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Substitution of Wheat by Sorghum Flour for the Production of African Bread: The Makabaye Bread

[1]Djoulde Darman Roger, [1]Gaston Zomegni, [1]Djomdi Ngouya, [2]Lendzemo Venassius and [2]Youri Alphonse
[1]*National Advanced School of Engineering of Maroua, University of Maroua, P.O. Box 46 Maroua, Cameroon, Central Africa*
[2]*Institute of Agricultural Research for Development, P.O. Box 33 Maroua, Cameroon, Central Africa*

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Corresponding Author:
Djoulde Darman Roger
National Advanced School of Engineering of Maroua, University of Maroua, P.O. Box 46 Maroua, Cameroon, Central Africa

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Abstract: Bread is one of the food items which drive the change in consumption patterns in central Africa. This bread is made basically of wheat, however, Africa does not produce enough wheat to fulfill growing demand. In order to overcome this obstacle, the idea here is to characterize some local sorghum variety the, so called "muskwari" and then substitute wheat with a local sorghum called muskwari and to use of African processing methods for bread making. The results of characterization indicate that most "muskwari" Sorghum are suitable for industrial uses. The "madjeri non crosse" was found to present interesting sensorial attributes for bread making. This study extends the list of potential use of local sorghum varieties and highlight possibilities to use most of them to produce bread.

INTRODUCTION

In Africa, the emergence of a "middle class" (34% of the 1.1 billion Africans today and which is expected to reach 42% by 2060, (Kingombe, 2014). This exponential population growth and the socio-economic evolution associated with urbanization have been accompanied by a transformation in food habits including increased consumption of bread, previously reserved for well-to-do classes (Benjelloun, 2002; Abassi *et al*., 2019; Harris *et al*., 2019). In most of sub Saharian African countries, bread is almost amongst the third most consumed food by in urban and semi-urban areas after meal porridge (maize or cassava) and meat (Mokono., 2015). In many of these countries, specially the French speaking African countries like Cameroon, Tchad, Senegal, Ivory Coast, …, everyone likes "French bread for its quality". It's say that "The French baguette is crispy and easy to store". Despite its good image and good penetration of African circles one bottle neck hinders the optimal use of this food. This is the use of wheat to make bread. The change in consumption patterns has led to an explosion in the demand for wheat in the sub-region which is much more important than it produces, according to various reports. In fact, African countries are the world's largest importers of wheat with >45 million tons in 2013 and are expected to grow by >30% by 2020, according to recent US Department of Agriculture. In order to overcome this obstacle, several researchers together with international organizations have proposed to substitute wheat with local cereals with more or less success. Yet, there are indeed typical African breads that have been consumed in sub-Saharan Africa for ages, different from French bread. The idea here is to substitute wheat with a local cereal and to use of African processing methods for bread making and to evaluate their acceptability as an alternative to African bread.

MATERIALS AND METHODS

Biological material: Ten types of off-season sorghum from Northern Cameroon were selected on the basis of their good agronomic characteristics and their ability to produce flour. They're all from the collection of the Institute of Agricultural Research for Development (IRAD) in Cameroon: The tested varieties were as follow: Safrari non Crossé; Safrari 40Crossé (touringuel), Soulkéiri, Madjéri Crossé (tolotolo), Madjéri non Crossé (tchellori), Tchangalari, Adjagamari, Bourgouri (gassa), Mandouwéiri and Soukatari (Fig. 1-4).

The wheat used for comparison were from a local miller who imports wheat from France and transforms it on locally into flour for sale to bakeries. It wheat flour from soft wheat of "Tarascon" variety according to the charterer.

Fig. 1: The tested local varieties of sorghum

Fig. 2: Substituted flours and ingredients for Makabaye bread making

Fig. 3: Makabaye bread samples

Fig. 4: Appearance of Makabaye bread

Evaluation of the technological characteristics of the local varieties of sorghum used: Technological characteristics of the ten varieties of sorghum obtained from the research center were not available. We have to carry out some physicochemical analyzes in order to have some data likely to help us better interpret the results, especially, their behavior in bread making.

Physical evaluation

Vitrosity: The index of vitrosity of the grain is given according to the visual method suggested by IBPGR-ICRISAT (Bello *et al*., 1990). Each grain of a representative sample of 10 grains is divided longitudinally in its medium using a scalpel. The proportion of vitrosity and farinaceous endosperm is estimated visually. A note from 1 to 5 is allocated to each grain. It varies from 1 = very vitreous, 2 = vitreous, 3 = semi vitreous, 4 = farinaceous, 5 = very farinaceous. The average of 10 grains represents the average index of vitrosity of the variety.

1000-kernel weight: The weight of 1000-kernel grains is determined by counting of 200 grains of sorghum which is then weighed to determine the weight (Serna-Saldivar *et al*., 1991). Thus, by extrapolation, we determines the weight of 1000 grains of sorghum.

Particle Size Index (PSI) (The hardness index): It is given according to the method developed and describe by Fliedel after crushing 20g of grains with moisture ranging between 11.5 and 13,5% in a standard needle crusher (Falling Number KT 30; head of crushing coarse semolina, adjustment 4) and sifting of crushed during 1 mn through a carpet of 250 µm mesh (sifter with draught standard Alpine 200 LS). The particle size index or PSI represents, thus, the percentage of crushed passing through the sieve. The harder the grain is the more the PSI is weak.

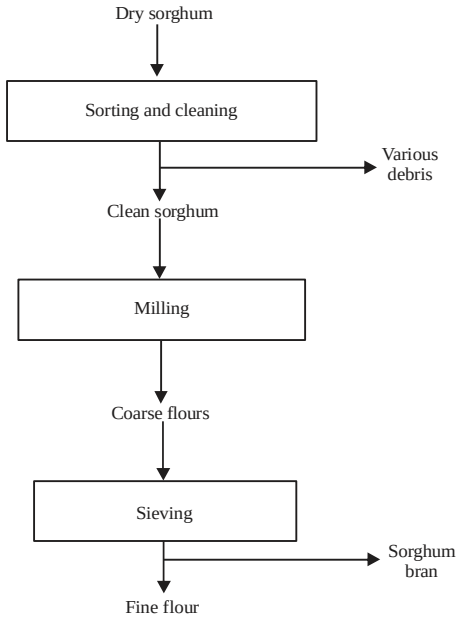

Fig. 5: Sorghum flour preparation

Color of the grain: It is determined by visual comparison according to the scale of colours of IBPGR-ICRISAT.

Evaluation of the chemical characteristics

Dhurin: It realizes according to the standardizes method described by the Official Journal of the European Communities (Methode de reference L 197/19 du 24 Juillet, 1994; Journal officiel des Communautés Européennes 1984).

Bread making: Flour preparation (Fig. 5): 1kg of each variety of sorghum was finely ground using a hammer mill. The coarse flours obtained were sieved using a series of sieves with mesh sizes ranging from 1 mm to 50 microns. Fine flours of the same grain size as wheat flour were used to make substitutions for making African bread.

Bread making formula: For bread making, we use 500 g of compound flour (X% Sorghum flour+Y% Wheat) with X = three substitutions were selected for each variety: 20, 40 and 60% (g/g) of sorghum flour/wheat flour in the standard bread making formula:

Y = amount of wheat flour added

The remaining ingredients were almost the same in all formula as follow: 10 g dehydrated baker's yeast; 30 g of milk powder; 80 g of sugar; 1 egg; 1.5 teaspoon of salt; 200 mL of milk; 120 mL of 35% fat whipping cream concerning the step of preparation (Fig. 6), all the ingredients are introduced into a robot mixer and turn at

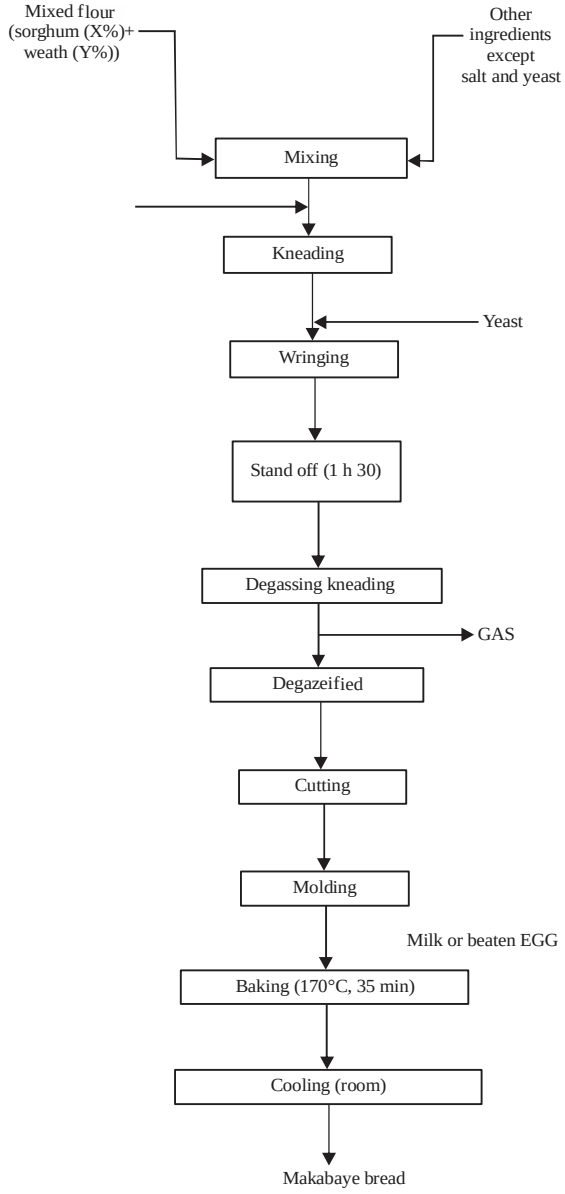

Fig. 6: Processing of African bread (Makabaye bread)

300 rpm. The salt is then added follow by yeast. The dough is kneaded until it is supple and elastic. This last is introduced in a bucket by wringing gently. The set is allowed to rise away from drafts for about 1 h 30, until it doubles its volume. The dough obtained is then spilled on the worktop and then again kneads in order to get the gas out of the dough. Degazeified dough is then cut into pieces of the same weight (about 250 g each). Each piece is roughly shaped ball-shaped and then produced in molds previously oiled. The whole paste is again allowed to rise from drafts for 1/2 h. The dough is golden with a brush soaked in milk or in beaten egg. The whole is bake in a preheated oven at 170°C. The baking lasts 35 min after which the mold containing bread is removed from the oven. The bread obtained is thus gently removed from the mold after it has cooled to room temperature (Fig. 3).

Sensory analyses: Different coded samples of bread [20, 40 and 60% (g/g) of sorghum flour/wheat flour] and bread à 100% wheat flour were presented to a panel of experienced tasters comprising 25 members of regular bread user. The sensory analysis procedure suggested by Rivella was used.

Procedure: Each taster was given an evaluation form for each of the bread samples. The form included four sensory attributes:

- Taste
- Aroma
- Visual examination (Color and overall appearance)
- Overall acceptability (harmony)

Panelists were asked to assess the breads in terms of the listed attributes using a nine-point hedonic scale with nine representing like extremely and one indicating dislike extremely. Tasting was carried out in a highly illuminated tasting room. Tasters were provided with water to rinse their mouth after each round of tasting and were prevented from communicating to each other to avoid undue bias. Each taster was served with 25 mg of each bread sample in a different coded form to allow for replications and mean values were recorded. Data were subjected to analysis of variance and means were separated using Duncan's multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

Cameroon sorghum is cultivated mostly in the Far-North region of Cameroon. This region is the principal production basins with an average annual production estimated at 1,132,670 tons which rank Farth north as the first in terms of cereal production with a total annual production estimated in 2011 at 1,599,979 tons. The majority of this production is for self-consumption with a rate that varies between 60 and 80% (DERADER, 2004-2008). The evaluated physic chemical characteristic of local sorghum varieties indicates that the weight of 1000 seeds of "muskwari" sorghum types seems greater as compared to FAO standards (25-29) and rained sorghum varieties (13-15) (Table 1). The Bourgouri, SAF 40 Crossé and Soulkeiri are vitreous (index less 3) Adjagamari, Mandoueri, SAF 40 non Crossé are semi vitreous ($V \geq 3$ and ≤ 4) Soukatari, Madjeri cross, Madjeri uncrossed, Tchangalari are floury ($V \geq 4$). Regarding the hardness, according to the PSI classification established by Fliedel *et al*., for sorghum, types: Bourgouri, Saf40 Crossé are very hard (the PSI is less than 13), Adjagamari, Madjeri non crossé, Soulkeiri and Soukatari

Table 1: Somme physical parameter of Northern Cameroon sorghum varieties

Variety	1000-kernel weight	Shape	Vitrosity	Color/Munsell indice	PSI (‰)/Hardeness	Dhurine
Adjagamari	50,4±8,7	4,41±0,48	3,6±0,5	157#CC6600/Light Yellow	13,22± 0,76/ Hard	70,31±10,91 [a]
Bourgouri	50±4,6	4,10±0,52	1,8±0,4	163#CC9900/Back Brown/white belly	9,21±0,15/ Very hard	169,41±26,11 [d]
Madjeri Crossé	44,8±3,0	3,82±0,61	5±0	216#FFFFF/Ivory white	20,31±0,25/ Soft	86,23±7,27 [a]
Madjeri non Crossé	46,4±3,2	3,67±0,72	8,4±0,5	216#FFFFF/Ivory white	12,12±0,94/Hard	108,25±15,95
Mandoueri	45,6±2,1	3,62±0,41	3,8±0,4	205#FCC0/Yellow Red	22,41±0,22/Soft	70,31±10,91 [a]
SAF 40 Crossé	46,4±2,6	4,12±0,71	1,2±0,4	212#FFF33/Golden yellow	11,23±0,92/very hard	225,11±23,67
SAF 40 non Crossé	41,2±2,2	4,11±0,72	3,4±0,5	212#FFF33/Golden yellow	13,70±0,10/hard	212,14±13,08
Soukatari	51,2±1,0	4,40±1,01	4,8±0,4	215#FFFCC/Dirty white	12,05±1,30/hard	105,43 ±2,54
Soulkeiri	39,2±2,6	4,26±0,63	2,6±0,5	216#FFFFF/Ivory white	23,12±0,91/Soft	73,39±9,88 [ab]
Tchangalari	53,2±3,34	4,80±0,27	4,6±0,5	158#CC6633/Violet red	14,11±0,85/hard	112,56±9,39

are hard (the PSI is between 13 and 16). They would give horticultural yields a yield >75% which testifies to their great ability to dehull (Good for the large processing industry). The types Madjeri Crossé and Tchangalari are soft with a medium hardness (the PSI is between 16 and 19) they may be indicated for household use but as they present poor performance in hulling they may not be useful for industries. All “muskwari” are higher than the 10 ppm as recommended by FAO. More important variation in Safrari and Bourgouri. Séréme classified sorghum varieties by tannin content and proposed corresponding uses for food. Sorghum varieties with high levels of cyanogenic glucosides (dihurin content greater than 100 ppm) are not recommended for direct household level preparations (Roger *et al*., 2008; Liu, 2018). They can be used for the preparation of beer and other fermented products. Other varieties that are either low glycoside varieties (50 pmm or less) or medium varieties (ranging from 50-100ppm inclusive) can be used for the preparation of couscous, porridge, donuts, ..., it has to be mentioned that in northern Cameroon the use of sorghum for human consumption varies according to tribes. The grain can be eaten whole or shelled to make porridge, couscous, pancakes, etc. Its fermentation yields to alcoholic beverages or traditional beer in Africa and East Asia. The characterize sorghum varieties seems so much appreciated by urban and rural populations in the area that it may have a better image if it leads to a diversification of its uses through other forms that are more attractive than culinary, technological, organoleptic and economic points of view.

Physical appearance of the breads: The crust of the bread is not too hard but slightly crisp. The crumb is yellowish to dark brown in appearance (Fig. 2 and 4). This coloration varies with both the color of the sorghum meal used and the degree of substitution. Indeed, the more sorghum flour is darker the crumb is brown.

The products obtained vary in color from yellow for 100% wheat to dark brown bread for breads with 60% sorghum flour (Fig. 3). At first glance, the color varies both with the rate of substitution of sorghum flour and with the color of the sorghum flour itself. At substitution rates above 40% the crust becomes irregular and not pleasant to view but gives off a strong smell of sorghum. The crumb is hardened over time and is not stable at rates above 20%.

Regarding the sensory analyzes we note that 80% of the tasting panel estimates that the bread made with Madjeru Crossé is identical to 100% wheat bread (Fig. 7). Several studies have been carried out on the development of composite flours in which part of the wheat is replaced by other starchy sources. The result as point out in these studies seems similar to these of previous authors, as the end product is not so much identical to modern compared by sub-product. Sorghum does not have gluten which suggests that the role played by this protein fraction of bread making flours is that sorghum is not. However, there are allergies developed, especially by young children and gluten intolerances developed by people with celiac disease (autoimmune chronic inflammatory enteropathy induced by gluten ingestion in genetically predisposed individuals causing the production of antibodies and cytokines that will cause damage to the intestinal mucosa) which puts a lot of hope in the processing of other gluten-free starchy sources such as sorghum grain. Linking the rate of sorghum substitution to similarity to 100% bread, we likely have the same felling by the panelist (Fig. 8) which confirm previous observation that the factor most affecting the similarity is not the rate of substitution but the type of variety. Despite the rate of substitution, the same Madjeru non Crossé seem closer to 100% wheat bread than other.

This can be explained by the fact that breads from sub-Saharan Africa are mainly made from millet or sorghum. On a daily basis, these cereals are eaten in the form of porridge or polenta while on festive days pancakes are made. Niger millet balls (fura) are closer to Western bread but it is the tapalapa from Senegal that most resembles it, since, it is kneaded and fermented before cooking. The substitution may thus not affect the perception of local population as they may think this is not a foreign product as it’s close to what they use to consume.

Bread made from wheat semolina is usually made in Northern Africa. Some loaves are raised, such as matlou (round bread) or tamtunt (Kabyle bread). Very close to the Greek pita, Egyptian, Lebanese and Syrian breads are

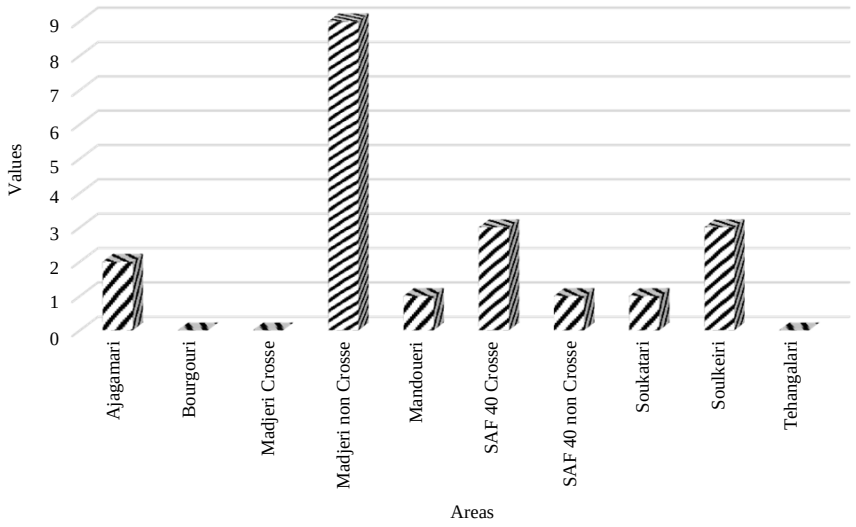

Fig. 7: Similarity with 100% wheat bread

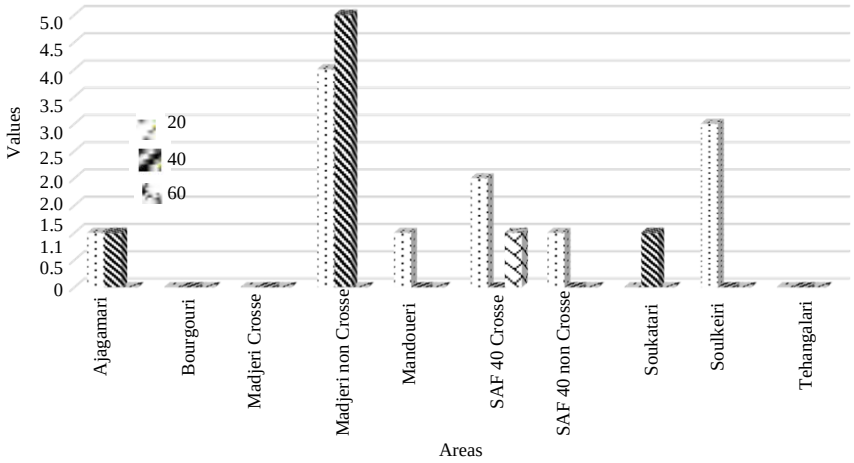

Fig. 8: Similarity of % wheat bread compare to bread make with sorghum as substitute

often flat, supple and crumb-free. Fold, they allow to serve directly in the dish arranged in the center of the table. In Morocco, flatbread is M'semmen. Olive oil is added to the dough of some breads. Of course, recipes vary a lot from country to country! It thus, likely to. The color, texture and taste were the factor which determines more acceptability of breads (Fig. 9). The urban dynamics that, we observe in the region may favors changes in eating and cooking habits: We see the emergence of new needs in terms of light, richer foods (bread, biscuits, porridge, donuts, beers, compound flours that can combine sorghum and wheat, gritz, parboiled sorghum, puffed products, ...,).

The most preferred sample according to panelist is again the one bake with Madjeri crossé, followed by Mandoueri and soukatari. Bourgouri and Tchangalari bread were less preferred by panelist.

The “Madjeri bread” exhibited significant ($p<0.05$) increase in scores for aroma (5-8) vs. (4-5) in commercial vines (Fig. 10). This can be link to the vitreouness of Madjeri (8,4±0,5) and confirm the high levels of flour recorded (Table 1). The taste exhibit records varying from (3-6) vs. 4 and 7, respectively for madjeri bread at 60 and 100% wheat bread, respectively. Meaning that sorghum bread present lest taste than wheat bread. This may be due to absence of gluten from sorghum bread. Anyway, we can notice a strong correlation r = 0.91) between the percentage of sorghum flour and panelists choice base on taste. This may indicate that the sorghum is the main ingredient driving consumer’s choice in theses local bread. In regard to the appearance wheat bread seem to be better than sorghum breads.

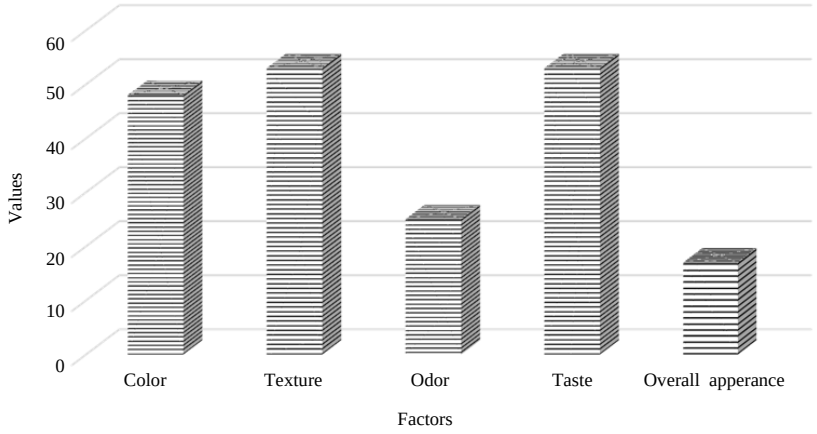

Fig. 9: Factors affecting more the acceptability of samples

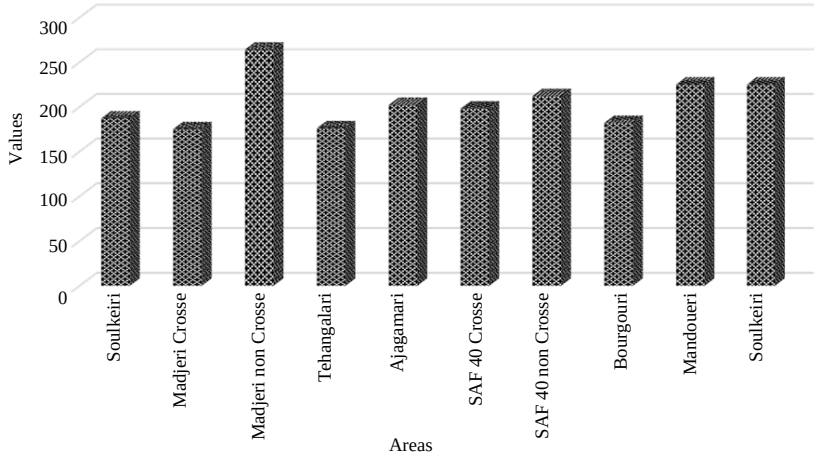

Fig. 10: Preference of samples according to type of sorghum

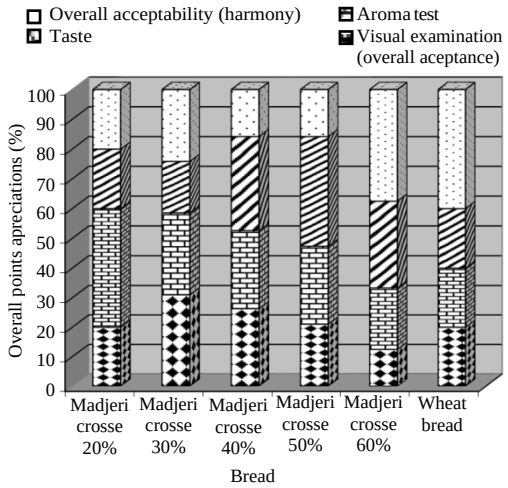

Fig. 11: Overall sensorial attributes of sorghum based African bread

Overall acceptability (harmony) (Fig. 9-11) indicates that sorghum bread are les accepted when compared to wheat bread. This may also be due to the strong acidity recorded.

Irrespective of the type of the percentage of sorghum flour added, multiple regression analyses revealed an inverse significant ($p<0.05$) relationship between aroma, taste, visual examination and overall acceptability of a bread. While vitrosity also associated significantly ($r = 0.4$; $p<0.05$) with crisp (Fig. 11).

CONCLUSION

This research aims at studying characteristics of some Cameroonian sorghum varieties “muskwari” and propose the substitution of wheat flour by “msukwari” flour in the African bread processing. The results of characterization indicate that most “muskwari” Sorghum are suitable for industrial uses. The “madjeri non crosse” exhibited

interesting sensorial attributes for bread making. This study extends the list of potential use of local sorghum varieties and highlight possibilities to use most of them to produce bread. First results obtained and discuss above give great expectations for further cocoa vine development. However, the variation of noticed in sensorial analysis shows that substitution of wheat by sorghum needs standardization and more systematic production in order to ensure a homogenous and more quality product.

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