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Effect of Fermentation Time on the Physico-Chemical Properties of Maize Flour

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Abstract: *Maize (Zea mays) flour is a major staple for most people in developing countries, notably African populations. However, this food product is currently subject to perishable status due to lack of adequate conservation, which may cause substantial loss of nutritional and functional values. In this study, the impact of fermentation duration on the physical and chemical properties of this important foodstuff was examined.*

The results showed that the total acidity of maize flour increased from 37.97 to 71.59 °D with increasing time of fermentation (0–120 h), while its pH decreased considerably from 6.67 to 3.85. The moisture content varied from 7.63 to 11.57% and the block density decreased from approximately 0.70 to 0.62. The values of functional parameters, namely the water retention capacity, oil retention capacity, and hydrophilic-lipophilic index of maize flour increased with increasing duration of fermentation. In the whole, sufficient (96–120 h) fermentation appeared to improve the functional characteristics of maize flour. This behavior of the maize flour to absorb and retain ample amounts of water and oil may be used to improve the structure, flavor, and taste and reduce the moisture and fat loss of various foodstuffs.

Keywords: *Maize; Flour; Fermentation; Physicochemical properties*

1. Introduction

Maize (*Zea mays*) is thought to be native to central and southern America. In the vernacular tongue of Indian from America, «maize» means «what holds life». Maize was the main staple of people living in these regions for many centuries [1]. Nowadays, maize is one of the food staples of people in developing countries, especially African populations. This food product is consumed by no less 50% of the sub-Saharan populations and therefore represents the most important cereal crop in this part of the world. In Côte d'Ivoire (Ivory Coast), the annual production is about 472,000 metric tons, and is totally domestically consumed at the rate of 28.4 per capita. It is essentially consumed in the form of fresh (unfermented) flour. However, maize flour is frequently submitted to different technological treatments such as cooking, fermentation, germination, soaking, and roasting for the manufacturing of various food products ([2], [3]). It has been shown that some of these technological transformations, notably fermentation [4] and germination are likely to result in beneficial nutritional changes and also stabilize the (newly formed) nutritional constituents [5]. However, the loss of some nutritional and organoleptic properties, such as flavor and taste, of dried maize, during storage, in West African regions is a crucial problem to be circumvented.

In this study, the influence of the time of fermentation on the stability of the physicochemical properties of maize flour was investigated. Specifically, maize flour was submitted to fermentation at various times (0, 24, 48, 72, 96 and 120 h) during which possible changes in different physicochemical parameters, namely the water retention capacity, oil retention capacity, hydrophilic-lipophilic index, block density, moisture content, pH, and titratable acidity were continuously measured to see their impact on its functional characteristics.

2. MATERIAL AND METHODS

2.1. Raw Plant Material

Bags (100 kg) of dry maize *(Zea mays)* grains was purchased at a local market (Abobo-gare, Abidjan, Côte d'Ivoire).

2.2. Production of Maize Flour

Maize grains were sorted, air-cleansed and abundantly washed with distilled water to remove impurities and dried in air-circulated oven (UFE 700) at 45 °C for 72 h. The grains were ground and sieved to pass through 100 μm- mesh, and the resulting fine flour was dried at 45 °C for 3 h (Figure 1). The dried flour was packaged and stored under moisture-free and airless conditions until use. Experiments were performed in three independent runs.

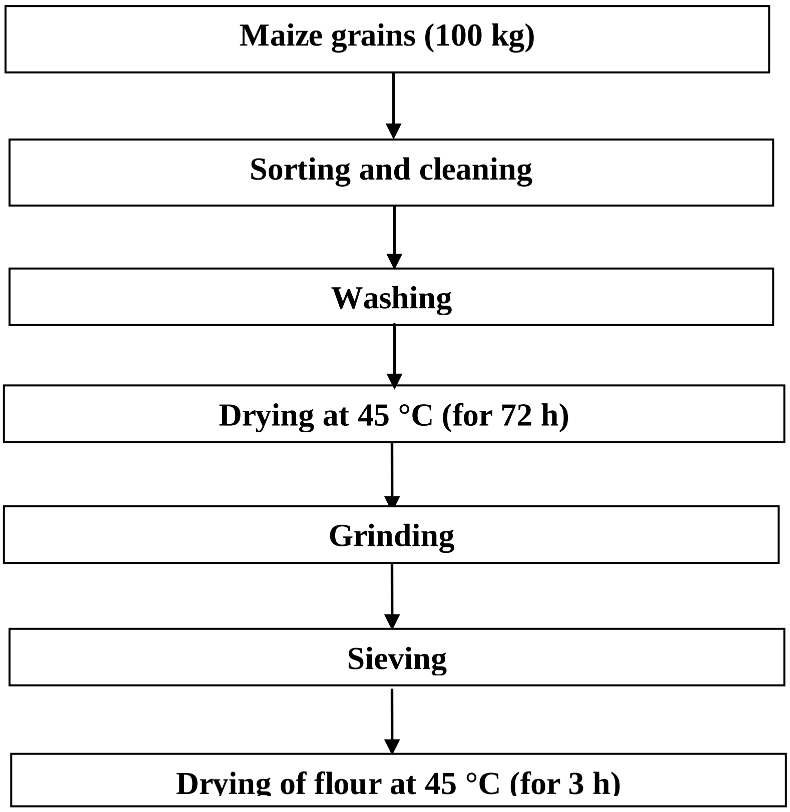

Figure 1. *Scheme of production of maize flour*

2.3. Fermentation of Maize Flour

Maize flour was put in different jars of the same kind, each corresponding to a specific time of fermentation (Table 1). Distilled water was added and the jars were hermetically sealed and stored at ambient temperature under airless conditions for fermentation to desired duration (Figure 2). The fermented flour was dried in an air-circulated oven at 70 °C for 3 h, cooled to room temperature, and stored under moisture-free and airless conditions pending analysis. Experiments were carried out in three independent runs.

Table 1. *Time of fermentation and corresponding maize flour*

Maize flour	Time of fermentation (h)
F0	0
F1	24
F2	48
F3	72
F4	96
F5	120

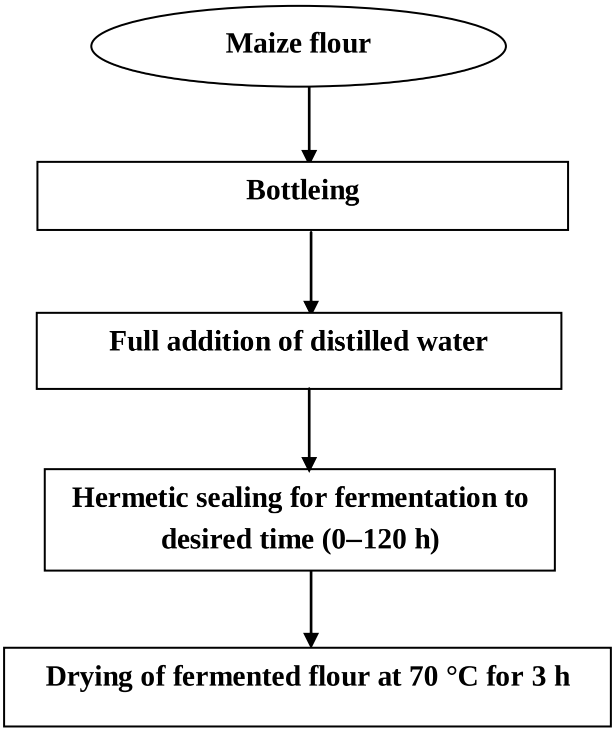

Figure 2. *Scheme of fermentation of maize flour*

2.4. Analytical

2.4.1. Determination of pH of Samples

The pH of samples was measured by the standard AOAC method (AOAC, 2003) [6] using a pH-meter (AOAC, 2003) [6] (HANNA INSTRUMENTS HI98150). Briefly, 10 g of (fermented) flours were suspended in 75 mL of distilled water and allowed to macerate for 30 min. The suspension was filtered and the pH of the dispersion obtained was measured. Experiments were done in three independent runs.

2.4.2. Determination of Titratable Acidity Of Samples

The titratable (or total) acidity of samples was measured by the standard AOAC method (AOAC, 2003) [6]. Briefly, 10 g of (fermented) flours were suspended in 75 mL of distilled water and allowed to macerate for 30 min. The mixture was filtered and 10 mL aliquots were titrated with 0.1 N NaOH using a phenolphthalein indicator for end-point determination. Acidity was calculated using equation 1.

$$N = \frac{n \times v}{V} \qquad (1)$$

where N (eq-g/L or °Dornic or °D) is the acid titer of (fermented) maize flour dispersion; V (mL), the quantity of (fermented) maize flour dispersion; v (mL), the quantity of 0.1 N NaOH needed for acid titration, and n (eq-g/L), the base titer of 0.1 N NaOH. Experiments were performed in three independent runs.

2.4.3. Determination of the Moisture Content Of Samples

The moisture content (MC) of samples was determined by the standard AOAC method (AOAC, 2003) [6] . Briefly, five grams (5 g) of (fermented) maize flour were dried in an air-circulated oven at 105 °C to constant weight. Experiments were performed in three independent runs. MC was calculated using equation 2.

$$MC\ (\%) = \frac{P1 - P2}{P0} \times 100 \qquad (2)$$

Where P1 is the initial weight of sample plus container; P2 the weight of dried sample plus container, and P0 the initial weight of sample before drying.

2.5. Determination of Physicochemical and Functional Properties of the Different Fermented Maize Flours

2.5.1. Water Retention Capacity

The water retention capacity (WRC) was determined as described elsewhere ([7]; [8]). Briefly, 1 g (P_0) of dry (fermented) maize flour was suspended in 10 mL of distilled water under stirring for 30 min and centrifuged (3000*g*, 20 min). The supernatant was removed, after which the wetted residue was recovered and weighed (P_2) and then dried at 105 °C to constant weight (P_1). Experiments were performed in three independent runs. The WRC was calculated as the ratio of the water retained to the initial dry weight of the sample using equation 3.

$$\textbf{WRC (g water/ g dry sample)} = \frac{P2-P1}{P0} \qquad (3)$$

Where *P2* is the weight of wetted sample; P1, the weight of dried sample and *P0*, the weight of the initial (dry) sample

2.5.2. Oil Retention Capacity

The oil retention capacity (ORC), also known as fat absorption capacity, was determined as described elsewhere (Sosulski, 1962[9]; Raghavendra et al., 2006 [8]). Briefly, 1.0 g (*P0*) of dry sample was put in centrifuge tube of known total weight (*P1*) to which 10 mL of refined oil were added and allowed to equilibrate overnight. It was then centrifuged (3000*g*, 20 min). The supernatant was removed and the weight of the oily residue plus centrifuge tube was recorded (P_2). Experiments were performed in three independent runs. ORC was calculated as the ratio of the quantity of oil held up to the initial dry weight of the sample using equation 4.

$$\textbf{ORC (g oil/ g dry sample)} = \frac{P2-P1}{P0} \qquad (4)$$

2.5.3. Hydrophilic-Lipophilic Index

The hydrophilic lipophilic index (HLI) was estimated, according to Njintang *et al*. (2007) [10], as the ratio of WRC to ORC using equation 5. This ratio enabled one to evaluate the "relative affinity" of (the different fermented) flours for water and oil.

HLI = WRC/ORC (5)

2.5.4. Block Density

The block density (BD) was determined as follows:

Twenty grams (20 g) of dry maize flour were placed in graduate tube and the whole was thoroughly tapped against a flattened surface at 50 cm-height. Experiments were performed in three independent runs. BD was calculated as the ratio of the weight [*P(g)*] of the dry sample to the volume [*V(mL)*] occupied by the sample in the graduated tube using equation 6.

$$\textbf{BD (g/mL)} = \frac{P}{V} \qquad (6)$$

2.6. Statistical Analysis

All the data obtained were statistically appraised by a single-factor analysis of variance (ANOVA), followed by the Newman-Keuls posthoc test for multiple comparisons, whenever applicable, using a Statistica V.6.0 software. The means of different treatments were significantly discriminated at *P-value <0.05*.

3. Results

3.1. Titratable Acidity of Fermented Maize Flours

The results of titratable acidity are shown in Figure 3. The values of titratable acidity of F_0 and F_1 maize flours were 37.97 and 38.65 °D, respectively. These values were not significantly different (*P* >0.05). However, the values of titratable acidity of F2 (41.99 °D), F3 (57.95 °D), F4 (67.96

°D), and F5 (71.59 °D) maize flours were significantly different (P <0.05). In the whole, the rate of titratable acidity of maize flour increased with increasing fermentation time.

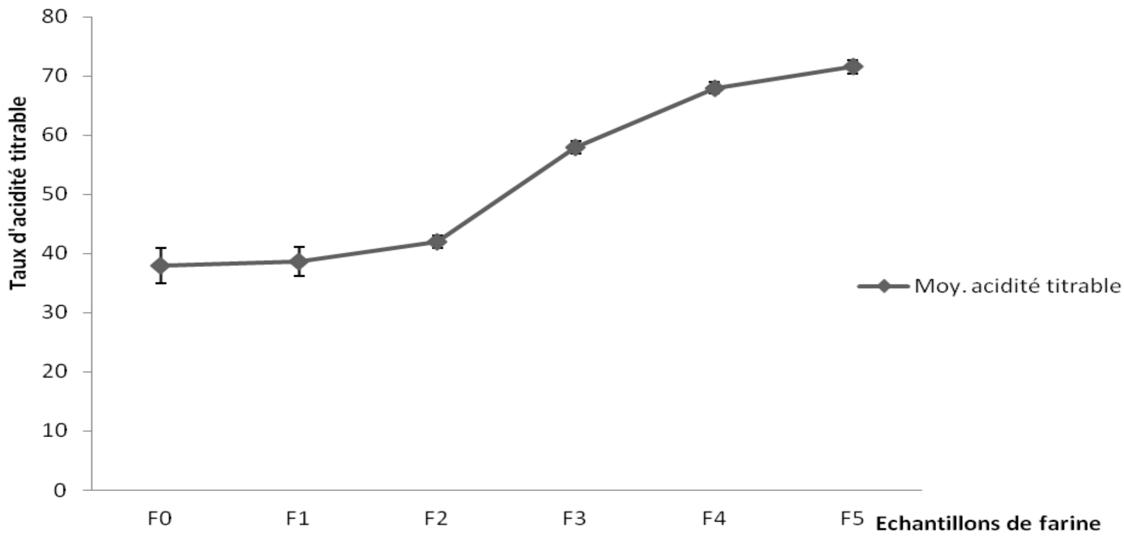

Figure 3. *Titratable acidity of maize flour as a function of time of fermentation*

3.2. Moisture Content (MC) of Fermented Maize Flours

The results of the MC of maize flour are presented in Figure 4.

The values of the MC of F0, F1, F2, F3, F4 and F5 were 10.1 ± 0.10, 9.85 ± 0.05, 10.84 ± 0.12, 11.57 ± 0.24, 7.63 ± 0.05 and 9.62 ± 0.1%, respectively. These values were significantly different from one another (P <0.05). Figure 4 showed that MC increased from 9.85 (F1) to 11.57% (F3) during the first 72 h of fermentation, after which it decreased sharply from 11.57 to 7.63% (F4) at 96 h-fermentation before increasing slightly again to 9.62% (F5) above 120 h of fermentation.

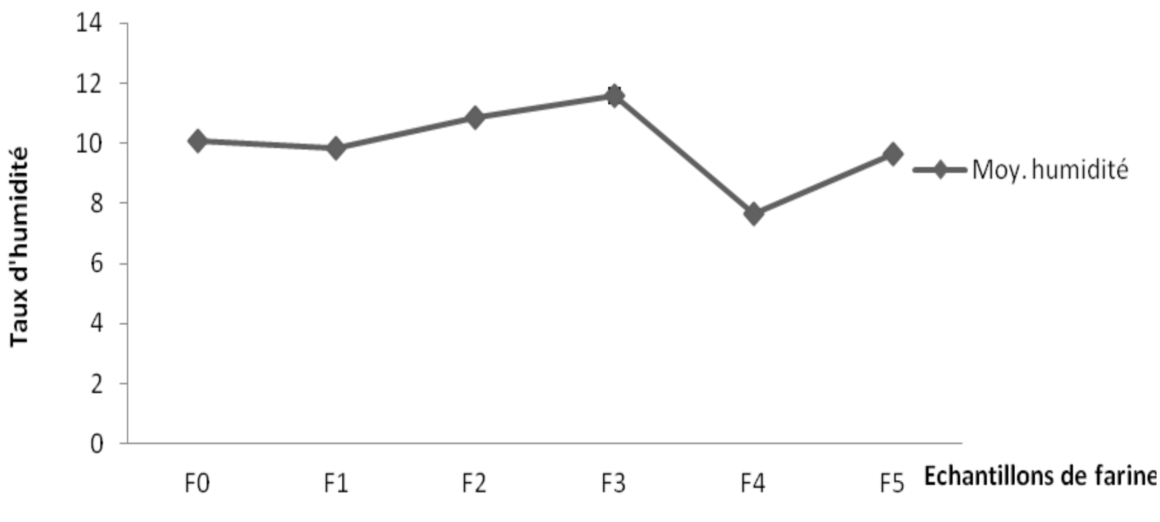

Figure 4. *Moisture content of maize flour as a function of time of fermentation*

3.3. Changes in pH of Fermented Maize Flours

Figure 5 illustrates the changes which occurred in the pH of maize flour during fermentation. The pH decreased with increasing duration of fermentation. The values of the pH of F0, F1, F2, F3, F4and F_5 were 6.67 ± 0.00, 5.97 ± 0.01, 5.14 ± 0.04, 4.19 ± 0.00, 4.06 ± 0.00 and 3.85 ± 0.00, respectively. These values were significantly different (P <0.05).

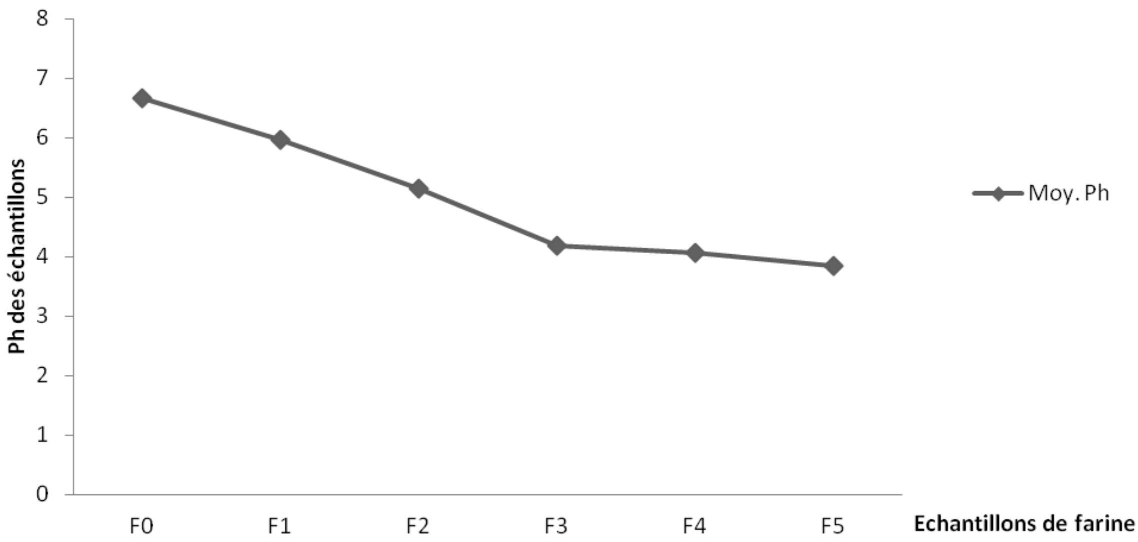

Figure 5. *Evolution of the pH of maize flour as a function of time of fermentation*

3.4. Block Density of Fermented Maize Flours

The results of block density are shown in Figure 6. In the whole, the BD decreased slightly with increasing time of fermentation. Three groups of fermented maize flours could be distinguished (*P* <0.05), depending on BD values. These are F0 (0.70 g/mL ± 0.01) > F1 = F2 (0.67 g/mL ± 0.01) > F3 ≈ F4 ≈ F5 (0.62 g/mL ± 0.01).

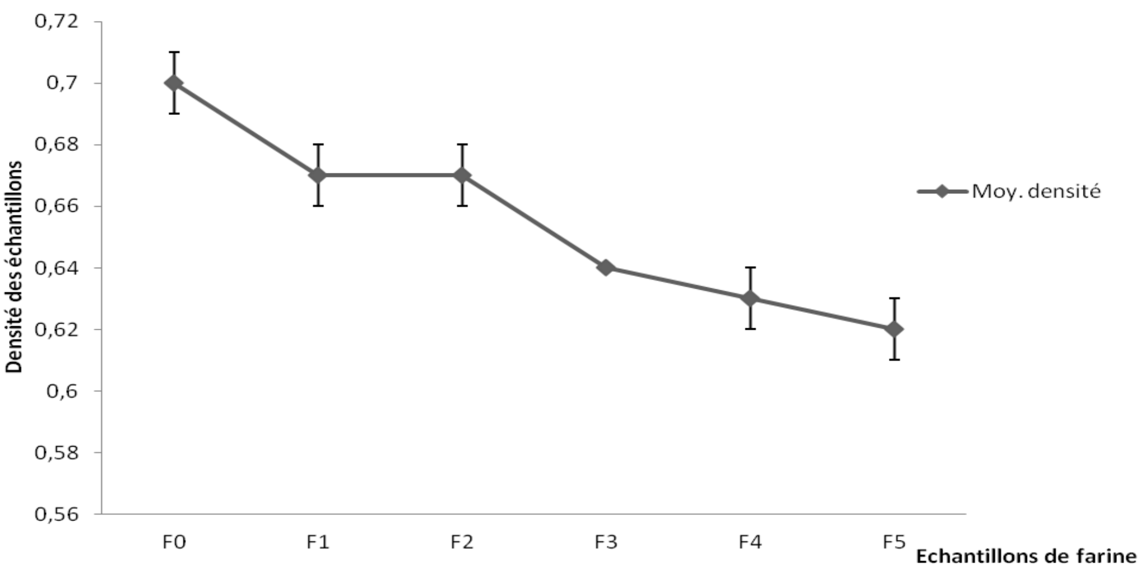

Figure 6. *Evolution of the block density of maize flour as a function of time of fermentation*

3.5. Water Retention Capacity (WRC) Of Fermented Maize Fours

The results of the WRC are presented in Figure 7. The WRC varied from 1.12 to 1.8 g water absorbed/ g dry sample. It could be seen that the WRC of maize flour was likely to increase with increasing fermentation time. In terms of WRC, four groups of fermented maize flours could be differentiated; these are F0 (1.12 ± 0.57 g/g) < F1 (1.33 g/g ± 0.15) ≈ F2 (1.22 g/g ± 0.15) < F3 (1.43 g/g ± 0.15) ≈ F4 (1.46 g/g ± 0.11) << F5 (1.8 g/g ± 0.00).

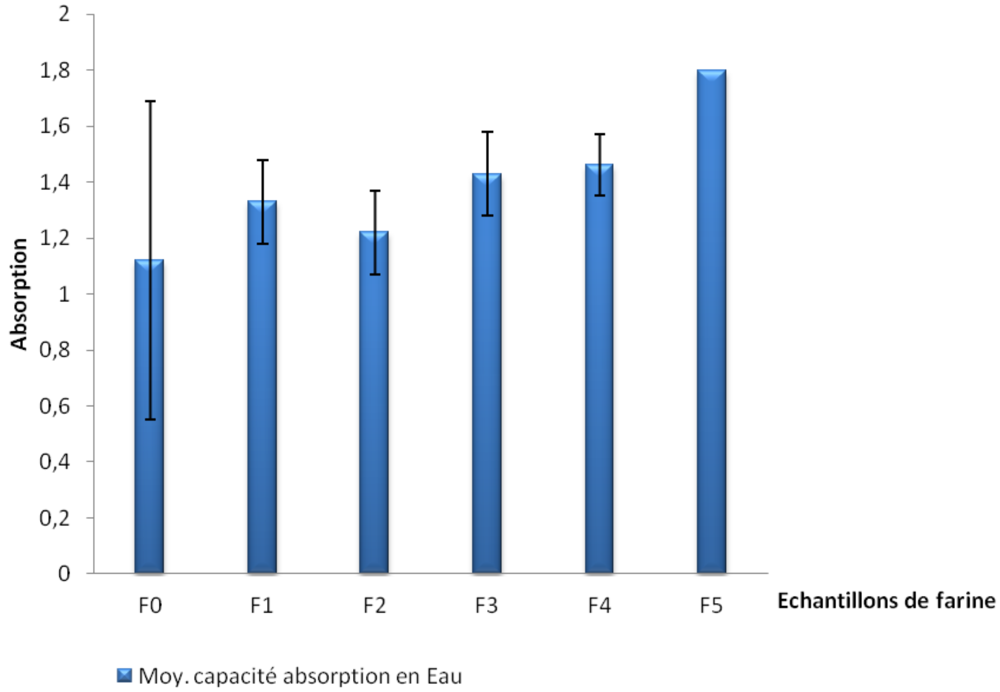

Figure 7. *Changes in the water retention capacity of maize flour as a function of time of fermentation*

3.6. Oil Retention Capacity (ORC) of Fermented Maize Flours

The results of the ORC are shown in Figure 7. The ORC ranged from 0.88 to 1.24 g oil retained/ g dry sample. The effect of fermentation time was observed only after 96 h of fermentation from which the ORC increased significantly ($P < 0.05$) from 0.88 g/g ± 0.02 (F0) to 1.13 g/g ± 0.04 (F4)–1.24 ± 0.66 g/g (F5).

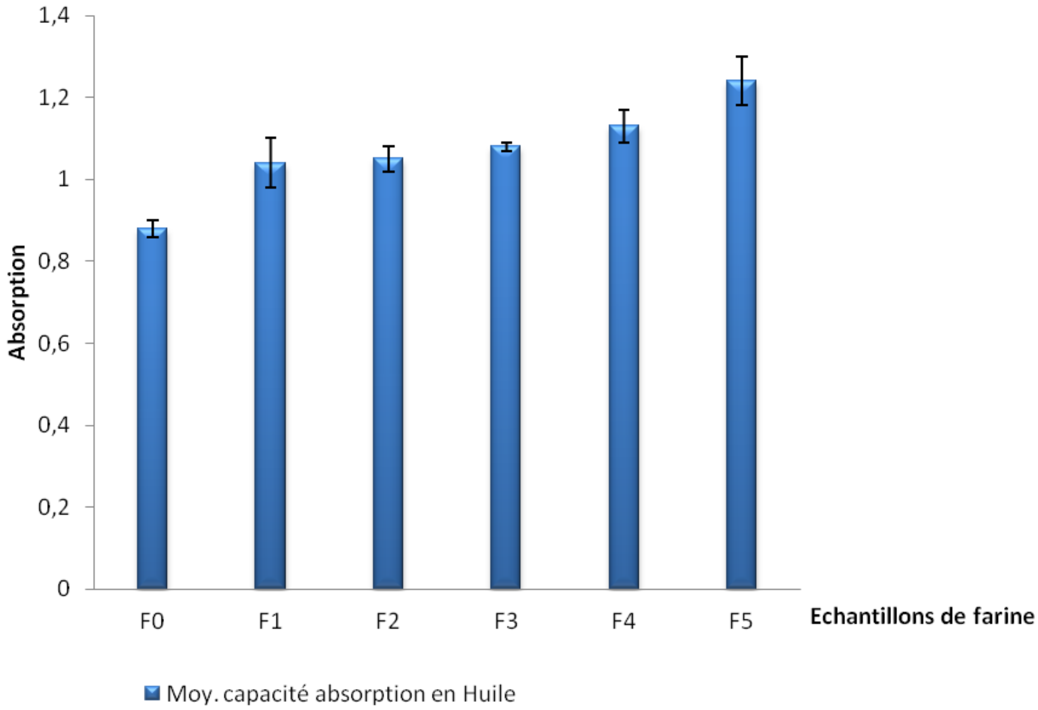

Figure 8. *Changes in the oil retention capacity of maize flour as a function of time of fermentation*

3.7. Hydrophilic-Lipophilic Index (HLI)

Figure 9 illustrates changes in the HLI of maize flour submitted to fermentation. The HLI varied from 1.22 ± 0.03 to 1.48 ± 0.01. The HLI was not significantly influenced ($P > 0.05$) by the duration of fermentation during the first 96 h. By contrast, above this time, the HLI was found to be significantly affected ($P < 0.05$).

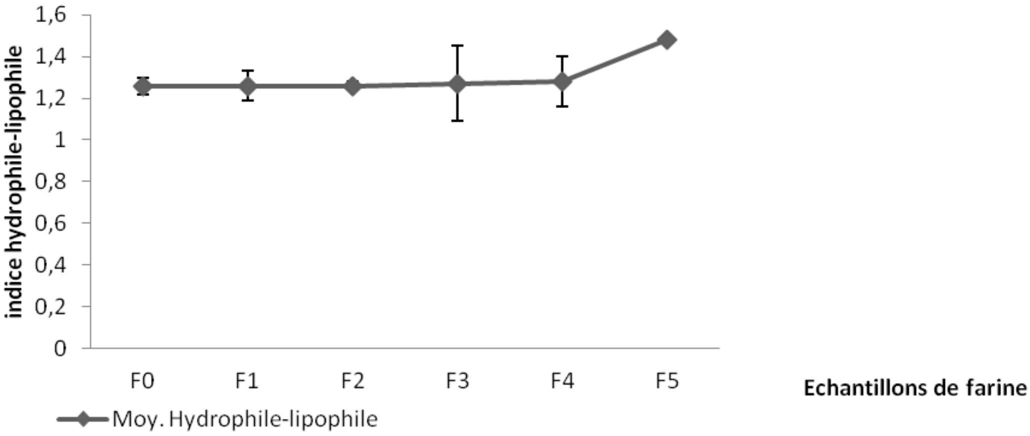

Figure 9. *Changes in the hydrophilic-lipophilic index of maize flour as a function of time of fermentation*

4. DISCUSSION

The results of analysis showed that the titratable acidity of the maize flour increased with increasing duration of fermentation. Thus, the decrease in pH resulted in increase of total acidity of the fermented flours. This acidity increase could be ascribed to increase of the maize flour concentration in fatty acids, phosphoric acids, H^+ and carboxyl groups of protein amino acids (11]; [12]; [13]). According to [14] , the pH drop is the result of the production of various organic (acidic) compounds such as lactic and acetic acids and ethanol in the course of fermentation. The WRC of maize flour increased with the fermentation time, which could be explained by rearrangement of water holding fiber and hydrophilic polysaccharide components of the maize flour ([8]**)** in addition to probable increase in less hydrophobic protein substances. It has, indeed, been reported that the WRC increases with increase in the amount of proteins [15] and that hydration of starchy polysaccharides is usually followed by that of proteins. Furthermore [16] has also reported that the polar amino-acid residues of proteins have a high affinity for water molecules. The values of WRC of fermented maize flours are essentillay higher than those reported for flours of legumes [17] and niébé (1.28 g water ⁄ g dry sample) by [18]. Moreover, the maize flours with high WRC values would contain high amounts of hydrophilic components, which may contribute to improve the solution viscosity of various food products [19]. The ORC was also found to increase with increasing duration of fermentation. This character of the amply (96–120 h) fermented maize flour to retain higher quantities of water and oil may help to improve the structure of miscellaneous food products and some of their sensory properties such as flavor and taste and reduce the loss of water and fat [20].

It could therefore be inferred that the higher the WRC and ORC of the fermented maize flour, the better its nutritional and organoleptic properties would be. The changes in the WRC and ORC of the fermented maize flour did not affect its HLI. However, the overall mean value of HLI, around 1.27, suggested that sufficiently (96–120 h) fermented maize flour may have an interesting affinity for oil and therefore would retain food aroma and flavor. Furthermore, the BD value decreased with increasing time of fermentation. As reported elsewhere [21], this may be beneficial to the formulation of infant food flour.

5. CONCLUSIONS

This study revealed that fermentation influenced the physicochemical and possibly the functional properties of maize flour. Indeed, pH, total acidity, moisture content, block density, water retention capacity, oil retention capacity, and hydrophilic-lipophilic index were found to be affected. It may therefore be nutritionally interesting to ferment maize flour before utilization as a food product.

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