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Physico-Chemical and Sensory Properties of Breads Produced from Wheat and Fermented Yam Composite Flour Fortified with Moringa Leaves Powder

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Abstract The use of yam flour *(Dioscorea alata)* substitution in wheat flour fortified with *Moringa oleifera* leaves powder to produce bread was studied. The composite flour was produced from varying proportions of yam flour (10 %, 20 %, 30 %, 40 %) fortified with 0,25% *Moringa oleifera* leaves powder. The proximate analysis and sensory evaluation of the bread samples were determined. The physico-chemical analyses results showed that there was no significant difference between the whole wheat bread and the composites breads produced except for the mineral content. There was a significant ($p < 0.05$) increase in phosphorus (P), zinc (Zn) and iron (Fe) contents from 104,25 ± 10,74 to 303,01 ± 31,21 mg/100g, 0,77 ± 0,08 to 3,11 ± 0,32 mg/100g and 1,40 ± 0,14 to 2,88 ± 0,30 mg/100g respectively. The sensory analysis showed that there were no significant differences ($p < 0,05$) between the whole wheat bread and the composite breads up to 20 % yam flour substitution in all the sensory attributes tested such as color, crust, shape, internal texture, taste, aroma and general acceptability. While significant difference ($p < 0, 05$) was observed with 30 % and 40 % yam flour substitution concerning crust, shape color and internal texture. The acceptability of all bread samples decreased with the increasing of yam flour substitution.

Keywords: *composite bread, yam, moringa leaves powder, physical properties, sensory properties*

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1. Introduction

Since antiquity, bread is one of the most important staple foods in human nutrition. It may be described as a baking fermented dough produced mainly from wheat flour, water, yeast and salt by a series of process [1]. In Côte d'Ivoire, the consumption of bread has steadily been on the increase. However, due to unfavourable climatic conditions, wheat has to be imported from other countries and the imports are increasing to satisfy the national demand [2]. These imports amount to about 45 million tons in 2013 in Africa, which is 60% of African consumption and 23 million tons in sub-Saharan Africa [3]. Moreover, many cases of people with celiac disease have been recorded due to the presence of gluten. This disease is manifested by the atrophy of the intestinal villi which leads to malabsorption of many nutrients resulting in stunting in children and a risk of osteoporosis in adults [2]. Epidemiological studies have classified celiac disease as one of the most common food intolerances [4,5]. In the face of this, great hopes have been placed in the development of composite bread made from local crops. Partial substitution of wheat flour with the tubers for bread production in non-wheat producing countries is on record [6,7]. Among these tubers, the yam ranks first and is the most important crop of the country with a production of 5 million tons per year in 2013 or 8% of world production [8]. West Africa alone accounts for about 96% of yam production in the world. It contributes to food security and have an important social and cultural role while constituting a source of agricultural income [9]. There are two economically important yam species in the country, *Dioscorea cayenensis-rotundata* and *Dioscorea alata*. yam production is dominated by varieties of the species *D. alata*. This species is the most cultivated in the world [10]. In Côte d'Ivoire, *Bètè Bètè* and *Florido* varieties represent more than 90% of *D. alata's* cultivated area [9]. Particularly *Bètè Bètè* has a good aptitude for flour production [11]. Therefore, the use of yam in breadmaking is a great socio-economic interest for the country. However, in the face of the increasing malnutrition cases in the world and especially in Africa, a lot of scientist work have been made to improve the nutritional quality of bread. Being mostly consumed and very accessible for both adults and children, bread can use as a vector to fight malnutrition. Most of bread are still made with flours with a low protein, fibers, and minerals contents [12]. In Côte d'Ivoire, malnutrition is a public health problem and women and children suffer from severe nutritional deficiencies [13]. *Moringa oleifera* is one of the most tropical plants used for food fortification because of its high nutritional value. Leaves are an important source of protein, minerals, vitamins, phenolic compounds also medicinal properties [14]. It is a sustainable and cost-effective solution to fight micronutrient deficiencies in developing countries [15]. So, in order to face the economic and nutritional challenges, the production of wheat/yam breads fortified with moringa could be a considerable advantage. The aim of study is to determine the physicochemical and sensory characteristics of breads made with wheat and yam fortified with moringa powder.

2. Material and Methods

2.1. Material

Yam tubers (*Dioscorea alata, bètè bètè*) used for this study were obtained from a local market (Abidjan, Côte d'Ivoire). Healthy leaves of *Moringa oleifera* were collected from the town (Gonzagville). Concerning wheat flour, it was bought in a supermarket.

2.2. Methods

2.2.1. Yam Flour Production

The yam tubers have been sorted and cleaned. Then, they were peeled and sliced into thin thickness of about 1,5 cm.These slices were soaked in a tank of water (½ mass / volume) to prevent browning. Subsequently, the slices bleached for 15 minutes and were transferred to a large tank containing water (½ mass / volume) for 24 hours of fermentation at room temperature. The slices were dried for 48 hours at 65 ° C in the kiln (MINERGY ATIE PROCESS, France) and then milled in a mill (Forplex, BETHUNE, France). The flour was packed and sealed in polyethylene bags until analyzed [16].

2.2.2. Moringa Leaves Powder Production

The leaflets were removed from the petiole. Diseased and damaged leaves were discarded. They were washed with tap water and washed again in a solution containing 1% bleach for five minutes to rid them of germs. Then, Leaves were rinsed with tap water again. After that, they were drained for one hour and dried in a hot air dryer between 50°C and 55°C to obtain a residual moisture of 10%. The dried leaves which became crumbly, were reduced to fine powder using a mechanical grinder [14,17]. The resulting moringa powder was dried at 50 ° C for 30 minutes to reduce the residual moisture to well below 7.5% because the moringa leaf powder strongly attracts moisture and the product can remoisten during or after grinding [18].

2.2.3. Formulation of Flours

The whole wheat flour was mixed in a blender with varying inclusions of 10, 20, 30 and 40% of the yam flour and 0,25 % moringa powder [19,20]. Control flour was made from 100% wheat flour without any fortification. The samples were stored in polyethylene bags at room temperature until use for analysis and bread production.

2.2.4. Bread Making Process

The yams/wheat composite flours lead to poorly hydrated dough according to the formulations. Thus, during the baking tests, the hydration rate and the kneading time were adjusted to find a shapeable dough [21]. The composite flours were blended with other baking ingredients (1.3% salt, 0.5% yeast, 0.5% enhancer and ice water) in a mixer, kneaded into consistent dough. After mixing and kneading, 200g dough pieces were formed. These dough pieces are left standing for 20 minutes (pointing) before shaping. The fermented dough was then allowed to undergo proofing for 90 minutes and then baked at 250°C for 20 minutes [22,23]. The breads were cooled to room temperature and used for analysis.

2.2.5. Physico-chemical Analysis

The moisture content is determined by drying with the electronic moisture meter set (METTLER TOLEDO, model MJ 33) at 150 ° C. Carbohydrate was determined by difference as described by FAO [24]. Crude protein, crude fibre and ash content were determined according to standard methods [25]. Mineral composition was determined using the Atomic Absorption Spectrophotometer (AAS) (UNICAM 960 series) [25]. Water absorption capacity (WAC) for each sample were determined by the hydration method [26]. The energy values of the samples were calculated by multiplying the percentage of crude protein, crude fat and carbohydrates by the energy values for gross nutrients conversion factors [24].

2.2.6. Sensory Evaluation

Descriptive analysis was carried out with 13 trained panelists evaluating the properties of flavor, color, texture, smell, aroma and aeration of the crumb on a linear scale (1 to 10). The different coded bread samples were presented simultaneously.

Hedonic test was used to express perceived satisfaction on various criteria (color, smell, taste, appearance) and to measure the acceptability of the breads by 100 untrained panelists. Their reaction was recorded on a tasting sheet according to a rating scale expressing three (3) levels of appreciation: Unacceptable, Acceptable, Excellent.

2.2.7. Statistical Analysis

Data were generated in triplicate and subjected to analysis of variance (ANOVA) using STATISTICA software version 7.1. Means were tested for significant differences by Newman Keuls Test. Significance was accepted at $p < 0.05$.

3. Results and Discussion

3.1. Results

3.1.1. Physico-chemical Properties

The physicochemical characteristics of flours and bread samples are shown in Table 1, Table 2, Table 3 and

Table 4. The physico-chemical results of the flours (Table 1) show no significant difference for the protein contents (9.57 ± 0.98 to 11.70 ± 1.21), total carbohydrates (73% to 78.69%) and fibers (2.40 ± 0.25 to 3.70 ± 0.38). The same is true for the energy value (346.90 ± 5.47 kcal / 100 g at 366.21 ± 3.47). On the other hand, composite flours have a lower moisture content and a higher ash content than the control flour F 100/0. Water absorption capacity (98.00 ± 10.09 to 150.00 ± 15.45) increase with the addition of yam flour. For the mineral composition (Table 2), Phosphorus (106.50 ± 10.97 mg to 340.68 ± 35.12 mg) zinc (0.70 ± 0.07 mg to 3.31 ± 0.34 mg) and iron (0.90 ± 0.09 to 3.50 ± 0.36) are significantly higher than control in flour.

Table 3 show that the moisture content (26.75 ± 2.76 at 26.85 ± 2.77), the protein contents (8.08 ± 0.83 at 9.87 ± 1.02), carbohydrates (60.12 ± 3.90 to 61.67 ± 3.98), and fibers (1.83 ± 0.19 to 2.65 ± 0.27) of the composite breads are statistically identical to the control bread (B 100/0). The same applies to the energy value (290.80 ± 10.87 to 323.68 ± 22.54). However, the ash content is slightly higher ranging from 0.38 ± 0.22 (B 100/0) to 2.10 ± 0.25 (B 90/10). This rate lead to high levels of phosphorus, zinc and iron (Table 4). These values are between 106.50 ± 10.97 (B 100/0) and 340.68 ± 35.12 (B 70/30) for phosphorus; 0.70 ± 0.07 (B 100/0) and 3.31 ± 0.34 104.25 ± 10.74 (B 80/20) for zinc between 0.90 ± 0.09 (B 100 / 0) and 3.50 ± 0.36 (B 60/40) for iron.

3.1.2. Sensory Properties

Figure 1 shows average sensory characteristics of different breads. These results show that with the exception of crumb color, crumb texture, crisp texture and aroma, no significant differences were found in the different bread samples. According to Figure 2 the preference of the majority of the tasters was for the control sample B 100/0 which records 23% of the favors, because of its taste and the general aspect, they are considered attractive. Samples B 90/10 and B 80 / 20 rank second but close to the witness with 21% of favors. As for the samples B 70/30 and B 60/40, they were less appreciated. They each record 19% and 17% of favors. Samples B 90/10 and B 80 / 20 were therefore the most appreciated outside the control (B 100/0).

Table 1. Biochemical composition of composite wheat/ yam flours fortified with moringa leaves powder (g/100g)

Flour sample	Moisture	Crude protein	Carbo hydrates	Fibers	Ash	WAC (g /100g MS)	Energy value (Kcal/100g)
F 100/0	13,90±1,43 a	11,70±1,21 a	73,00±2,78 a	2,40±0,25 a	0,50±0,05 b	98±10,09 c	346,90±5,47 a
F 90/10	7,44 ±0,77 b	10,50±1,08 a	78,69±2,19 a	2,50±0,26 a	2,04±0,21 a	104±10,71 cb	360,59±4,96 a
F 80/20	8,92±0,92 b	10,45±1,08 a	78,17±0,64 a	2,70±0,28 a	2,25±0,23 a	114±11,74 cba	361,49±3,96 a
F 70/30	8,95±0,92 b	9,75±1,00 a	78,17±2,25 a	3,15±0,32 a	2,32±0,24 a	146±15,04 ba	364,20±3,70 a
F 60/40	9,00±0,93 b	9,57±0,98 a	78,08±0,68 a	3,70±0,38 a	2,38±0,25 a	150±15,45 a	366,21±3,47 a

Table 2. Mineral composition of composite wheat/yam flours fortified with moringa leaves powder (mg/100g)

Flour samples	Calcium (Ca)	Phosphorus (P)	Zinc (Zn)	Sodium (Na)	Magnésium (Mg)	Iron (Fe)
F 100/0	24,00±2.47 a	106,50±10,97 b	0,70±0,07 b	2,90±0,30 a	24,80 ±2,55 a	0,90±0,09 b
F 90/10	15,35 ±1,58 b	340,12±35,04 a	3,28±0,34 a	2,33±0,24 a	22,30±2,29 a	3,46±0,36ab
F 80/20	15,41 ±1,59 b	340,25±35,05 a	3,31±0,34 a	2,35±0,24 a	22,09±2,28 a	3,45±0,36ab
F 70/30	15,44 ±1,59 b	340,68±35,12 a	3,29±0,34 a	2,50±0,26 a	22,09±2,25 a	3,43±0,38 a
F 60/40	15,41 ±1,59 b	339,09±34,93 a	3,30±0,34 a	2,35±0,24 a	22,38±2,31 a	3,50±0,36 a

Table 3. Biochemical composition of composite wheat/ yam breads fortified with moringa leaves powder (g/100g)

Bread samples	Moisture	Protein	Carbo hydrates	Fibers	Ash	Energy value (Kcal/100gMS)
B 100/0	26,75±2,76 a	8,50±0,87 a	61,50±3,96 a	1,83±0,19 a	0,38±0,22 b	323,68±22,54 a
B 90/10	26,85±2,77 a	8,08±0,83 a	61,67±3,98 a	2,16±0,22 a	2,10±0,25 a	324,03±22,40 a
B 80/20	26,80±2,76 a	9,87±1,02 a	60,12±3,90 a	2,45±0,25 a	2,06±0,2 a	290,31±12,30 a
B 70/30	26,83±2,77 a	8,25±0,85 a	61,64±3,96 a	2,55±0,26 a	2,03±0,21 a	290,81±11,26 a
B 60/40	26,80±2,79 a	8,48±0,88 a	61,52±2,40 a	2,65±0,27 a	2,00±0,25 a	290,80±10,87 a

Table 4. Mineral composition of composite wheat/yam breads fortified with moringa leaves powder (mg/100g)

Bread samples	Calcium (Ca)	Phosphore (P)	Zinc (Zn)	Sodium (Na)	Magnésium (Mg)	Fer (Fe)
B100/0	36,17±3,72 a	104,25±10,74 b	0,77±0,08 b	113,08±11,73a	20,40±2,10 a	1,40±0,14 b
B 90/10	36,16±3,72 a	299,00±30,80 a	3,00±0,31 a	114,35±11,78 a	22,08±2,28 a	2,06±0,21 a
B 80/20	36,21±3,72 a	303,01±31,21 a	3,02±0,31 a	113,08±11,65 a	22,00±2,26 a	2,32±0,24 a
B 70/30	36,25±3,73 a	296,00±35,62 a	3,11±0,32 a	117,35±12,09 a	22,15±2,28 a	2,76±0,28 a
B 60/40	36,20±3,73 a	296,02±35,62 a	3,16±0,32 a	118,45±12,20 a	20,35±2,10 a	2,88±0,30 a

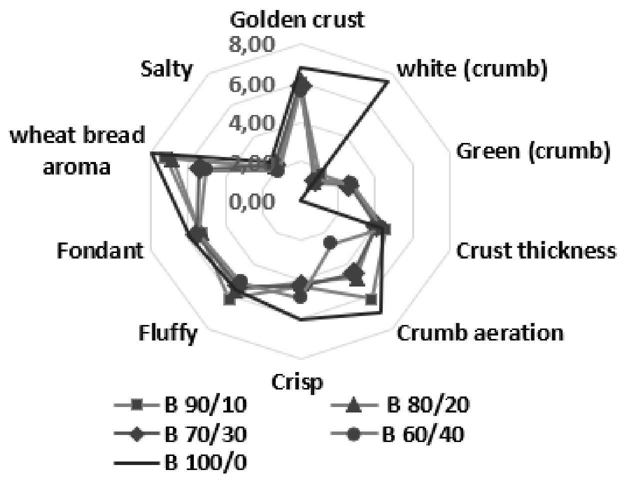

Figure 1. Sensory attributes of wheat/ yam breads fortified with moringa leaves powder

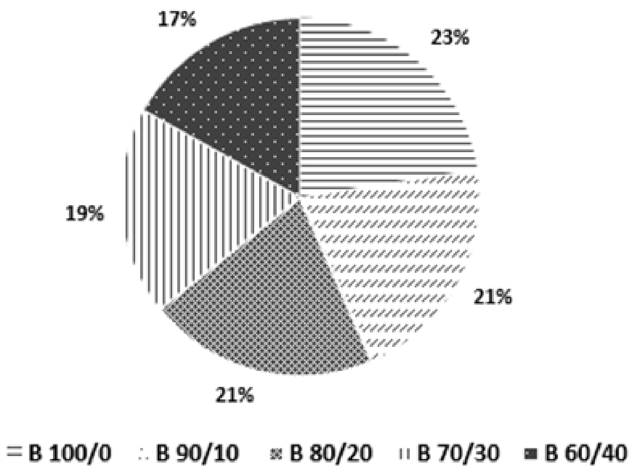

Figure 2. General acceptability of wheat/ yam breads fortified with moringa leaves powder

3.2. Discussion

The physicochemical results show that the moisture content of the composite flours (7.44 ± 0.77 to 9.00 ± 0.93) is low compared to the control flour F 100/0, the moisture content decreases after the addition of yam flour [27]. The low moisture content (less than 12%) of the flours produced, would allow better conservation. In fact, a water content of flour greater than 12% promotes the development of microorganisms [22]. These values could thus allow a good behavior during storage. The water absorption capacity of composite flours is higher (98 ± 10.09 to 150 ± 15.45), the water absorption of composite flours increases with increasing incorporation of yam flour. Some studies have shown that the water absorption of composite flours increases with increasing incorporation of yam flour [28]. This shows that these flours can be used in breadmaking because the addition of water improves the usual characteristics of the dough and increases the yield. Total carbohydrates are the most important biochemical components. The consumption of breads made from these composite flours could thus help cover the daily needs for carbohydrates. Carbohydrate requirements are estimated at 10g / kg / day for infants and 6-7g / kg / day for adults [29]. This high proportion of total carbohydrates gives them a high energy value (between 346.90 ± 5.47 and 366.21 ± 3.47) [29]. The ash contents (between 2,04 ± 0.21 and 2,38 ± 0.25) of the composite flours higher than the control flour F100/0 (0.50 ± 0.05) indicate that they contain a little more minerals than this. The increase of phosphorus, iron and zinc could be given to the addition of moringa powder because wheat flour Type 55 has a low mineral content (0.5 g/100g ash) as does yam flour (1.25 ± 0.11) [16,30]. The addition of Moringa powder to 0.25% would therefore have an influence on the mineral content of the flours.

The physico-chemical characteristics of the different flours determine those of the formulated breads. According to the proximate composition there are no significant differences ($p \leq 0.05$) between the composite breads and the whole wheat bread. The moisture content of all breads, which is equivalent to about 26%, is in the recommendations for a good conservation of bread [28]. The composite breads produced also have higher levels of phosphorus, zinc and iron, which would be explained by the mineral composition of the flours used especially moringa powder. These breads could thus contribute to the improvement of the nutritional status of the populations. According to the sensory attributes, the strongly perceived differences concern the color and aeration of the crumb. Indeed, these loaves differ from the control by a slightly green crumb colour due to the presence of chlorophyll responsible for the green color in Moringa leaves. They are less and less aerated with the increase in the rate of incorporation of yam flour. The volume of bread decreases with the increase in the rate of local flour substitution. This can be explained by the fact that the gluten proteins are then dispersed and in small quantity, they are then less likely to associate and form a network viscoelastic able to retain the fermentation gas, which gives a bread less Developed [22]. Samples B 90/10 and B 80/20 are closest to the witness. This could be explained by the fact that the increase in the rate of yam flour and the amount of Moringa powder did not result in any appreciable difference in taste compared to bread 100% wheat (B 100/0). Similar results on yam/wheat composite flour noodles may have resulted in the same finding [31]. These results showed that the aroma, taste and texture of these noodles varied very little with the increasing proportions of yam flour and had a acceptability closely related to commercial noodles. These samples were therefore appreciated for their general appearance and for the taste close to the witness. The general acceptability of breads decreases as the rate of yam flour increases. Beyond 20%, the overall acceptability of the loaves decreases. This could be explained by a gradual decrease in the crunchy texture and especially the volume. According to some authors, by increasing the amount of local flour substitution in wheat flour, there is a gradual decrease in the quality of the bread [32]. This has been attributed to reducing the strength of the flour and the capacity of gas retention due to a reduction in the gluten content, thus reducing the volume of bread and the sensory appetite of most of the composite breads. The results obtained by some studies showed that up to 20% yam flour (*Dioscorea esculenta*) could be included in the bread formulation without altering the sensory acceptance of compound bread [33]. According to these authors, the incorporation of yam flour into bread has significantly increased the antioxidant capacity of bread as tested by both the trapping of free radicals and the anti-oxidation tests of total antioxidation. Breads containing yam flour can broaden the use of yams and can be considered food that can promote health. The incorporation of Yam at 20% retains the values and characteristics of wheat bread but with a low glycemic index which could be a good food for diabetics [33]. An acceptable bread quality can be produced using a composite flour of up to 25% yam substitution (*Dioscorea bulbifera*) beyond this rate the acceptability decreases [27].

4. Conclusion

Bread was successfully produced from composite flours of wheat and yam flour fortified with Moringa leaf powder. Both bread and flours have similar physico-chemical characteristics compare to the witness. The flours and bread samples produced have increased minerals of phosphorus, iron and zinc contents. However the acceptability of these loaves decreases with the rate of incorporation of yam flour. The sensory characteristics showed that up to 20% of yam flour could be incorporated without appreciable depreciation of the characteristics of the loaves. The rate of Moringa incorporation made no change in taste except for a slightly green colouring of the bread. Beyond 20% of yam substitution rates, breads from composite flours have some imperfections (low volume, lack of crispness). Increase in yam flour substitution reduced the preference/acceptability of the bread samples. The successful production of bread with added yam flour will not only encourage the improvement of this crop, but will also improve its economic value. Breads with 20% yam flour, similar to wheat bread, could help reduce the dependence on wheat flour in our country. Moreover, the improvement of the content of these breads in minerals (P, Zn, Fe) compared to wheat bread is a real nutritional benefit. In perspective it will be able to study enzymatic activity on composite flours in order to optimize the fermentation process and compensate for the absence of gluten in yam flour.

Conflict of Interest

The authors declare that they have no conflict of interest.

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