation of baking dough at different rates on the evolution of baker's yeast (Saccharomyces cerevisiae) activity during fermentation. Composite flours were prepared by blending wheat flour (the witness: 100% wheat) with 0%, 5%, 10%, 15%, 20% and 25% of each flour. The results generally show that soy, millet and maize flours are a good source of protein and total carbohydrate. Compared to the control, soy, millet and maize flours have a good Water Absorption capacity (WAC) and Oil Absorption capacity (OAC) than the control. Dough incorporated up to 15% millet flour results in dough definitely raising higher than that of 100% wheat flour. Dough incorporated up to 10% of maize flour and 20% soy flour raise well during fermentation. The results obtained in this study show that these flours can be used in bread making.*

Keywords: *millet, soy, maize, composite flour, bread making.*

I. INTRODUCTION

Cereal has been the staple food of many populations for several decades. According to [1] world cereal production is estimated at 2.480 billion tonnes. In West Africa, they occupy an important place in food consumption [2]. The most widely used cereals in the human diet are millet, wheat, sorghum, maize and rice, the percentages of which vary from one country to another. Bread is described as a fermented confectionery product mainly obtained from wheat flour, water, yeast and salt. Manufacturing process includes a series of mixing, kneading, waterproofing and cooking [3]. The consumption of wheat products is expected to increase due to the increase in the world population [4]. Urbanization and the exotic eating habits adopted by most non-wheat producing countries make bread a staple in the world [5]. In Africa, although it has never been part of the staple diet, consumption of wheat flour has increased in recent years [6]. According to a United Nations estimate in 2014, about 60% of the African population is expected to live in urban areas by 2050, which would lead to an increase in bread consumption. Continent produces only about 44% (27 million tonnes) of the wheat it needs [7]. This dependence on imports has a huge impact on African economies, a situation aggravated by the rise in the price of wheat on the international market. In view of the above reasons, the use of alternative sources of flour for partial wheat substitution [8] is encouraged. Several studies have examined the use of flours from cereals, roots, tubers and legumes at various proportions for composite bread production [9, 10], which would be a means of reducing wheat dependence for the production of bakery products [11]. Results of these studies have shown that the partial substitution of wheat flour by other types of flours presents considerable technological difficulties. This is explained by the absence of proteins capable of forming the gluten network necessary to retain the carbon dioxide produced during the fermentation of these flours [12]. Also, the formed dough is more difficult to handle and thus leads to reduced quality bread [13].

In this sense, the works of [14] showed that the partial substitution of wheat flour with cassava flour in breadmaking produces bread of satisfactory quality. Hence the objective of this study is to evaluate the effect of the partial substitution of wheat flour by soy flour (*Glycine Max*), millet (*Panicum Miliaceum*) and maize (*Zea Mays*) on wheat fermentative activity of Saccharomyces cerevisiae in compound bread formulation.

II. MATERIALS AND METHODS

Materials

Biological material used in this study consists of soy, millet, corn, wheat flour type 55 and baker's yeast that were purchased from the Korhogo market.

Methods

Flour production

Flour production was carried out according to the method described by [15]. Different grains are sent to the laboratory where they are sorted and washed with distilled water. Grains are drained at laboratory temperature and then dried in an oven (Memmert) at 60 ° C for 24 hours. After 24H the grains are crushed using a micro-grinder (culatti) equipped with a mesh screen 10µm.

Preparation of compound flours

Flours were incorporated into the wheat flour type 55 with percentage of 5, 10, 15, 20 and 25%. This formulation is summarized in the table 1.

Flour analysis

Determination of physico-chemical parameters of flours

Proximate analysis was performed using official methods [16]. pH was determined as follow: 10 g of dried powdered sample was homogenized with 100 mL of distilled water and then filtered through Whatman No. 4 filter paper. The pH value was recorded after the electrode of pH-meter (Hanna, Spain) was immersed into the filtered solution. For acidity 10 mL of filtrate have been titrated by NaOH 0.1N. The moisture content was determined by the difference of weight before and after drying sample (10 g) in an oven (Memmert, Germany) at 105°C until constant weight. Ash fraction was determined by the incineration of dry matter sample (5 g) in a muffle furnace (Pyrolabo, France) at 550°C for 12 h. The percentage residue weight was expressed as ash content. Proteins were determined through the Kjeldhal method and the lipid content was determined by Soxhlet extraction using hexane as solvent. Carbohydrates were calculated using the following formulas [17]:

Carbohydrates (%) = 100 – (% moisture + % proteins + % lipids + % ash).

Analysis of Functional properties

Apparent density of the flours was determined according to the method of [18]. (10 g) Samples were weighed using an analytical balance (Denver Instrument). This mass is transferred to a graduated cylinder after calibration the volume has been determined.

Density (g/ml) = Sample weight / Volume sample

Oil Absorption Capacity (OAC) was determined according to the method of [18]. (1) Gram of sample was introduced into a previously weighed test tube. (10) Milliliters of oil were added and the resulting mixture stirred. After a night of rest at the laboratory temperature. Mixture is centrifuged at 3200 rpm for 25 min. Mass of the pellet was determined by weighing. The following formula allowed us to determine the OAC.

$$OAC(\%) = [(Pm - Sw) / Sw]x100$$

with Pm: pellet mass , Sw: sample weight

Table 1: Proportion of incorporation of wheat, soy, millet and maize flour

Types of flour	Percentage incorporation of soy, millet and maize flour					
	0%	5%	10%	15%	20%	25%
Wheat flour (g)	150	142,5	135	127,5	120	112,5
Incorporated Flour (g)	0	7,5	15	22,5	30	37,5

Water absorption capacity (WAC) is determined according to the [19] method modified by [20].
Principle is based on the amount of water retained per 100 g of flour after saturation. (1) Gram of sample is mixed with 10 mL of distilled water. Mixture is stirred for 30 min in a centrifuge (Sigma type 3-16L). The pellet is weighed and the WAC is determined according to the following formula:

$$WAC(\%) = [(Pm - Sw) / Sw]x100$$

with Pm: pellet mass , Sw: sample weight

Swelling capacity (SC) was determined according to the method described by [21]. (4) g of sample is diluted in 40 mL of distilled water. Mixture is heated at 90 ° C. in a water bath for 1h while stirring the tube every 15 minutes. After 1h, the tube is cooled to the temperature of the laboratory and then centrifuged at 5000 rpm for 10 min. The supernatant is transferred to a crucible of known mass. The crucible-supernatant mixture is dried at 100 ° C. for 4 hours. After cooling to the desiccator, the residue is weighed and the following formula makes it possible to determine the solubility:

$$SC(g/g) = Pm / [Sw (1 – Mo)x(100-So)]$$

with Pm: pellet mass , Sw: sample weight , Mo: moisture , So: solubility.

Influence of flours on the fermentative activity of *Saccharomyces cerevisiae*

Formulation of the paste was made according to the method of [22]. Table 2 presents the different formulations.

Table 2: Formulation of compound pasta

	Formulations					
Sample	**100% wheat**	**F5 %**	**F10 %**	**F15 %**	**F20 %**	**F25 %**
Wheat flour (%)	100	95	90	85	80	75
Flour (soy, millet and maize) (%)	0	5	10	15	20	25
Water (%)	62	62	62	62	62	62
Yeast (%)	1,5	1,5	1,5	1,5	1,5	1,5
Salt (%)	1.5	1.5	1.5	1.5	1.5	1,5
Improving (%)	0,5	0,5	0,5	0,5	0,5	0,5

Statistical analysis

Statistical analyses were performed with the Graph Pad Prism software version 8.0.2 (263) of January 30, 2019. Variance analysis (ANOVA) was performed to determine the differences between the averages according to the method of Turkey at the 5% threshold ($P < 0.05$ is considered significant). The results were expressed as averages with the standard error on the mean (mean ± SEM).

III. RESULTS AND DISCUSSION

Characteristics of studied flours

Physico-chemical Parameter

The physico-chemical results of various flours are presented in Table 3. The results show that the millet flour has the higher moisture (13.02%) than wheat (11.71%), (maize (8.76%) and soy (7.43%). These moisture are below the maximum rate of 15.5% defines by the Commission of the Codex Alimentarius [23]. However, moisture between 8 and 12% do not have an influence on the quality of the flour because dependent water is preserved [24]. Indeed, when the moisture content is high, there is an aggregation of flour particles thus reducing its quality and its functionality [25]. It was noteworthy that, cereals are rich source of carbohydrates and often known with the same name, because cereals consist of almost 75% carbohydrates [26]. Total carbohydrate value of studied flour (from 71.6 to 82.34%) is consistent with this statement. Soy flour has high protein value (14.76%) than those of wheat (12.54%), millet (7.64%) and maize (7.33%). According to the literature, cereals have low protein contents. In many instances, protein supplementation of cereals is desirable [27].

The maize has a pH (4.63) more acid than wheat (5.93), millet (4.69) and soy (6.47). The pH of the studied flours varies very little and remains lower than 7. This result is comparable with that of [10]. The pH is the sign of the acidity or alkalinity of the flour and affects largely its performances during its use in the food system. When a flour has a pH<4 this flour is known as very acid what indicates a significant fermentation and consequently a great degradation of the starch present. This type of flour would thus not be adapted for bread making [28].

Titratable acidity measures the total acid content of a food product. On the level of titratable acidity, we observe that the soy has a titratable acidity (9.16%) higher than those of the wheat (0.40%), maize (0.5%) and millet (1.96%). Titratable acidity is consider as a correct measure of the food products acid content in the sense that it makes it possible to measure at the same time the free hydrogen content and been dependent on the acid organic molecules [29]. It is a significant parameter because it makes it possible to know if an ingredient contains the quantity of acid excluded for its use in a given product. The high percentage of soy flour titratable acidity could indicate the presence of a greater quantity of fermentable sugars.

Table 3: Physicochemical parameters of wheat, soya, millet and maize flour

	Flours			
Parameters	Wheat	Soy	Millet	Maize
Moisture (%)	11.71 ± 0.07	7.43 ± 0.064	13.02 ± 0.2	8.76 ± 0.1
Ash (%)	0.55 ± 0.6	3.33 ± 0.60	1.08 ± 0.12	0.19 ± 0.36
Proteins (%)	12,54 ± 0.33	14.76 ± 0.44	7.64 ± 0.32	7.33 ± 0.26
Lipids (%)	2,5	2.48	3.13	1.27

	± 0.42	± 0.31	± 0.13	± 0.16
Total carbohydrate (%)	75 ± 0.71	71.60 ± 0.51	75.52 ± 0.56	82.34 ± 0.65
pH	5.93 ± 0.11	6.47 ± 0.01	4.69 ± 0.03	4.51 ± 0.06
Titratable Acidity (meq/100g)	0.40 ± 0.00	9.16 ± 0.034	1.96 ± 0.11	0.5 ± 0.01

Functional properties

Functional properties values are shown in Table 4. The solubility values of the studied flours range from 6% to 10.67%. Solubility is the capacity of the flour solid substances to be dissolved or disperse in an aqueous medium. The solubility is associated with the flour amylose content. Consequently more the amylose content is high large is solubility [30].

Swelling is a measurement of the hydration and swelling capacity of starch granules and reflects also the extent of the associative forces existing between the amorphous phase and the crystalline phase of the starch grains [18, 30]. A larger index of swelling would indicate a low intermolecular association between the starch granules. The millet flour has a low swelling capacity (6.53 g/g) compared with wheat flour (8.65 g/g), soy flours (22.91g/g) and maize flour (7.76 g/g).

Flour WAC plays a significant role in the food process preparation because it predicts the capacity of the flour to absorb water under conditions where water is limited. Besides, WAC is an index of the maximum amount of water that flour can absorb or retain [31]. The WAC of the studied flours is 66.63%, 152.69%, 96.74%, and 121.02% respectively for wheat, soy, millet and maize. A high capacity makes it possible to add more water to the paste, thus improving its workability. Moreover, WAC is an essential property of the pastes and the bakery products because it allows the thickening and the increase in food viscosity [18]. Soy has a WAC more raised than that of wheat, millet, maize and is lower compared to voandzou flour WAC which is 190.36% obtained by [32]. A high WAC makes it possible to add more water to the paste, thus improving its handiness and the maintenance of freshness in bread [32]. With a high WAC, soya, millet and maize flour can be used in the manufacture of bakery products.

OAC is great importance, since fat acts as flavor retainer and also increases soft texture to mouth feel of foods, especially bread and other baked foods [33, 34]. They are also important because of their storage stability and particularly in the rancidity development [35]. The soy flour OAC value is 110.4% and is higher than those of wheat flour (87.59%), soy flour (101.84%) and millet flour (100%). Our studied flour OAC (from 87.59% to 110.4%) range between those observed by [36] for composite flours (from 19.36% to 156%).

The bulk density is a measure of flour heaviness [37] and an important parameter that determines the suitability of flours for the ease particulate foods packaging and transportation [38]. Bulk density value of studied flours is range from 0.64 to 0.8g/mL. The millet, maize, and soy flour are less dense than that of wheat. That could mean that for the same quantity of flour, millet, maize, and soy flour could occupy less space than the flour of wheat. The low density of flour of soy, of corn millet compared to the flour of corn is also an indicator of its low content of starch [39]. Our findings were similar to those reported for maize [40], soybean [40] and pearl millet [40] and followed trend i.e. lower the moisture content, lesser is the particle density.

Table 4: Some Functional properties of wheat, soya, millet and maize flour

	Flours			
Paramters	Wheat	Soy	Millet	Maize
Solubility (%)	10.67± 0.01	6± 0.11	8.14±0.02	9.5± 0.01
Swelling capacity (g/mL)	8.97± 0.08	22.91±0.02	6.53±0.01	7.77± 0.01
WAC (%)	66.63± 0.31	152,69±0.43	96.74±0.95	121.02±2.3
OAC (%)	87.59± 0.41	101,84±0.83	100±0.34	110.4±0.21
Bulk Density (g /mL)	0.8± 0.04	0,78± 0.02	0.64±0.03	0.67± 0.06

The obtained values are averages ± standard deviation of triplicate determinations

Influence of composite flours on the fermentative activity of Saccharomyces cerevisiae

Figure 1, 2 and 3 shown swelling capacity of composited flour of soy, millet and maize respectively. Incorporation of Saccharomyces in the paste during the bread making results in the production of the carbon dioxide during fermentation [41]. During fermentation, the yeast consumes fermentable sugars of the flour and product of the carbon dioxide which is responsible of paste lifting [42]. In the presence of this gas, the pockets or bubbles formed during kneading dilate. What increases the volume of the paste thus causing a ventilated structure of the bread crumbs. During fermentation, 100% wheat flour as control reached the maximum volume (50 ml) in 120 min.

With regard to composed flours, the paste volume of soy flour decreases from 47.5 in 100 minutes mL for 5% soy to 32mL for 25% soy in 60 minutes. That is due to the fact that, soy being a leguminous plant. Its flour contains little starch compared to the wheat which is a cereal [43].

On the other hand, 5 to 15% millet flour results in dough definitely raising higher than that of 100% wheat flour. A comparable result was also obtained by [44] from 10% tigernuts flour and 90%

wheat flour. But, incorporation of millet flour at going rate from 20 to 25% results in dough definitely raising lower than that of 100% wheat flour. This can be explained by the fact that progressively the rat of wheat flour decreases in each sample, the wheat gluten concentration also thus decreases a reduction in the dough raising. [45] are obtained a bread of a similar quality to the bread produced starting from 100% wheat following incorporation of 20% plantain flour to wheat flour.

Dough incorporated up to 10% of maize flour raise well during fermentation. On the other hand, beyond 15%, we observe a fall of dough raising which would be due to the dispersion of the gluten proteins which have less chance to join to form a viscoelastic network able to retain gas of fermentation. What gives a less developed dough [46].

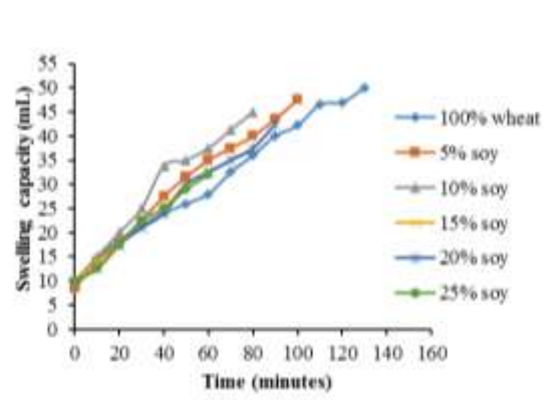

Figure 1: Swelling capacity of soy composited flour

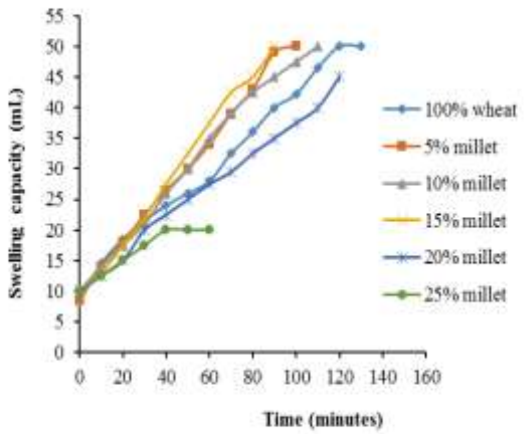

Figure 2: Swelling capacity of millet composited flour

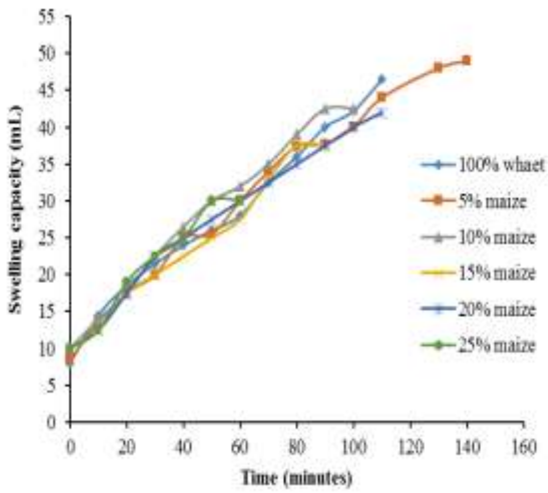

Figure 3: Swelling capacity of maize composited flour

IV. CONCLUSION

The partial substitution of wheat flour with soy, millet and maize flour considerably improves the dough raising. The tests of breadmaking showed that incorporated level of 5 to 15% millet flour in the wheat flour results in dough definitely raising higher than that of 100% wheat flour. Dough incorporated up to 10% of maize flour raise well during fermentation. Taking into consideration these obtained result; the maize flour could be incorporate without notable depreciation of dough raise up to 10% while soy and millet can be incorporated in the wheat flour respectively at the rates up on 20% and 15%. The values obtained show that these flours can be used in breadmaking. The partial substitution of wheat flour with soy, millet and maize flour seems to us interesting for two reasons. On the one hand, it is integrated in the valorization of local cereals in order to produce bread at lower cost. In addition, to develop again produced having a good food value to ultimately combat nutritional deficiencies.

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