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Full Length Research Paper

Impact of the storage conditions and duration on some nutritional parameters of three flours of mass consumption in Cameroon

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Wheat, maize and cassava flours are of mass consumption in Cameroonian households. Depending on the frequency of consumption and the size of households, these flours can take several months before complete exhaustion. The present work assessed the impact of three common storage conditions (aerobic, partial aerobic and anaerobic) on the evolution of some nutritional parameters of these flours. The results showed that nutritional parameters varied with conditions of storage and duration. Crude protein was the most affected parameter. After a month of storage, more than 90% of crude protein content dropped irrespective of storage condition and type of flour. Carbohydrate content increased after a month of storage and decreased during the second month. On the other hand, total lipid and ash content did not varied. Generaly, nutritional parameters deteriorated more in aerobic condition, followed by partial anaerobic and then total anaerobic condition. Ultimately, total anaerobic environment was recommended for better conservation of flours.

Key words: Flour, mass consumption, storage conditions, nutritional evaluation.

INTRODUCTION

Cereals (corn, wheat and rice) remain the main staples in Sub saharan African (36.2% caloric intake and 40% protein intake), followed by roots, tubers and starchy foods. According to the ‘Document of Development Strategy of Rural Area (DSDSR, 2005) report of the Cameroonian Ministry of Agriculture and Rural Development, cereals, fruits, vegetables, and tubers represent 50% of the total food demand, while animal production contribute for only 23 %.

However these grains (rice and wheat) which are

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imported represent 56% of the total budget spent by urban households in constrast to those produce locally (maize, millet, sorghum), which represent 37% of the total budget (Dury et al., 2000). Cereals are usually processed into flour and are used in baked products. FAO,1990) They are also the basis of several dishes like fufu, pasta and cakes. Cereals can also be eaten in the form of semolina and broken grains (Khaly, 1998). Depending on the size of the household and the frequency of consumption, these flours can spend several months before being completely eaten. The conditions of storage are a critical factor in determining the storage stability of cereal products. (Cell of the NGO Green Africa, 2003).The humid tropical climate of some African regions is a critical factor for the preservation of these products. In this type of atmospheric humidity conditions, preservation of flour is a main constraint.

The general objective of this study was to study the impact of the storage conditions on some nutritional parameters of three flours of mass consumption (maize, wheat, cassava). More specifically, this study was to determine some physico-chemical parameters (moisture, ash, protein, carbohydrate, lipid contents) of these flours under three different storage conditions.

MATERIALS AND METHODS

Traditional production of cereal flours

Corn and cassava flours were processed locally at the Laboratory of Food Technology of the Institute of Agricultural Research for Developpment (IRAD) Cameroon while the wheat flour was procured from a local market in the city of Yaoundé:

1. *Wheat flour* (*Triticum aestivum*) being an imported commodity was bought at a local market in the city of Yaoundé.
2. *Corn flour*: Yellow corn (Zea mays) was crushed and ground into flour with a hammer mill. The resulting powder was sieved to separate chaff from flour.
3. *Cassava flour*: Cassava tubers (Manihot esculenta) were washed in clean water, then peeled and sliced into chips. The strips were dried under the sun for 3 days. These chips were later milled with a hammer mill. The cassava flour obtained was sieved in order to eliminate impurity.

Experimental set up

Three conditions of flour storage was studied:

1. Storage in aerobic conditions where samples were kept in a completely open container and exposed to ambiant environment (about 25°C);
2. Storage in partial anaerobic conditions where samples were kept in a semi-open container at room temperature.
3. Storage in anaerobic conditions where flour samples were kept in a container hermetically closed, at room temperature.

Flours were kept for 60 days and every 4 weeks, samples of each treatment were analysed.

Physico-chemical analysis

The studied parameters were: Moisture content, ash, crude protein, total lipid content, and carbohydrate content.

1. The moiture content was carried out according to the standard ISO NF ISO 11465: 1994 X31-102. Five grams of each sample was heated in an oven at 103°C for 4 h. Samples were then cooled in a desiccator. The lost in weight was calculated as percent moisture.

$$\text{Moisture H (\%)} = (P - P1) \times 100) + 0.3) / P1$$

Where P = the test and P1 = weight of dry residue intake dry.

2. Ash content: 5 g of each flour sample underwent oxidation combustion in an oven at 550°C for 24 to 48 h. The mineral residue remaining was calculated as the ash percentage.
3. Crude protein: The crude protein was determined using the KJELDAHL method (AFNOR, 1991). Samples were mineralized by concentrated sulphuric acid in the presence of a catalyst, followed by an alkalinazation of the reaction products (ammonium sulphate) with soda concentrated laundry.
4. Total lipid content was determined by the soxhlet extraction method as described by Bourely (1982). Fat was extracted from 5 g of flour samples in 300 ml at about 50°C. After 3 h of extraction, the extracted fat was dried at 95°C for 1 h.
5. Total carbohydrate content was determined using an undirect method as described by Noor et al. (2012). This method consisted of subtracting the sum of moisture, ash, protein, lipid percentage from a hundred.

$$\text{Total carbohydrate} = 100 - [\text{ash (\%)} + \text{protein (\%)} + \text{fat (\%)} + \text{moisture (100\%)}].$$

Statistical analysis

The results were analysed using the statistical software R.3.1.2. Normality tests (Kolmogorov Smirnov) were first made to assess storage conditions on the physicochemical parameters of different types of flours. For normally distributed data, the analysis of variance (ANOVA) three factors allowed to study the influence of the type of flour, the storage duration and storage condition on the various nutritional parameters. However for abnormally distributed data, the kruskal-Wallis test was used to measure the influence of different factors among themselves. At the end of these tests, the boxplots was done to illustrate these various measured parameters.

RESULTS AND DISCUSSION

Effect of storage conditions and duration on some physico- chemical parameters

The macromolecules of the flours (lipid, protein and carbohydrate), as well as the moisture and ash content varied from one flour sample to another, and also within the same flour, depending on the storage condition and duration. These various variations are presented in Tables 1 to 3.

Effect on moisture content

The effet of the storage conditions and duration on the

Table 1. Evaluation of some nutritional parameters of wheat flour with storage conditions and duration.

Storage condition	Storage duration (days)	Moisture content (%)	Lipids (%)	Protéin (%)	Ash (%)	Carbo-hydrate (%)
	0	15.304	1.84	1.257	0.700	80.898
Aerobic	30	14.505	1.756	0.160	0.800	82.778
	60	12.610	1.200	0.086	0.600	82.404
	0	15.304	1.840	1.257	0.700	80.898
Partial anaerobic	30	14.155	1.761	0.079	0.700	82.304
	60	13.760	1.400	0.051	0.700	81.809
	0	15.304	1.840	1.257	0.700	80.898
Total anaerobic	30	13.970	1.787	0.159	0.800	83.283
	60	13.631	1.801	0.064	0.700	80.706

Table 2. Evaluation of some nutritional parameters of corn flour with storage conditions and duration.

Storage condition	Storage duration (days)	Moisture content (%)	Lipid (%)	Protéin (%)	Ash (%)	carbohydrate (%)
	0	11.970	3.500	1.725	2.000	80.804
Aerobic	30	13.070	3.340	0.110	1.800	81.679
	60	11.975	3.600	0.101	1.700	79.838
	0	11.970	3.500	1.725	2.00	80.804
Partial anaerobic	30	11.851	3.320	0.116	1.800	82.913
	60	12.740	3.200	0.055	1.900	79.205
	0	11.970	3.500	1.725	2.000	80.804
Total anaerobic	30	12.301	3.160	0.110	1.900	82.529
	60	11.850	3.600	0.115	1.900	80.992

Table 3. Evaluation of some nutritional parameters of cassava flour with storage conditions and duration.

Storage condition	Storage Duration (days)	Moisture content (%)	Lipids (%)	Protéin (%)	Ash (%)	carbohydrate (%)
	0	14.505	1.820	1.486	3.100	79.089
Aerobic	30	12.930	1.770	0.000	2.900	81.41
	60	13.245	1.400	0.028	3.100	80.422
	0	14.505	1.820	1.486	3.100	79.089
Partial anaerobic	30	14.301	1.730	0.000	3.100	80.87
	60	13.760	1.200	0.000	3.400	79.718
	0	14.505	1.820	1.486	3.100	79.089
Total anaerobic	30	14.170	1.800	0.000	3.200	80.83
	60	14.015	1.600	0.000	3.000	79.764

moisture content depended on the type of flour: after 60 days of storage, the moisture content of wheat flour decreased from 15.3%(T_0) to12.6% in aerobic conditions, from 15.3% (T_0) to 13.7% in partial anaerobic conditions, and from 15.3 to 13.6% in total anaerobic conditions. As for cassava flour, moisture content decreased from 14.5 -

13.2%, 14.5-13.7%, and 14.5-14.0%, respectively in aerobic, partial anaerobic and total anaerobic conditions. Concerning corn flour, the moisture content did not significantly vary in aerobic conditions (about 11.9%). In partial anaerobic conditions, moisture content varied from 11.9 to 12.7%, and from 11.9 to 11.8% in total anaerobic conditions.

Effect on ash content

The initial ash contents were 0.7, 2 and 3% respectively for wheat flour, corn and cassava. Irrespective of the storage conditions (aerobic, partial anaerobic and total anaerobic) and duration, the values remained almost constant with no significant variation.

Effect on crude protein content

Crude protein varied considerably regardless of the storage duration. Atfer 30 days of storage, total protein content dropped irrespective of the storage condition, more than 90% of total protein was lost during the first month of storage. Crude protein in corn flour varied from 1.7 to 0.1%, irrespective of the storage condition. In cassava flour, crude protein was not more detectable after two months as it varied from 1.5% to undetectable irrespective of the storage condition. Crude protein in wheat flour varied from 1.3 to 0.1%, irrespective of the storage condition.

Effect on total lipid content

Lipid content of corn flour was relative constant regardless of the storage condition and duration. It varied from 3.5 to 3.6, 3.5 - 3.2 and 3.5 - 3.6% respectively in aerobic, partial anaerobic and total anaerobic conditions. Variation in cassava flour was more significant than in corn flour with values varying from 1.8 - 1.4, 1.8 - 1.2 and 1.8 - 1.6% respectively in aerobic, partial anaerobic and total anaerobic conditions. The same trend was observed in wheat flour with values varying from 1.8 - 1.2, 1.8 - 1.4 and 1.8 - 1.8% respectively in aerobic, partial anaerobic and total anaerobic conditions.

Effect on carbohydrate content

The carbohydrate content in wheat, maize and cassava flour underwent a very slight variation during storage (aerobic, partial anaerobic or total anaerobic) with the mean carbohydrate content fixed at 81%. There was a slight increase of the sugar content after 30 days of storage, followed by a slight decline after 60 days.

Most of grains and oilseeds productions in wet tropical climate and especially in wet African regions are simply lost, or else sees their nutritional and health characteristics deteriorate because of poor storage conditions. Some physico-chemical parameters of corn, cassava and wheat flours were followed during 60 days of storage under 3 conditions of storage: Aerobic, partial anaerobic and total anaerobic. The results had showed that nutritional parameters were much more deteriorated in aerobic condition, followed by partial anaerobic and total anaerobic conditions.

Low moisture content in flour is essential during storage because it favours shelf life stability of flour (Eleazu et al., 2012). Higher moisture content has been reported to accelerate or enhance microbial growth (Aryee et al., 2006, Souci et al. 1994) by hydrolysis of starch through their amylases and thereby facilitate acidification of flour. Chene (2001) stated that moisture content of flour for a good storage must be range between 10 and 13%. This was in conformity with our results as the values obtained (11 to 14%), fell within the range. Thus, according to Amarachi et al. (2015) humidity criteria, the flours used in this study had the potential of good storage quality.

Knowledge of the ash content in flours is essential because it not only gives a quantitative estimates of the minerals available (Eleazu et al., 2012), but also allows the milling industries to estimate the expected flour yield as well as identify the milling functionality of flour. The ash content is a measure of the purity of the flour. It defines commercial types of flours (Feillet, 2000). The results obtained showed that only wheat flour samples were in conformity with the standard (inferior to 1%) as stated by Codex Alimentarius. Therefore, independently to storage condition, corn and cassava flour had ash content largely above the standard.

Crude protein content in corn flour was very low, tending to zero after just one month of storage. This results was far below the normal value (7%) as recommended by FAO,1996. It could be attributed to the high husking of corn grains which favours elimination of protein contained in the pericarp of the grain. Amarachi et al. (2015) reported that cassava tubers are generally low in protein, with cassava flour having 1.5% content. Cassava flour samples had initial crude content which are conform to the recommandation, but after 30 days of storage, these value dropped and become undetectable. Crude protein in wheat flour was lower than the value given by Godon and Michelle (1998),Grandvoinnet and Pratx (1994) for whom the normal value destined for manufacturing cooking products must be range between 7 and 15%.

Samples of maize flour presented a total fat values ranging from 3.2 to 3.6%, which is less than the value determinated by the codex Alimentarius (4.5%). The process of obtaining flour from local products seem not to have a significant impact on the lipid content of corn flour. According to Khally (1998), total fat content of cassava

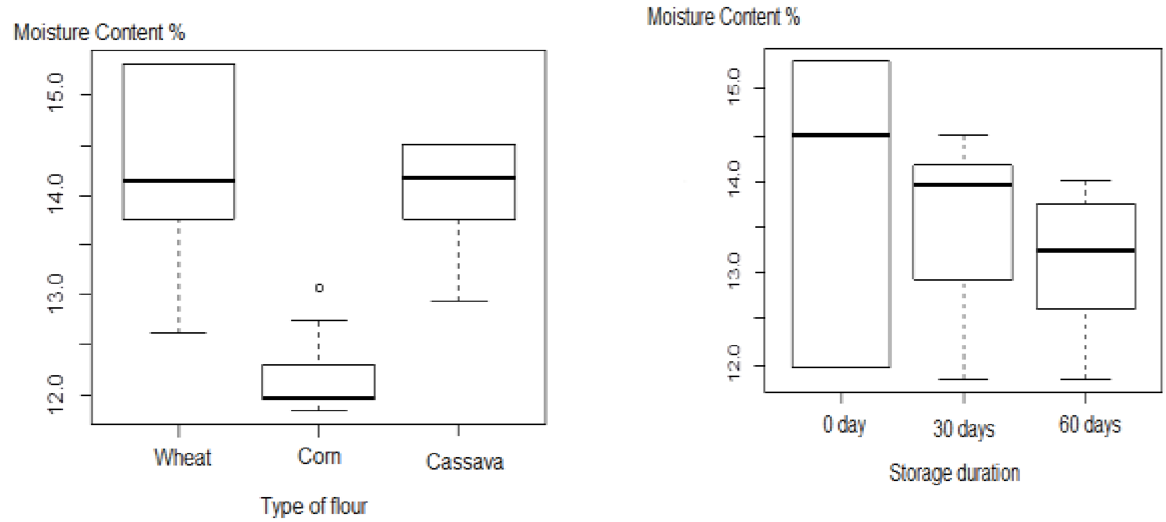

Figure 1. Moisture content based on: (a) The type of flour; (b) The storage duration.

flour is 1.5%. In this study, certain samples had total fat content superior to this threshold value, drawing attention to the need for good storage. If not, lipolysis of free fatty acids could occur and could impairing alteration in short-term period (Finney et al., 1950). For Feillet (2009), wheat flour have lipid content of 1.4 to 2%. This results was in conformity with the studied wheat flours.

The test of normality of datas from studied parameters

The test of normality on moisture, carbohydrate, total lipid, crude protein, and ash datas revealed that only moisture and carbohydrate data were normally distributed (p-value inferior to 0.05).

Analysis of variance on the normally distributed data

Three way ANOVA for moisture content of flour: The ANOVA three factors was carried out on the moisture content of flours. Significant p-values were obtained with the parameters: Type of flour, duration of storage and the interaction of both parameters (type of flour/duration of storage). These results demonstrated the influence of these 3 settings on the moisture content of flours.

Figure 1a and b illustrates these influences. Figure 1a revealed that wheat and cassava flour moisture content were significantly higher than that of corn. This could be explained firstly by the water added to the wheat before milling and secondly by water content of the cassava tuber. Similarly, Figure 1b below revealed that the moisture content of flours decreased with the increase of the storage time. This could be due to the use of water molecules included in flours for the hydrolysis of constituents. In fact, a high water content promotes the proliferation of microorganisms capable of using their amylases to hydrolyze the starch present in the flour over time. This decrease is more pronounced for the storage in total anaerobic than aerobic. This confirms that the anaerobic was more favourable to good preservation of the flours.

ANOVA three factors in the carbohydrate content of flours: Significant p-values ($p<0.05$) were obtained with the type of flour and storage duration. This respectively revealed the influence of the type of flour and duration of storage on the carbohydrate content of flours.

Figure 2a and b below illustrates these result. Figure 2a showed that carbohydrate content was significantly higher in the wheat and corn flours, than in that of cassava. Similarly, Figure 2b showed that carbohydrate content in the flour increased after a 30 days of storage, then decreased after 60 days. This increase would bedue to the release of reducing sugars by hydrolysis of starch content in the different flours (Collard and Lev, 1959) then the decrease in time T2 will be the effect of the use of these sugars for fermentation. Indeed the simple sugars are quickly used by the yeast during the fermentation (Grandvoinnet and Pratx, 1994).

Ranking Kruskal-Wallis test on non - normally distributed data

The test of Kruskal-wallis ranking was achieved on the physicochemical parameters not complying with the

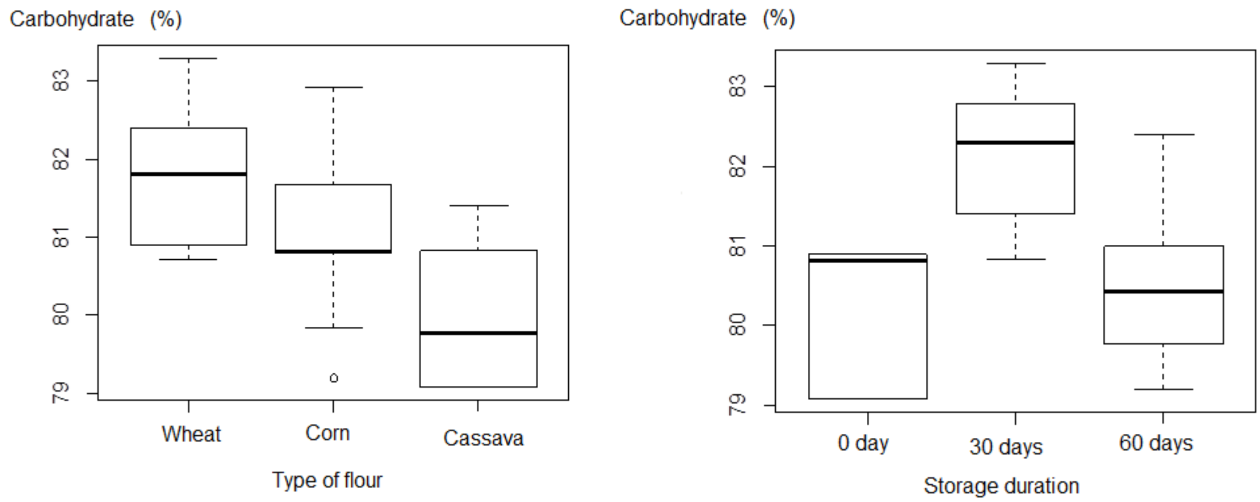

Figure 2. Carbohydrate content based on: (a) The type of flour; (b) The time of storage of flour.

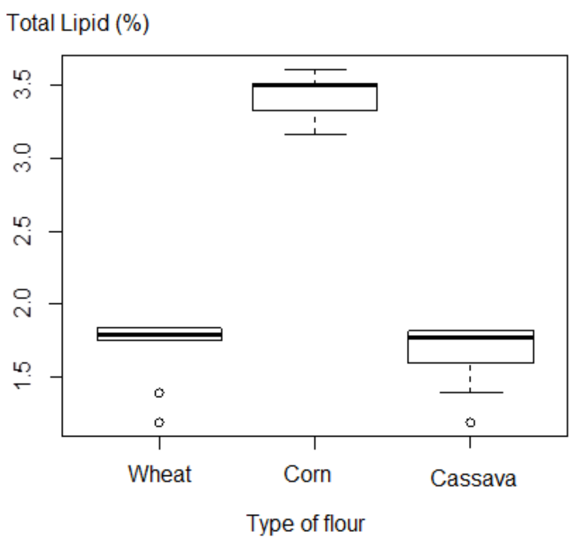

Figure 3. Total lipid content of flours.

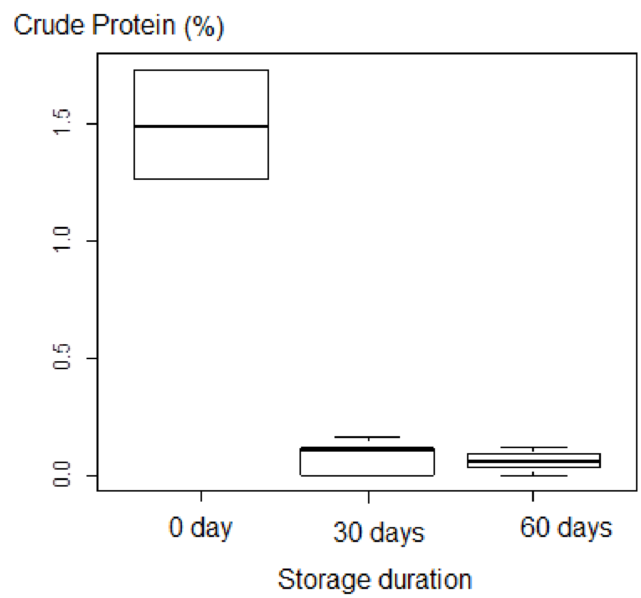

Figure 4. Variation of crude protein based on the storage time.

normal law namely lipids, protein and ash.

Total lipids: For 3 types of flours, the total lipid content did not varied with the storage conditions and duration. This showed that the evolution of total fat content was not dependent on the duration and the storage condition. Nevertheless the Kruskal-Wallis test shows a significant p-value, which indicates the change in the quantity of lipid based on the type of flour. This variation was illustrated in Figure 3. There was a significantly higher amount of lipid in corn flour compared to wheat and cassava flour. Indeed high levels water of the wheat flour and cassava could lead to the phenomenon of lipolysis within it and encourage decreases in their lipid content.

Crude protein: It should be noted that the type of flour and the storage condition did not influence crude protein content (not significant p-value). However the Kruskal-Wallis test revealed a significant p-value, which indicated the variation in the quantity of protein according to the storage duration. This variation was illustrated in Figure 4 where there was an amount of protein higher at time T_0, then a sharp drop at T_1 and T_2. This decline in the rate of protein based on the duration translated the degradation of these flours, and was pronounced in partial anaerobic and aerobic conditions. It was therefore recommended to

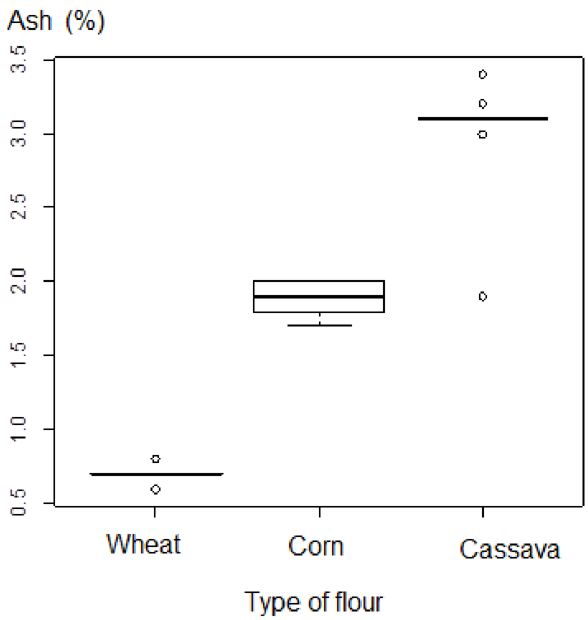

Figure 5. Variation of ash content with the type of flour.

maintain flours in anaerobic environment in order to maintain the nutritional quality.

Ash content: The duration and the storage condition did not influence ash content of flours (not significant p-value). The test revealed a significant p-value with the type of flour. This indicates a change in the quantity of ash depending on the type of flour. This variation was illustrated in Figure 5 where the highest ash quantity was obtained with the cassava flour and the lowest with wheat flour.

This disparity between the wheat, corn and cassava was mainly due to the level of efficiency of the shelling and a bad pulping of cassava. Milling of wheat was done through cutting-edge technology, which reduced considerably the amount of hull that could end up in the flour and induce a significant ash rate. High ash levels in maize and cassava flours showed quite clearly an ineffective shelling of local cereals and poor technique of transformation at the artisanal level. Therefore, there is an urgent need to improve the process of producing flour from the cassava.

Conclusion

The aim of this work was to study the impact of the storage condition and duration on the quality 3 flours of high consumption (corn, wheat, cassava). The different flours were evaluated for their physicochemical characteristics. It emerges that these nutritional parameters are influenced by the storage condition and duration and also by the type of flour. Crude protein content was the most affected with storage. Ultimately this study advocates the total anaerobic environment for better conservation of the flour over a short period, in order to maintain the nutritional properties of the flour.

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CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

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