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Study of the functional properties and breadmaking ability of a composite flour made of cowpea (*Vigna unguiculata*) and soft wheat (*Triticum aestvum*)

Etude des propriétés fonctionnelles et de l'aptitude à la panification d'une farine composite à base de niébé (Vigna unguiculata) et de blé tendre (Triticum aestvum)

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RÉSUMÉ :

L'utilisation de farine de blé seule dans les produits de boulangerie met en péril la sécurité alimentaire non seulement sur le plan de la disponibilité mais également de la qualité nutritionnelle de ces produits. La présente étude a été menée dans le but de réduire la quantité de blé utilisée en panification par une substitution partielle avec la farine de Niébé (1 à 30 %), vu sa forte teneur en protéine. La composition chimique des farines de blé, niébé et des mélanges de farine blé / niébé a été déterminée, ainsi que leurs propriétés fonctionnelles et rhéologiques. Une analyse sensorielle a été réalisée sur le pain témoin (100 % farine de blé) et sur les pains composite (substituée à 10 %, 15 %, 20 %, 25 % et 30 % par la farine le niébé). La teneur en protéine, fibres, lipides et minéraux augmente avec l'incorporation de la farine de niébé tandis que la teneur en eau et glucides diminue. Les propriétés fonctionnelles augmentent tandis que caractéristiques rhéologiques de la pâte se détériorent. Les pains à différents taux de substitution ont un volume significativement inférieur à celui du pain témoin, sans substitution. Les résultats d'analyse sensorielle indiquent que les pains issus des mélanges de farine blé / niébé sont acceptables jusqu'à 25 % d'incorporation, et que le pain à 10 % d'incorporation de farine de niébé est supérieur au témoin. Cette analyse suggère que la farine de blé peut être efficacement remplacée par de la farine de niébé jusqu'à un taux de 25 %, ce qui contribuerait à valoriser nos ressources locales et à diminuer les importations de blé.

Mots clés : Farine de blé, Farine de niébé, Farine composite, Panification, Analyse sensorielle.

ABSTRACT

The use of wheat flour alone in bakery products endangers food security not only in terms of the availability but also the nutritional quality of these products. The present study was carried out with the aim of reducing the quantity of wheat used in breadmaking by partial substitution with cowpea flour (1 to 30 %), given its high protein content. The chemical composition of wheat flour, cowpea and wheat / cowpea flour mixtures was determined, as well as their functional and rheological properties. A sensory analysis was carried out on the control bread (100 % wheat flour) and on the composite breads (substituted at 10 %, 15 %, 20 %, 25 % and 30 % by cowpea flour). The protein, fiber, fat and mineral content increases with the incorporation of cowpea flour while the water and carbohydrate content decreases. The functional properties increase while the rheological characteristics of the dough deteriorate. The breads with different substitution ratios have a significantly smaller volume than the control bread, without substitution. Sensory analysis results indicate that breads made from wheat / cowpea flour mixtures are acceptable up to 25 % of cowpea flour incorporation, and present a better appreciation at 10 % incorporation, compared to the control bread. This analysis suggests that wheat flour can be effectively replaced by cowpea flour up to a rate of 25 %, which would enhance our local resources and reduce wheat imports.

Keywords: Wheat flour, Cowpea flour, Composite flour, Breadmaking, Sensory analysis.

1. INTRODUCTION

Professional constraints, lifestyle and acculturation significantly influence food trends. More and more, fast foods are solicited, as is the case of bread, whose consumption is constantly increasing in developing countries (Okonkwo, 2014). Bread is often made from wheat flour that differs from other plants by its viscoelasticity properties. Indeed, wheat contains a protein call gluten consisting of gliadin and glutenin which are responsible for the elasticity and extensibility of the dough respectively. These properties make wheat flour suitable for bread making (Kamelah, 2016). In Cameroon as in other tropical countries, all the wheat consumed is imported, the values amount to 691,778 tones for an expenditure of around 103.7 billion CFA francs (National institute of statistics, 2017) and this import dependence destabilizes food security. Moreover, when the wheat is milled, it loses the major part of its nutrients which are mainly located outside the seed, resulting in a deficit in macro and micronutrients of wheat flour-based products. This is the reason why the Food and Agriculture Organization (FAO, 2006) and developing countries, collaborate to find out the possibility to replace or reduce the amount of wheat flour in bread using locally produced flours (Okonkwo,2014). Wheat like all other cereals is rich in sulfur amino acids but poor in lysine and methionine, whereas legumes are rather rich in them. Therefore, a combination of legumes and cereals can improve the nutritional value of the mixture by reciprocal correction of their acid profile amines (Ouazib, 2017).

Cowpea (*Vigna unguiculata*) is an annual herbaceous legume grown predominantly in Africa and is an important staple crop providing an affordable source of protein (Boukar et al., 2011). According to the FAOStat (2019, the worldwide production of cowpea in 2017 was 8157000 tons, with 7107000 tons from Africa and 198000 tons from Cameroon who is one of the top ten producers of dry cowpea. For this purpose, cowpea is an affordable food and according to the data of the FEWS NET (2020), the average price of cowpea in the Far North Region of Cameroon is 200 FCFA/kg. Cowpea contains 25 % protein, 50-67 % starch, folic acids and essential micronutrients (Mebdoua, 2011).. Due to its relatively high protein content and interesting micronutrient composition, cowpea could be valued in several areas, especially in composite flours and the enrichment of traditional foods (Casimir et al., 2016).Vigna Unguiculata flour can then be used to fortify flours that are poor in proteins such as those of certain tubers and cereals (Appiah et al., 2011). Indeed, several studies have evaluated the ability of bread production from composite flours constituted of cowpea and wheat. This is the case with Oluwole et al (2013) who showed that replacing wheat with cowpea increases the protein level of bread; Olapade and Oluwole (2013) showed the ability to make a wheat-based composite flour-purchase (*Digitaria exilus staph*) enriched with cowpea; Alima et al (2016) showed the influence of cowpea flour incorporation on bread preservation. All these studies show that composite flours can give products whose characteristics are similar to those of wheat flour-based products, with positive effects on the functional, physicochemical and nutritional properties. Therefore, the combination of cowpea and wheat in breadmaking would improve the nutritional quality of bread while maintaining wheat bread characteristics. However, these works are relevant only in bakeries. Meanwhile one of the difficulties of integrating composite flours is the complexity of their use, because they must be formulated for each baking. However, if composite flours were available and pre-formulated as in the case of wheat flour, they would be readily adopted. Generally, the formulation of composite flours from wheat and local crops, is made of local crops and wheat flour already adjust resulting in the dilution of final formulation. In addition, the wheat flour was adjust according its own shortcomings. So, to facilitate composite flours integration in other to contribute in the fight against food insecurity, we have undertaken this study with the aim of producing a pre-formulated breadmaking flour from cowpea and soft wheat.

2. MATERIALS AND METHODS

2.1. Raw materials

Cowpea seeds (*Vigna unguiculata*) and soft wheat (*Triticum aestvum*) were used: Cowpea seeds(*Vigna unguiculate)* used in our study were purchased from the local Bafoussam market and soft wheat seeds (*Triticum aestvum*), Additives and processing aids: ascorbic acid, lipase (monozyme L), gluco-oxidase (gluzyme), xylanase (pentopan), DATEM (diacetyl-tartic ester of mono and fatty acid diglycerides) and potable water from the Cameroon Wheat Processing Company (SCTB, Douala-Cameroon). Yeast (Germapan) provided by SOMADIR (casablanca,Maroc) Salt (white Diamant) provided by SOCAPURSEL (Douala,Cameroon) were purchased in the local supermarket .

2.2. Production of Cowpea flour

The flour production of *Vigna Unguiculata* was made by modifying the method as described by Olapada and Oluwole (2013). Cowpea seeds were dehulled and washed to remove foreign materials. The cowpea seeds were soaked for 12 hours in drinking water to reduce antinutritional factors. Then the cowpea seeds were peeled and dried in the oven during almost 24hour at 45 °C. Simultaneous grinding and sieving of the dried seeds at 160 µm were done using a laboratory mill.

2.3. Production of soft wheat flour

Wheat flour was produced according to the standard process of processing wheat flour (AACC, 2000). After determining the moisture of the wheat, the water was added to reach a humidity wet basis of 16 % according to equation 1, then the wheat was at rest for at least 16 hours. Simultaneous grinding and sieving of wheat seeds at 160 µm were done using a laboratory mill.

$$\boldsymbol{Water\ (g)} = \left(\frac{\mathbf{16}}{\mathbf{100-16}} - \boldsymbol{Moisture}\right) \cdot \boldsymbol{m} \quad (1)$$

Moisture: dry basis sample humidity (g/100 g d.b.); **m**= dry mass of the sample used (g).

2.4. Formulation of composite flours

The composite flour was formulated by substituting wheat flour with cowpea flour at different proportions (Table 1). The correction of the defects in dough and bread resulting from these flours passes using some enzymes and additives. The Table 2 summarizes the different enzymes and additives used with their corresponding concentrations.

Table 1: Proportions of wheat flour and cowpea used

Sample	Wheat %	Cowpea %
A	100	0
B	90	10
C	85	15
D	80	20
E	75	25
F	70	30

A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, with WF/CF corresponding to wheat flour/cowpea flour.

Table 2: Enzyme and additive used

Enzymes/additives	Mass in g for 100g
Acide ascorbique	0.022
DATEM	0.5
Lipase	0.004
Xylanase	0.002
Gluco-oxydase	0.01

2.5. Chemical characterization

Wheat flour, cowpea flour and the composite flour were analyzed for moisture, ash, protein, fat, fibers and minerals according to the standard methods of the association of official Analytical Chemists (AOAC, 1990). Reducing sugars were extracted by the method (AACC, 1990), specific to flour and meal, and dosed by the Colorimetric method using the DNS (3, 5-dinitrosalicylique acid) AACC (1999). The principle of this method is the reduction of DNS in an alkaline medium by sugars and the formation of a reddish-brown product when heated. The intensity of the color developed at 540 nm is proportional to the sugar concentration. Total lipids were extracted from the Soxhlet according to the Russian method described by Bourely (1982): It is based on the differential solubility of lipids in organic solvents (hexane or petroleum ether). It is done hot for about 8 hours. After this operation, the solvent remaining on the sample is removed by drying in an oven at 45 °C.

2.6. Determination of water absorption capacity of cowpea, wheat, and WF/CF flours

The water absorption capacity of flours was determined by the method described by Lin et al (1974) served for this measure. Flour (1 g) was mixed with 10 mL of water in a centrifuge tube and put in the Bain-Marie for 30min at different temperatures ranging from 30 to 90 °C with intervals of 10 °C and then centrifuged at 4500 rpm during 15minutes. The water absorption capacity was estimated as the amount of water in mL retained by the sample pellet after settling per gram of flour according to the formula:

$$\mathbf{Ka = (Vo\text{-}V1)/M \cdot 100} \quad (2)$$

M = dry weight of sample used (g), V_0= initial volume of water (ml), V_1= sedimented volume after centrifugation (mL), Ka = water absorption capacity (g/100 g)

2.7. Determination of swelling capacity of cowpea wheat, and WF/CF flours

The swelling capacity of flours was determined by the method described by Lin et al (1974). Flour (1g) was mixed with 10 ml of water in a centrifuge tube and put in the water bath for 30min at different temperatures ranging from 30 to 90 °C with intervals of 10 °C and then centrifuged at 4500 rpm for 15min. The pellet from the centrifugation was collected and weighed; the swelling capacity is given according to the formula:

$$\mathbf{Tg = (M_1 - M_2)/M_1 \,.\, 100} \quad (3)$$

M_1 = mass of the pellet (g), M_2 = initial flour weight (g), Tg = swelling capacity (g / g)

2.8. Determination of amylase activity

The test of Hagberg gives the determination of the enzymatic activity of the α-amylase of flours according to ICC 107/1, ISO 3093-2004, AACC 56-81B by the Hagberg-Perten number. The test is known as failing number. The failing number measures the time taken by an agitator to cross the preparation under the effect of its own weight. After determination of the moisture content and depending on it, a mass of flour was weighed and poured into a viscometric tube. 25 mL of distilled water was added to the tube with the flour and then stirred vigorously by hand, in order to obtain a uniform suspension. The tube and agitator were placed inside the boiling water bath and triggered the automatic meter.

2.9. Rheological Analysis of dough

The dough rheological characteristics of the composite flour was done with a Chopin NG alveograph, associated with an alveolink integrator recorder (Chopin Technologies, Villeneuve-La-Garenne, France) according to standard protocol ISO.27971. It is based on the three-dimensional extension of a piece of dough (water + flour) which, under the action of an air pressure, deforms into a bubble. The Alveolink reproduces the dough deformation curve under the influence of the mechanically generated gas thrust. 250g of flour was poured into the kneader at 25 ° C. After activation of the kneading function, the water of 2.5 % NaCl was added according to the percentage of humidity during the first 20 seconds. After 8 minutes kneading the rotation of the crusher has been reversed to eliminate the dough that will be rolled and cut into test tubes using a cookie cutter. These will be placed in the rest room until the 28th minute then they will be on the platinum inflated with a generator. The acquisition of the measurements was recorded by a calculator which gives the values P, L, P / L and W.

2.10. Assessment of flour coloring

The color of flours was measured using a chromameter CR210 (Minolta France S.A. Quarries – sur-Seine) based on the parameters L *, a * and b * Himida et al (2012). The values of (L) represent the brightness or luminance of the flour, the higher the value, the more the flour is clear, (a) the green-red balance and b the blue-yellow balance. The whitening index (IB) represents the overall whitening of food products that can indicate the extent of discoloration during the drying process. The instrument was calibrated against a tile Light yellow reference. A glazed cell containing the flour was placed over the source and covered with a white plate and the values L *, a* and b * were recorded. The Flour Whitening index (IB) was determined according to the following equation

$$\mathbf{IB = 100-\sqrt{(100-L)^2 + a^2 + b^2}} \quad (4)$$

2.11. Baking test

The loaves of different proportions were prepared using the French bread protocol, according to Ndiayé et al (2009). Initially, the ingredients (composite flour 1.2 kg, water (adapted), salt 12 g, yeast 6 g) was weighed and mixed for 15 to 20 minutes, the obtained dough was divided in parts of 200 g and moulded. After putting the moulded dough in bread trays, they were fermented for 1 h 15 min, at 35 °C, and baked in the oven at 220 °C for 19 minutes. The bread volume was determined by the rapeseed displacement method AACC (2009).

2.12. Sensory analysis

The purpose of this operation was to assess the organoleptic characteristics of the bread after cooling. It was processed by a hedonic test according to the method described by Amerine et al (1973)**.** The bread samples were presented at the same time to the tasters. They had to fill out a sheet by giving their appreciation of the loaves on a scale ranging from 1 (bad) to 5 (very good) for the specific descriptors that are (appearance, smell, texture, taste, and the crispness). Additional information on sex, age, and frequency of bread consumption was also requested for the characterization of the surveyed population.

2.13. Statistical analysis

The results of the analyses performed in triplicate were expressed by standard deviations and were calculated using the Excel software version 2013, the statistical analysis by SPSS software version 23.

2.14. Principal component analysis (PCA)

For a better overview of our results, a principal component analysis (PCA) was performed, using the following parameters: The approximate chemical composition (Proteins, lipids, carbohydrates, water, fibers, calcium, magnesium, phosphorus and potassium); functional properties (water absorption capacity and swelling capacity); rheological properties (rheological behavior of the dough, coloring, volumes) and sensory properties (appearance, odor, taste, texture, crispness and overall satisfaction).

3. RESULTS AND DISCUSSION

3.1. Chemical Composition of cowpea flour, wheat flour and WF/CF mixtures

Tables 3 and 4 show the chemical composition of the different flours. It is observed that the proteins, lipids, fibers, phosphorus, calcium, magnesium, potassium and moisture content differ significantly $p < 0.05$ with the incorporation of cowpea flour which is rich in those elements compared to wheat flour. However, ash and reducing sugar content do not differ significantly with cowpea flour incorporation. However, although rich in carbohydrates, wheat flour has the same content as that of cowpea in ash and reducing sugars. The incorporation of cowpea flour thus results in an increase in proteins, lipids, phosphorus fibers, calcium, magnesium and potassium with values ranging from 14.44 % - 18.92 %; 1.93 % - 5.60 %; 3 % - 3.96 %; 0.34 % - 0.49 %; 0.027 % - 0.051 %; 0.12 % - 0.60 %; 293.33 % - 337.73 % respectively and a decrease in water content. Which varies between 14.13 (soft wheat flour) and 10.97 % (70 % wheat and 30 % cowpea). There is also a decrease in the carbohydrate content with the increase in cowpea flour with values ranging from 70.80 (soft wheat flour) to 66.94 (70 % wheat flour and 30 % cowpea flour). Globally we notice that the nutritional value of the composite bread increases with the incorporation of cowpea flour.

Table 3: Chemical Composition of wheat flour, cowpea and FB/FN mixtures

Sample	Chemical composition						
	Proteins	**Moisture**	**Lipids**	**Carbo-hydrates**	**Sugar**	**Fibers**	**Ash**
A	13.12 ± 1.31^{b}	14.13 ± 0.69^{a}	1.93 ± 0.85^{b}	70.80 ± 1.48^{a}	1.99 ± 0.09^{a}	2.95 ± 0.05^{b}	0.57 ± 0.00^{a}
N	26.87 ± 2.37^{a}	10.07 ± 0.09^{c}	3.99 ± 0.39^{a}	59.05 ± 2.66^{b}	1.91 ± 0.02^{a}	6.16 ± 0.15^{a}	0.75 ± 0.03^{a}
B	14.12 ± 1.32^{b}	11.53 ± 0.13^{b}	1.37 ± 0.87^{c}	72.96 ± 2.32^{ba}	1.92 ± 0.00^{b}	3.16 ± 0.05^{cd}	0.68 ± 0.00^{a}
C	15.71 ± 2.61^{b}	11.56 ± 0.00^{b}	2.68 ± 1.85^{b}	70.03 ± 0.76^{ba}	1.91 ± 0.00^{b}	3.28 ± 0.03^{bcd}	0.76 ± 0.04^{a}
D	15.83 ± 2.33^{b}	11.55 ± 0.00^{b}	3.80 ± 0.0^{a}	68.81 ± 2.31^{ba}	2.26 ± 0.23^{a}	4.13 ± 1.18^{b}	0.89 ± 0.11^{a}
E	16.28 ± 2.48^{b}	11.15 ± 0.15^{b}	4.40 ± 0.30^{a}	68.16 ± 2.63^{b}	1.88 ± 0.00^{b}	3.57 ± 0.02^{bcd}	0.97 ± 0.05^{a}
F	16.47 ± 2.35^{b}	10.97 ± 0.38^{b}	5.60 ± 0.53^{a}	66.94 ± 2.50^{b}	1.88 ± 0.00^{b}	3.95 ± 0.05^{b}	093 ± 0.07^{a}

Results with the same letters in the same column have no significant difference ($P < 0.05$)
A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, N: 100 % cowpea with WF/CF corresponding to wheat flour/cowpea flour.

Cowpea is a legume and they generally have a good nutritional profile with significant proteins and micronutrients levels (Farah, 2015). Meanwhile, wheat as a cereal is not rich in proteins and it loses most of its nutrients when it is processed into flour. These results corroborate to those of Mohamed (2012) who noted the superiority of the nutritional quality of cowpea compared to wheat except for lipids and fibers. Nevertheless, we have opposite results for moisture which is rather superior for cowpea. Similar results have been obtained by Olopade and Adeyemo (2014), who demonstrated the increase in macro and micronutrients and the decrease in water content with the incorporation of cowpea flour. Igbabul et al. (2014) reported similar results with bread made from wheat, plantain and soy. Indeed, the protein content is an essential element in determining the rheological behavior of the dough and later the bread quality (Doga et al ., 2018).

Table 4: Mineral Composition of wheat flour, cowpea and FB/FN mixtures

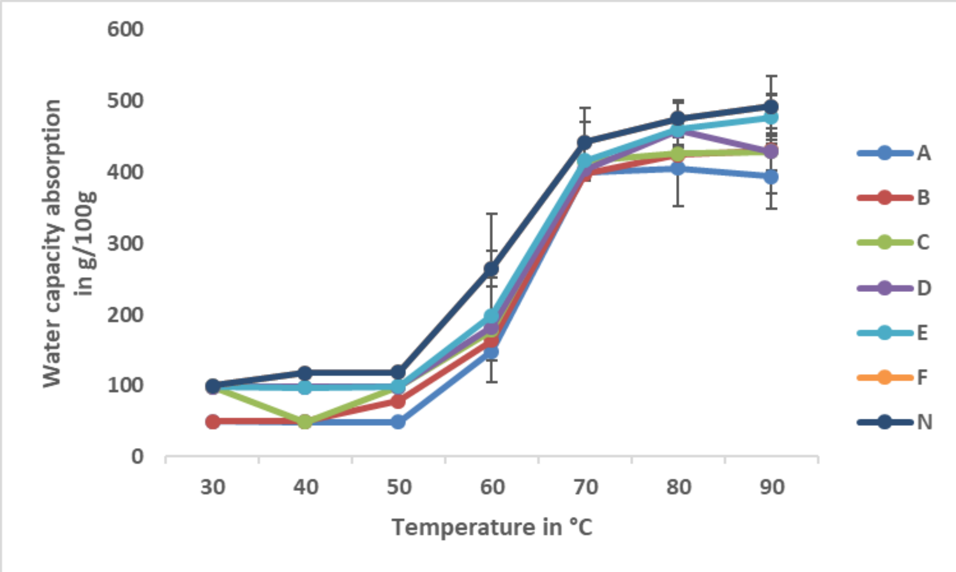
	Mineral composition			
Sample	**Phosphorus**	**Calcium**	**Magnesium**	**Potassium**
A	334.66 ± 4.50[b]	26.00 ± 1.00[b]	122.02 ± 1.00[b]	293.33 ± 0.58[b]
N	864.44 ± 4.19[a]	100.66 ± 6.02[a]	198.23 ± 7.50[a]	672.10 ± 2.15[a]
B	382.33 ± 2.51[cd]	33.46 ± 1.50[de]	124.10 ± 1.01[dc]	294.75 ± 0.25[d]
C	377 ± 20.80[cd]	37.13 ± 1.02[dc]	130.39 ± 4.42[d]	294.33 ± 0.57[d]
D	397.00 ± 2.64[c]	40.50 ± 1.32[c]	130.24 ± 1.64[d]	296.52 ± 1.29[d]
E	406.66 ± 62.51[c]	44.06 ± 0.90[c]	141.57 ± 2.97[c]	318.38 ± 15.98[c]
F	488.66 ± 8.08[b]	52.00 ± 1.00[b]	161.63 ± 2.91[b]	337.73 ± 13.11[b]

Results with the same letters in the same column have no significant difference ($P < 0.05$)
A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, N: 100 % cowpea with WF/CF corresponding to wheat flour/cowpea flour.

Regarding the protein quality, our formulations are recommandable. In fact, the low methionine and cysteine content and the high lysine content observed in cowpea seeds is complemented by its association with wheat, since it is limited in lysine and rich in methionine (Karolin et al ,2017). This combination will make it possible to have bread providing all the essential amino acids, which are generally found in animal meats. Compared to meat, bread is more accessible and consumed. Therefore, a combination of legumes and cereals can improve the nutritional value of the mixture by reciprocal correction of their acid profile amines (Ouazib, 2017). In contrast, carbohydrate content decrease with the substitution rate. Similar trends have been reported by Serrem et al (2011), in the fortification of wheat flour with defatted soy flour. In addition, the use of these composite flours are of paramount importance in reducing the risk of diabetes thanks to their low glycemic index (Ugwuona et al., 2012). With regards to the water content of the samples analyzed (11.53 % - 11.15 %), it complies with the standard required for the storage of flours which is 10 to 15 % (Doga et al., 2018). The increase in fiber content will be beneficial to the health of consumers by facilitating the digestion of food at the colon. This action reduces the risk of constipation associated with the consumption of wheat flour dishes (Elleuch et al., 2011). The increase in mineral content is beneficial in the sense that they play a role in body development and child growth. It could also reduce the occurrence of certain nutritional deficiencies (Doga et al., 2018).

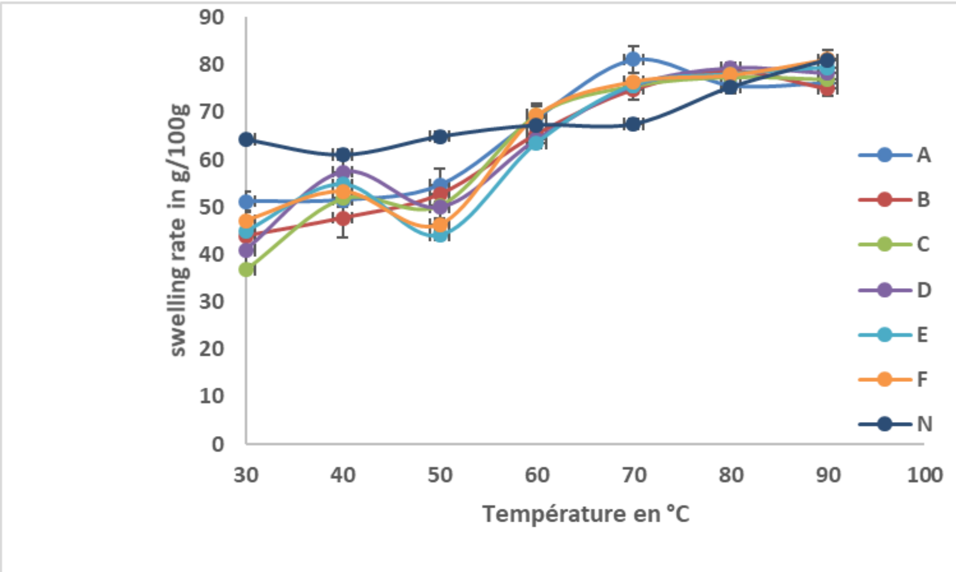
3.2. Water absorption Capacity (K_A) and swelling capacity

The substitution of wheat flour with cowpea flour has a significant impact on water absorption and swelling capacities. Figures 1 and 2 show the evolution of water absorption and swelling capacity of flours with temperature and the incorporation of cowpea flour. They show that for the same temperatures, cowpea flour as well as the mixtures of FB/FN flours absorb more water and inflate more. At the same time, the increase of the water absorption capacity with temperature for all the flours is observed.



A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, N: 100 % cowpea with WF/CF corresponding to wheat flour/cowpea flour.

Figure 1: Water absorption capacity of composite flours



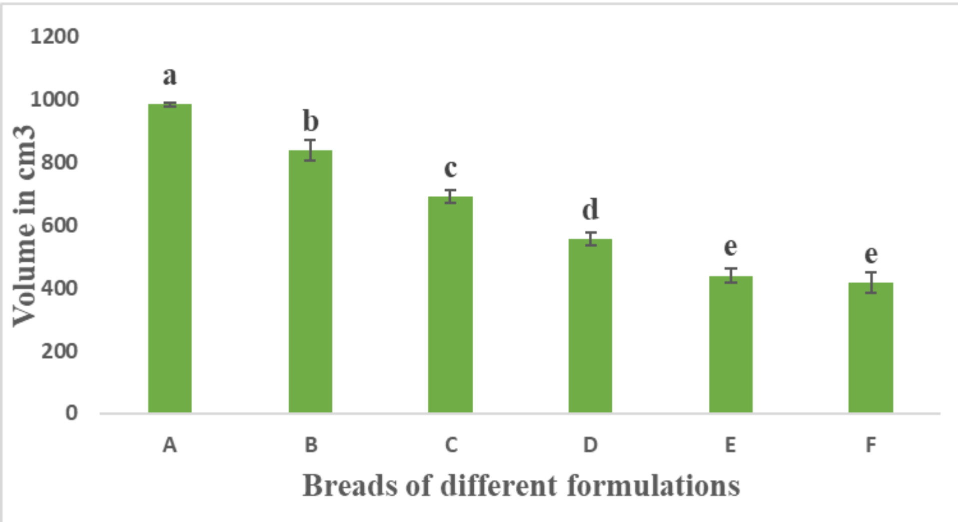
A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, N: 100 % cowpea with WF/CF corresponding to wheat flour/cowpea flour.

Figure 2: Swelling capacity of composite flours.

The increase of the water absorption and swelling capacities for all flours with the increase in temperature can be explained by the fact that at high temperatures the hydrogen bonds stabilizing the starch structure rip open and fix water molecules (Awuchi et al, 2019). The decrease in absorption from 70 °C for wheat and the continually low growth of the water absorption of cowpea flour reveals that wheat and cowpea starch do not have the same gelatinization temperature. The increase in water absorption and swelling capacities observed with the incorporation rate of cowpea is due to the high-water absorption of cowpea flour. This result can be explained by the more abundant proteins' presence compared to wheat. The polar amino acids of proteins have an affinity for water. In fact, the hydrophilic and hydrophobic properties of proteins permit them to interact with water in foods (Awuchi et al., 2019). According to George et al (2019), the gelatinization of starch and the denaturation of proteins during heat treatment is the reason for the high-water absorption capacity of cowpea flour. Otherwise, the low moisture content of cowpea flour contributes to its water absorption capacity. These results were also observed by Alima et al (2016), who reveal the increase in absorption capacity with cowpea substitution.Similar results have been observed by Diallo et al (2015) during the substitution of wheat flour by voandzou flour .The water absorption capacity is very important in baking, in fact the more flour absorbs water, the more it is manageable and the higher the yield. According to Olapade et al. (2013), water absorption and swelling capacities contribute to dough formation and stability.

3.3. Drop Index

The drop index permits to measure the activity of the amylase; it is given in seconds and is inversely proportional to the activity of the alpha amylase. Figure 3 show the drop index of Wheat flour, cowpea and WF/CF Drop. In this graph, a reduction of the parameters with the incorporation of cowpea is observed. The higher the rate of cowpeas, the more the fall index increases. The values are between 373 to 441 s, which are above the standard. So, all these flours have low amylase activity. The control (100 % wheat flour), and the mixtures 90/10, 85/15 (wheat flour % / cowpea flour %) have the lowest value and are not significantly different. These results show that the fall time increases with the incorporation of cowpea.



A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, with WF/CF corresponding to wheat flour/cowpea flour.

Figure 3: Influence of the substitution of wheat flour by cowpea flour on bread volume.

The fall indices observed are all high compared to the optimal standards for bread-making which places the fall time in the interval 220-280 (Bensedik, 2017). Therefore, all these flours have a low amylase activity. There is a correlation between protein content and falling number (Ross et al., 2012), and in the present study, there was a negative correlation between falling number and protein content. The same result was obtained by Kisonas et al, (2018) in their study on the relationship between falling number, α-amylase activity and milling on the quality of some bakery products of soft white wheat.

3.4. Rheological Analysis of dough

Table 5 show the influence of wheat substitution by cowpea on the rheological parameters of flour. It is noticed that the incorporation of cowpea flour has a major impact on the rheological characteristics of the dough, including:

- The (P) tenacity value of the dough (indicator of the gas retention by the dough) increases with the incorporation of cowpea flour. All composite flours have a significant difference with the threshold indicator ($p < 0.05$). The mixture 90/10 and 85/15 (wheat flour % / cowpea flour %) are not significantly different ($P < 0.05$) and mixtures 80 %, 75 %, 70 % (wheat flour) and 20 %, 25 %, 30 % (cowpea flour) are not significantly different ($P < 0.05$).

- Swelling (G) in relation to extensibility decreases as cowpea flour is incorporated. All flours are significantly different from the control.

- Deformation work (W) and elasticity (IE) decrease with the rate of incorporation of cowpea flour. The mixture 90/10 (wheat flour % / cowpea flour %) and 100 % wheat flour are not significantly different ($P < 0.05$). In the same way 80/20 and 70/30 (wheat flour % / cowpea flour %) are not significantly different ($P < 0.05$).

- The P/L ratio, which reflects the equilibrium between the tenacity and the scalability of the pulp, increases when the rate of cowpea incorporation increases. The mixture 90 % wheat / 10 % cowpea flour and 85 % wheat flour / 15 % cowpea flour are not significantly different ($P < 0.05$) and 75 %, 70 % (wheat flour) and 25 %, 30 % (cowpea flour) are not significantly different ($P < 0.05$).

- The elasticity Index (IE) decreases with the increase in cowpea flour. Mixture 90 % wheat flour / 10 % cowpea flour, 85 % wheat flour / 15 % cowpea flour are not significantly different ($P < 0.05$) from the control 100 % wheat flour and formulations 80 %, 75 %, 70 % (wheat flour) / 20 %, 25 %, 30 % (cowpea flour) are not significantly different ($P < 0.05$).

Table 5: Influence of wheat substitution by cowpea on rhéological parameters of flour

Sample	Rheological parameter					
	IE	P	L	G	W	P /L
A	67.1 ± 0.3^{a}	84 ± 1^{e}	72 ± 0.00^{a}	18.9 ± 0.00^{a}	247 ± 1^{a}	1.16 ± 0.01^{d}
B	56.85 ± 0.15^{b}	121 ± 4^{d}	43.5 ± 1.5^{b}	14.9 ± 0.00^{b}	224.5 ± 2.5^{a}	2.79 ± 0.19^{c}
C	51.2 ± 0.9^{c}	126.5 ± 7.5^{cd}	41.5 ± 0.5^{c}	14.35 ± 0.05^{c}	220.5 ± 10.5^{b}	3.05 ± 0.22^{c}
D	0.00 ± 0.00^{d}	139.5 ± 11.5^{ba}	30.5 ± 1.5^{d}	12.3 ± 0.3^{d}	188 ± 24^{c}	4.565 ± 0.155^{b}
E	0.00 ± 0.00^{d}	165 ± 1^{a}	26.5 ± 0.5^{e}	11.5 ± 0.1^{e}	191 ± 3^{c}	6.23 ± 0.08^{a}
F	0.00 ± 0.00^{d}	157.5 ± 17.5^{ba}	23 ± 0.00^{f}	10.5 ± 0.2^{f}	157 ± 16^{d}	6.85 ± 0.76^{a}

Results with the same letters in the same column have no significant difference ($P < 0.05$)
A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, N: 100 % cowpea with WF/CF corresponding to wheat flour/cowpea flour. P: Maximum pressure, L: length, G: Swelling, W: surface of the Alveogramme, IE: Elasticity index.

The increase of dough tenacity (P) with the incorporation of cowpea flour, is due to the increase of protein content which provide strength for the retention of more gaz by the dough. Similar results have been obtained by Cappelli et al (2019) in their study of the incorporation of crickets' flour in breadmaking. The decrease of L and G as the percentage of substitution of cowpea flour increases is due to the different composition of flours; in particular, the increase in total protein content, which reduces starch and gluten content, with a consistent reduction in L and G. According to Cappelli et al. (2018),, G and L are closely related to gluten and starch content in ancient wheat flours. The reduction of the dough strength index (W) with the incorpation of cowpea flour can be explained by the reduction of the cabohydrate and gluten content in the composite flours .In fact there is a relationship between W, protein , fat , and carbohydrate content (Cappelli et al., 2019) All these formulations are adopted for breadmaking with values of W between 160 and 250.The control has a (W) surface of the optimum alveogram required in bread, a good Baker force with a (G) swelling of less than 23 mm. This high W value of wheat flour dough indicates the presence of strong gluten which appears to get weakened and destabilized by the incorporation of cowpea flour. Its ratio of P/L is between 0.8 and 2, reflecting the equilibrium of the alveogram characteristic of a flour suitable for bread according to boulemkahel (2014). Otherwise, the composite flours have a P/L ratio above that range, which is a characterristic of an imbalance between the tenacity and elasticity of the dough. The P/L ratio plays a key role in the technological success of leavened products. These results reflect the observations made in breadmaking and show that these flours are quite strong but unbalanced with a lack of elasticity as shown by Osimani et al. (2018). This behaviour agrees with the literature which reports an increase of the alveographic W (dough strength) and P (dough tenacity) while the L (dough extensibility) decrease when performing the test on a blend of carob flour with wheat flour, compared to 100 % wheat (Turfani, et al., 2017). Differences in the rheological characteristics (viscoelasticity) of the dough are due to the different compositions of wheat flour (starch, gluten, mineral salts....) and that of Cowpea which does not contain gluten, the essential element during kneading and formatting responsible for elasticity and the scalability of the dough (Némar, 2015).

3.5. Coloring of wheat flour, cowpea and mixtures of wheat/cowpea flour

Table 6 shows the effect of the incorporation of cowpea flour on the color parameters. The incorporation of cowpea flour decreases the parameter L and IB. The flours substituted at 10 %, 15 %, 20 % by Cowpea do not differ significantly (p < 0.05) as well as the flours substituted at 25 % and 30 %. But all are significantly different compared to the control (100 % wheat flour) for the L and IB parameters. So, the brightness and whiteness of the flour decrease with the incorporation of cowpea flour.

Table 6: Influence of wheat substitution by cowpea on flour color parameters

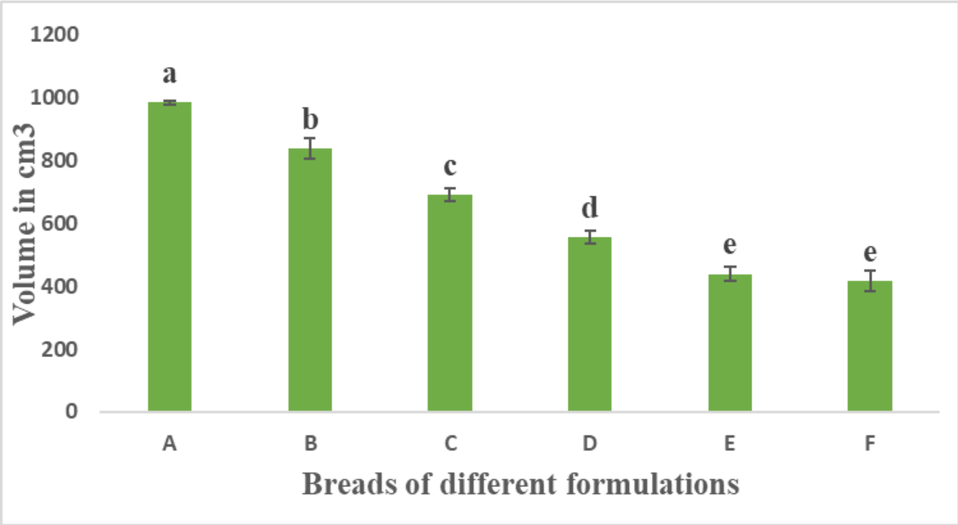
	Color parameters			
Sample	**L**	**A**	**B**	**IB**
A	93.08 ± 0.04^{a}	-0.67 ± 0.01^{d}	9.69 ± 0.04^{d}	88.06 ± 0.04^{a}
B	92.11 ± 0.06^{b}	-0.47 ± 0.01^{c}	10.07 ± 0.06^{c}	87.19 ± 0.08^{b}
C	91.94 ± 0.03^{b}	-0.48 ± 0.01^{c}	10.17 ± 0.07^{c}	87.01 ± 0.08^{b}
D	92.01 ± 0.58^{b}	-0.38 ± 0.01^{b}	$10,32 \pm 0.04^{b}$	86.93 ± 0.37^{b}
E	91.21 ± 0.005^{c}	-0.13 ± 0.01^{b}	10.38 ± 0.06^{b}	86.40 ± 0.04^{c}
F	91.11 ± 0.03^{c}	-0.16 ± 0.01^{d}	10.72 ± 0.14^{a}	86.07 ± 0.12^{c}

Results with the same letters in the same column have no significant difference (P < 0.05)
A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, N: 100 % cowpea with WF/CF corresponding to wheat flour/cowpea flour: The brightness of the flour, A: balance green-red, B: blue-yellow balance, IB: Whiteness index,

The decrease in the whitening index observed when the proportion of cowpea increases can be explained by the non-enzymatic browning that cowpeas would have undergone during drying as it is rich in proteins. This coloring of the flour has a direct impact on the color of the breads Himida et al. (2012). In addition to this, cowpea flour is not as bright as wheat flour, so its incorporation reduces the parameters L and IB. Besides, Büsra (2018) showed that lysine, glycine, tryptophan and tyrosine are the most effective amino acids on color development. It is because cowpea flour is rich in those amino acids that when incoporated it reduces the brightness of the flour.

3.6. Effect of the substitution of wheat flour by cowpea flour on the aspect and bread volume.

The breads obtained from 75 % / 25 % and 70 % / 30 % wheat flour / cowpea flour mixtures are less bulky and too colorful while the breads obtained from 90 % / 10 %, 85 % / 15 % and 80 % / 20 % wheat flour / cowpea flour mixtures produce common bread. As shown in figure 5, 100 % wheat bread has the highest volume directly followed by 90 %/10 % wheat flour/cowpea flour and 85 %/15 % wheat flour/cowpea flour breads which have a slightly lower volume, while there is a significant reduction in the volume in the 20.25 and 30 % substitute rolls (figure 4). The results obtained for the 75 % / 25 % and 70 % / 30 % Wheat Flour / Cowpea Flour formulas show a crumb with an elastic, compact, sticky, non-aerated texture and with small tight cells. Meanwhile, those of breads from composite flours of 10 to 20 % incorporation show a white crumb characterized by good loosely pressed and well ventilated, non-compact and not very sticky nature. Figure 6 shows the appearance of the bread crumbs depending on the incorporation of cowpea flour.



A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, with WF/CF corresponding to wheat flour/cowpea flour.

Figure 4: Influence of the substitution of wheat flour by cowpea flour on bread volume**.**

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Figure 5: Appearance of breads from flour mixtures

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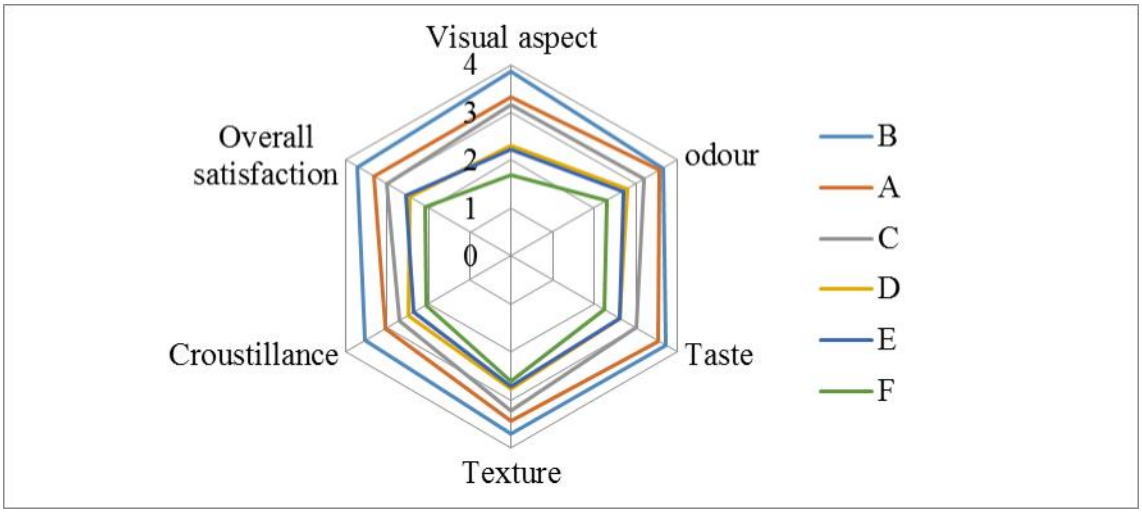
Figure 6: Bread mixes of flour mixes

The decrease in volume observed is resulting from the dilution effect of gluten by the addition of cowpea flour causing the decrease in gas retention (Kamelah, 2016). This can be attributed to a reduction in dough extensibility and the weakening of the gluten network caused by dilution and interactions with non-starchy carbohydrates and non- gluten-forming proteins (Cappelli et al., 2019). The non-aerated texture obtained and with small tight a result obtained is equally a result of the decrease in gaz retention.Tatiana et al., (2012).Also showed that the addition of legumes in the dough result in a decrease in bread volume.

3.7. Sensory analysis of cowpea - wheat bread and 100 % wheat bread.

Figure 7 show the sensory analysis results of breads from composite flour wheat flour/cowpea flour and wheat flour. This sensory profile shows that the properties of bread derived from incorporation 90 % / 10 % wheat flour / cowpea flour is the most appreciated on all sensory attributes.



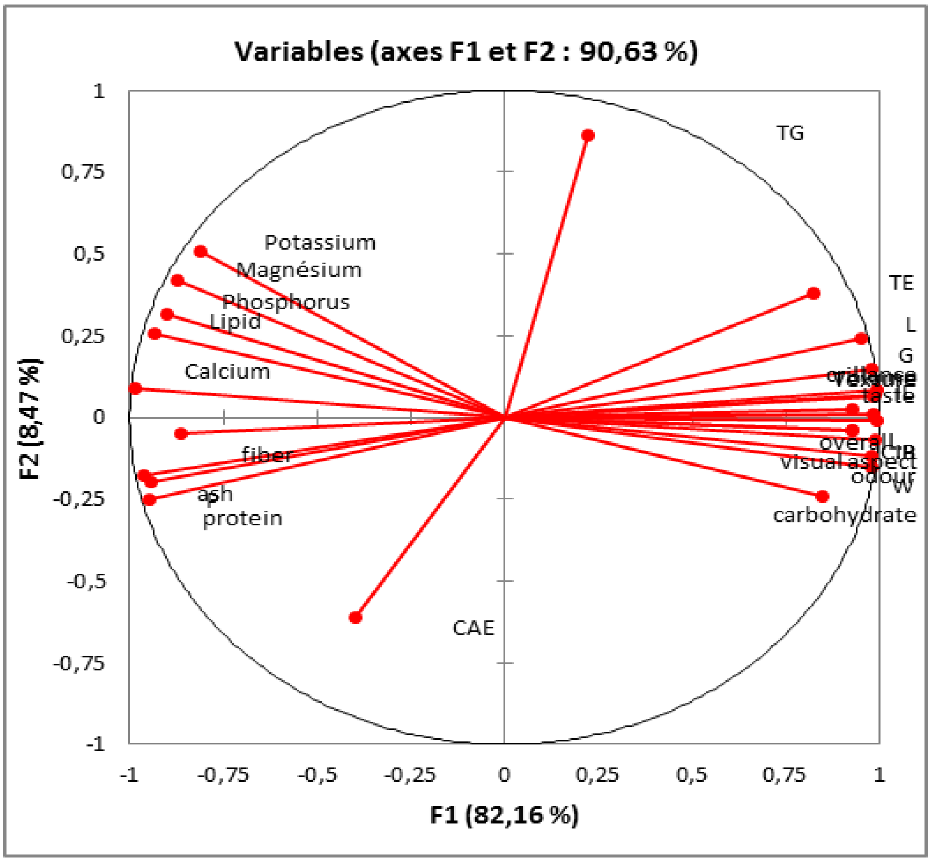
A: 100 % Wheat, B: 90/10 WF/CF, C: 85/15 WF/CF, D: 80/20 WF/CF, E: 75/25 WF/CF, F: 70/30 WF/CF, with WF/CF corresponding to wheat flour/cowpea flour.

Figure 7: Hedonic analysis results of breads from composite flour wheat flour/cowpea flour and wheat flour.

Meanwhile the loaves are less appreciated as the quantity of cowpea increases. The variances analysis reveals that the 10 and 15 % substitution formulations do not show a significant difference ($p < 0.05$) with the control 100 %, whereas those of 20 to 30 % differ from the control and are not significantly different. The acceptance at 25 % of substitution and the higher score of 90 % / 10 % formula is due to its good golden color. The dark color of the crust in WF/CF loaves is due to the high probability for achieving the realization of the Maillard reaction between reducing sugars and proteins also attested by Helou et al., (2016). The bread depreciation with high proportion of cowpea can be explained by the fact that cowpea has a very pronounced effect on the taste of bread because it has been soaked for 12 hours. This aroma of cowpea begins to be felt when the incorporation of cowpea is 20 % and above and is depreciated by most panelists although some preferred this taste to that of 100 % wheat and said to perceive the taste of full bread. The results obtained by Seydou, in 2014 also show that the preference decreases with high proportion of cowpea, thus above 20 % of cowpea flour the consumers are not satisfied.

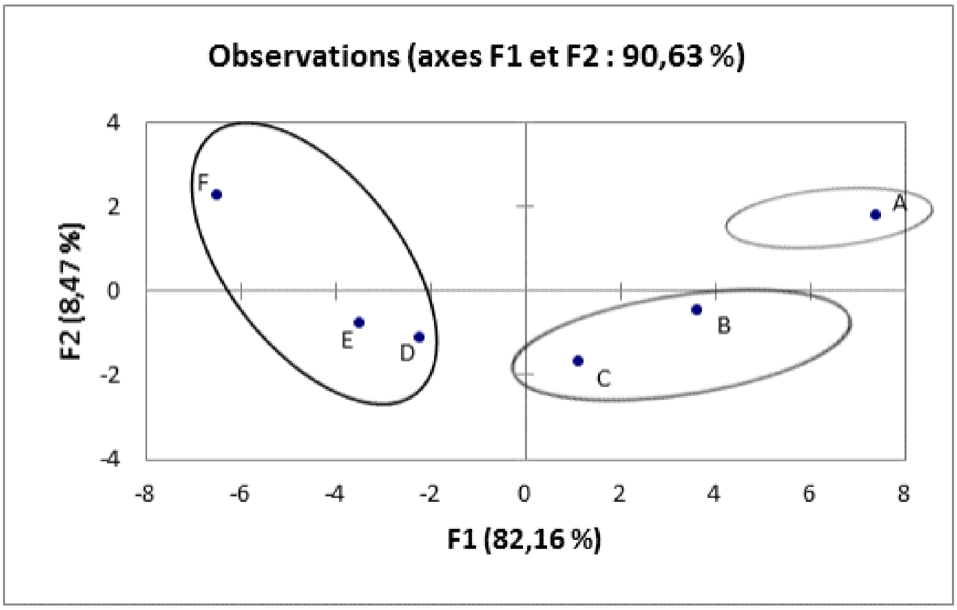
3.8. Principal component analysis

PCA analysis gives an overview of the nutritional and technological characteristics. The first and second main components (F1 and F2) respectively explain 82.16 % and 8.47 % of the total variation; which thus contain the essential information. Figure 8 shows the correlations between the variables and the factors as it appears that all the variables except the water absorption and swelling capacities contribute to the formation of F1 axis. On the one side there is a negative contribution of nutritional properties to F1 axis and on the other side a positive contribution of rheological and sensory properties to the F1 axis. In addition, the variables water absorption and swelling capacities contribute to the formation of F2 axis. Figure 9 presents a principal component analysis in which the different formulations are considered as individuals. It follows that along the axis F1 × F2, a demarcation of the samples A and F upward relative to the other samples. In addition, they are grouped into three classes (Figure 10). The first class consists of B and C; the second from A and the third from E, D and F. The negative correlations observed between the chemical composition, the rheological and sensory properties reveal that the incorporation of cowpea flour in the formulations, result in an improvement of the nutritional and a deterioration of the rheological and sensory properties. The three observed classes corroborate with the results of the different parameters evaluated. Indeed, the results of chemical, functional, rheological and sensory analysis show that there are no significant differences between B and C and between D, E and F. In addition, the samples D, E and F are better on the nutritional plan and poor in rheological terms while sample A is rheologically better and nutritionally acceptable, which explains why it is in the positive zone of the two axes. Formulations B and C are better nutritionally and rheologically and sensibly acceptable; they therefore constitute the best composite flours.



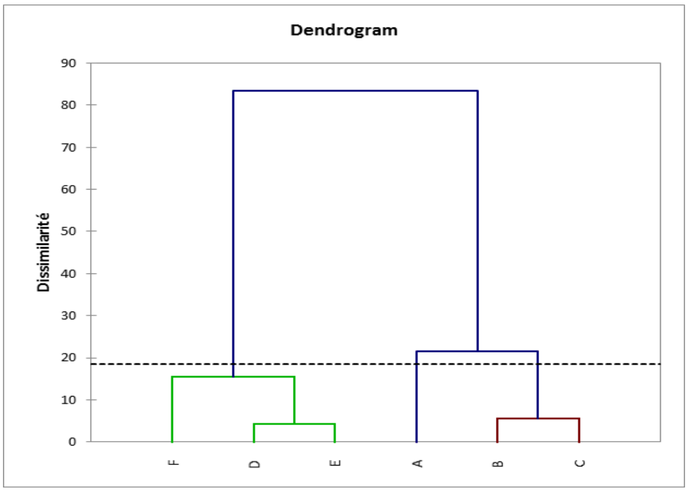
TE = water content, CAE = water absorption capacity; TG = swelling capacity; IE = elasticity index; P = tenacity of the leg; elasticity; G = swelling; W = strain force; IB = whiteness index; CP = paw behavior

Figure 8 Biplot.



A = 100 % wheat; B = 90 % Wheat flour / 10 % Cowpea flour; C = 85 % Wheat flour / 15 % Cowpea flour; D = 80 % Wheat flour / 20 % Cowpea flour; E = S75 % Wheat flour / 25 % Cowpea flour; F = 70 % Wheat flour / 20 % Cowpea flour.

Figure 9: PCA diagram of observations.



A = 100 % wheat; B = 90 % Wheat flour / 10 % Cowpea flour; C = 85 % Wheat flour / 15 % Cowpea flour; D = 80 % Wheat flour / 20 % Cowpea flour; E = S75 % Wheat flour / 25 % Cowpea flour; F = 70 % Wheat flour / 20 % Cowpea flour.

Figure 10: Dendrogram of observations.

4. CONCLUSION

Cowpea flour can be used in breadmaking and this would permit the reduction of wheat importation, the improvement of the nutritional qualities of bread, the valorization of local products and the formulation of new products. The high protein content of cowpea (26.87 %) qualifies it as a substitute to hard wheat in breadmaking flours. In fact, hard wheat is requested for its strength and its protein content higher than that of soft wheat (at least 14 %).

5. CONFLICTS OF INTEREST

None.

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