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Effect of aging on the physico-chemical and functional characteristics of maize (*Zea mays* L.) flour produced by a Company at Maroua (Far North of Cameroon), during storage

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The effect of aging on the physicochemical and functional properties of maize (*Zea mays L*) flour produced in Maroua (Far North-Cameroon) during storage, were investigated using standard analytical methods. The samples underwent natural (37°C) and accelerated (50°C) aging and packed in aluminum sachets. The results show that dry matter, starch and protein varied significantly ($p<0.05$) with the storage time and temperature. The variation of lipids content was minimal and statistically insignificant for 3 months for the flour storage at 37°C and decreased significantly ($p<0.05$) at 50°C. The functional characteristics shows that water absorption capacity, solubility index, water retention capacity and gel length varied ($p<0.05$) with the storage period and temperature. This study revealed that flours packed in aluminum bags at ambient temperature may be stored for three months without altering their physicochemical and functional characteristics, whereas two months is the maximum storage time at 50°C.

Key words: Maize flour, aging, physicochemical properties, functional properties, Maroua.

INTRODUCTION

Maize (*Zea mays* L.) was the main staple of people worldwide for many centuries (Galinat, 1977). According to FAO (2016a), 885.3 million tons were produced in 2011. The main producer was the United States with

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313.9 million tons, accounting for 35.5% of world production (Hamel and Dorff, 2016). Maize is the main staple of people in developing countries, especially African populations (Grah et al., 2014). This food product is consumed by not less 50% of the sub-Saharan populations and therefore represents the most important cereal crop in this part of world (Grah et al., 2014). However, maize production remains very low in Cameroon, with about 700,000 family, artisanal and modern farms producing about 1.1 tons per farmer and a national consumption of 700,000 tons ; maize is therefore the third foodstuff produced in Cameroon after cassava and plantain. It also contributes more than 150 billion FCFA to the gross domestic product (GDP) (http://www.camerpost.com/cameroun, 2015).

Most of the world's people affected by hunger and extreme poverty live in rural areas. According to FAO (2016b), achieving the Sustainable Development Goals (SDGs) requires moving to more productive and sustainable agriculture where everyone have a place, which strengthens rural livelihoods and ensures security for all while drawing less on natural resources and improving resilience to climate change. According to the New Partnership for Africa's Development (2015), maize is thus a potential source for improving food security and raising incomes for producers. Concerning the consumption and use of maize, the Conference of Ministers of Agriculture of West and Central Africa (2015) states that most of the produced corn is used for animal feed. It also shows that total maize uses are estimated at 583 million tons divided between human consumption (20%), animal consumption (67%) and other uses (13%).

Several products are carried and preserved as flours, because they are susceptible to attack by pests of cereals. Their role in the feed and in food industry is very important (Nip, 1997). Flours generally have low water and in this way, a means for the preservation of cereals. Its consumption became more important in urban areas in most African countries like Cameroon (Bricas et al., 1997).

Several factors influence the stability of food during storage, both among farmers and the food industry. These factors are generally related to the food or its environment (water activity, water content, food composition, pH and temperature) (Aboubakar et al., 2010). Therefore, this is why maintaining the quality of a food is a major industrial concern. Indeed, the acceptance of food by the consumer depends, among other things, on its quality, both organoleptic and nutritional.

The shelf life of food flours in general depends on their lipid content, the moisture content of the grain, the presence of contaminants and storage conditions (packaging material, ambient temperature and humidity). The storage time and conditions have an influence on the technological quality of cereal and result in modifications of the flour parameters (Goudoum et al., 2012). The evolution of maize flour during its storage is the result between chemical, physical and enzymatic phenomena. These results in a depreciation, mainly sensory, of the product. Indeed, the acceptance of a food by the consumer depends, among other things, on its organoleptic quality. However, this quality decreases with time of storage due to complex phenomena of alteration (Mertens, 2009). Loss of some nutritional and organoleptic properties such as flavor and taste of dried maize flour during storage is a crucial problem (Grah et al., 2014). In Far North region of Cameroon, the months of March and April are the hottest, with the monthly average of 40°C in the shade. Thus, a good mastery of these phenomena is an essential element to ensure an optimal conservation of food in this part of Cameroon. The objective of this study was to estimate the changes, the physicochemical and rheological modifications of maize flours produced in Maroua (Far North Region of Cameroon) during storage.

MATERIALS AND METHODS

The flour sample was obtained from milling corn (CMS 8504) in a processing company in Maroua. The products were kept in aluminum bags. The same amount of flour (± 500 g) was introduced into each bag. They were sealed with an adhesive tape. Each bag of flour was provided for a pair (time, temperature) to which corresponds a sample. On each bag is indicated the temperature (37 and 50°C) and the aging period (first day, one, two and three months).

Collection of samples and observation

The samples were allowed to age by natural and accelerated methods. For natural aging, the sachets were just placed on a laboratory shelf (at 37°C). For accelerated aging, one temperature was retained (50°C) and the remaining sachets are therefore introduced in ovens set at the chosen temperature.

Products were analyzed monthly. After opening, bags were sealed with an adhesive tape and stored in a refrigerator at 4°C until all analyzes are carried out (between 2 and 4 days).

Chemical and functional analysis before and after storage

The chemical characteristics and functional properties analysis were conducted before and after 1, 2 and 3 months of storage.

Proportioning of starch

The proportioning of starch was carried out using the method described by Ewers modified (BIPEA, 1978).

Proteins

The protein content was determined according to the Kjeldahl method for the total nitrogen determination (AOAC, 1990).

Table 1. Changes of water activity and dry matter of maize flour during three months storage at 37 and 50°C.

Period	37 °C		50 °C	
	WA	DM (%)	WA	DM (%)
First day	0.155[ab]	96.670[c]		
1 month	0.160[ab]	97.070[c]	0.150[ab]	97.400[b]
2 months	0.165[ab]	96.895[c]	0.140[bc]	97.785[b]
3 months	0.170[a]	96.880[c]	0.115[c]	98.030[a]

WA: Water activity ; DM: dry matter. Averages followed by the same letter in the same column are not different significantly with P < 0.05 (Test of Duncan).

Evaluation of oxidation state

The evaluation of oxidation state was made according to the AOAC method (2000).

Sugars

Sugars were extracted and analyzed by Fischer and Stein (1961) method.

Water absorption capacity

The determination of the water absorption capacity was performed by the method of Adebowale et al. (2005).

Solubility index

The solubility index (IS) in water is calculated using the Anderson et al. (1969) method.

Gel length

The gel length was determined by the method developed by Cagampang et al. (1973).

Ash content

Ash content was determined by AOAC method (2000).

Moisture

The hot air oven method, AOAC (2000) was used for moisture determination. The samples were dried in a hot air oven (Memmert) at 130°C for 1 h to constant weights.

Statistical analysis

The results obtained from the evaluation of chemical characteristics and functional properties of maize flour during storage were analyzed with analysis of variance (ANOVA) using the software Xlstat 2014. The average values were classified using Duncan multiple test with the same software.

RESULTS AND DISCUSSION

Evolution of water activity and dry matter of maize flour during storage

The results of the water activity and dry matter of maize flours stored at 37 and 50°C for three months are shown in Table 1. The water activity range from 0.155 to 0.170 when the flours were stored at 37°C and 0.155 to 0.115 at 50°C, respectively at the first day of flours production and 3 months after. The values were significantly different ($p < 0.05$). The result of dry matter varied with the storage period and temperature. The dry matter increased significantly ($p < 0.05$) during the storage of flours from 96.670 (first day) to 96.880 (3 months) and from 96.670 (first day) to 98.030 (3 months), respectively at 37 and 50°C storage temperature. This increase in the dry matter at 50°C would be due to the drying which continued under the experimental conditions. This evolution has been compared with the water activity (Wa). Indeed, during long-term storage, the Wa of a product is in equilibrium with the HR of the storage atmosphere (Aboubakar et al., 2010). Hruskova and Machova (2002) showed that the changes in moisture contents depends on the short time storage conditions.

Evolution of proximate composition of maize flour during accelerated aging

The results of proximate chemical composition of flour storage during 3 months at differents temperatures are shown in Table 2. The result shows that starch and protein varied with the storage period and temperatures ($p < 0.05$). The starch content decreased from 85.940 at the first day to 83.300 after 3 months at 37°C and shows minimal changes at 50°C during the storage. The protein content also decreased significantly ($p < 0.05$) during storage at both temperatures. There was non significant variation in the lipid content during three months storage at 37°C, but at 50°C the variation between average of different months are significant ($p < 0.05$). Changes were minimal and statistically non-significant for the flours storage 3 months at both temperature for ash and carbohydrate.

During storage of cereals, many physicochemical properties were subject to changes (Singh et al., 2006 ; Keawpeng and Venkatachalam, 2015). These changes are mainly dependent on their variety, storage conditions (light, temperature) and amylose content (Keawpeng and Venkatachalam, 2015). In this study, the variation in the protein and starch contents of maize flour was a function of storage time and temperature. These changes have been attributed to proteins, the interaction between proteins, the breakdown products of lipid oxidation and starch-protein interactions (Sodhi et al., 2003). A high

Table 2. Changes of proximate chemical composition of maize flour during the three months storage at 37 and 50°C.

Constituents (%)	37 °C				50 °C			Pr > F
	First day	1 month	2 months	3 months	1 month	2 months	3 months	
Starch	85.03[a]	84.82[ab]	84.15[b]	83.82[b]	85.05[a]	85.52[a]	84.35[ab]	0.032
protein	9.85[a]	9.87[a]	9.48[b]	9.45[b]	10.04[ab]	9.72[ab]	9.66[b]	0.041
Crude Fat	3.51[a]	3.62[a]	3.65[a]	3.77[a]	3.820[a]	3.22[b]	3.35[c]	0.013
Ash	0.86[a]	0.87[a]	0.88[a]	0.81[a]	0.72[a]	0.74[a]	0.89[a]	0.728
Free sugar	0.71[a]	0.75[a]	0.73[a]	0.78[a]	0.71[a]	0.72[a]	0.78[a]	0.486

Averages followed by the same letter in the same line are not different significantly with P < 0.05 (Test of Duncan).

Table 3. Changes of some functional properties of maize flour during three months storage at 37 and 50°C.

	37°C				50°C			Pr > F
	First day	1 month	2 months	3 months	1 month	2 months	3 months	
WAC (%)	131.900 [a]	134.250 [a]	136.250[b]	136.960 [b]	136.730 [b]	136.260 [a]	138.045[c]	0.000
SI (%)	20.975 [a]	20.195 [a]	19.700 [a]	19.645 [a]	18.100 [b]	16.885 [bc]	15.830 [c]	0.000
WRC (%)	197.690 [a]	197.175 [a]	193.700 [ab]	189.915 [bc]	186.885 [cd]	182.760 [de]	179.365 [e]	0.000
GL (mm)	90.110 [a]	88.775 [ab]	86.915 [b]	84.100 [c]	82.810 [c]	80.535 [d]	78.410 [e]	0.0001

WAC: Water absoption capacity, SI: solubility index, WRC: water retention capacity, GL: gel lenght. Averages followed by the same letter in the same line are not different significantly with P < 0.05 (test of Duncan).

temperature and shelf life could contribute to the acceleration of these phenomena. Teo et al. (2000) and Zhou et al. (2003) reported that the storage conditions are important in the aging process and impact on the number of changes in rice physical properties such as textural properties, pasting, color, flavor, composition and eating quality.

Protein content is an important criterion for assessing quality. It represents a technological and nutritional interest in the cereals process (Gate, 2015). These results corroborate with those of Khaly (1998) and Maloumba Kamba et al. (2008), who worked respectively on the techno-functional properties of maize and on the quality control of cereal meal placed on the market in Senegal. However, the small decrease in lipid content during storage time could result from the oxidation, which would be due to the presence of pro-oxidants such as metal ions and enzymes. Another hypothesis is that of cereal grinding, which puts lipolytic enzymes in contact with fat in flour, thus promoting lipid degradation (Khaly, 1998). As for proteins, their small decrease over time is due to proteolysis reactions by proteases. Indeed, during storage, proteases naturally present in certain foods or secreted by the microorganisms that contaminate these foods, can hydrolyze proteins. The decrease in proteins during storage could also be due to the result of Maillard reactions also called non enzymatic browning reactions.

The decrease in ash rate during storage time, however slight, is likely to be related to the intensity of dehulling-degerming and sieving operations (Khaly, 1998). These results are similar to those of Benhania (2013) on the flour processing and control of its quality.

Like other nutrients in corn flour, starch and free sugars degrade over time. After three months storage of maize flour, non significant difference was observed during tree months storage at both temperatures for starch and free sugars decreased. These results are similar to those of Lin (1997), who worked on the physicochemical properties of corn flour and starch.

Evolution of functional composition of maize flour during accelaration aging

The results of functional properties of maize flours stored during 3 months at different temperatures are shown in Table 3. The result shows that water absorption capacity, solubility index (SI), water retention capacity and gel length (GL) varied with the storage period and temperature. The WAC increased from 131.900 to 136.960 at 37°C and from 131.900 to 138.045 at 50°C during 3 months storage. The SI did not show any significant variation at 37°C, but at 50°C the variation was significant ($p < 0.05$) during the storage period. The WRC decreased significantly ($p < 0.05$) from 197.690 to 189.915 and from 193.690 to 179.365 during the storage respectively, at 37 and 50°C. The GL decreased significantly ($p < 0.05$) from 90.110 to 84.100 at 37°C and

90.110 to 78.410 at 50°C during the 3 months storage. The water solubility index of maize flour also decreased significantly ($p < 0.05$) after 2 months at 37°C and after one months at 50°C.

It can be seen from the results that the storage time of the corn flour increases the affinity of the latter to water. According to Anderson (1982), the WAC of food meal increases as the storage temperature increases. Several studies on the distribution of water among wheat flour constituents have shown that starch is the main component involved in the hydration properties of flour due to its presence in large quantities (Feillet, 2000; Goesaert et al., 2005). The increase in the WAC is due to the particle size because the finer the flour, the greater is its capacity of absorption of water (Feillet, 2000). The results show the variation of different rheological properties at different storage times and temperature. The WRC, SI and the GL decrease with the storage time and temperature. Sefa-dedeh and Afoakwa (2001) reported that the WRC increases with increase in the amount of proteins and that hydration of starchy polysaccharides is usually followed by the proteins. Grah et al. (2014) showed that the WRC of maize flour increased with the fermentation time, because of the rearrangement of water holding fiber and hydrophilic polysaccharide components. Goudoum et al. (2012) showed that the change of the GL, WAC and SI found, was due to the modification of the grains parameters such as pH and certain minerals such as calcium, by weevils droppings, and even by the presence of eggs in the middle.

Conclusions

The results obtained showed some differences in the physico-chemical and functional properties of maize flour during storage. The study revealed that during the three months of storage, variations in water content of flours were recorded. Water absorption capacity and water solubility index increased during the first three months for the two temperatures. This result showed that the date line of storing maize flour in Maroua can not exceed three months in allimium bags at ambient temperature.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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