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Experimental and comparative brewing of *Sorghum Bicolor* and *Eleusine Coracana* cereals found in Haut-Katanga in the DR Congo and in the Copperbelt in Zambia

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ABSTRACT: The objective of this work was to carry out micro-brewing trials of some cereals commonly used as a starchy material in the preparation of artisanal drinks in the province of Haut-Katanga in Democratic Republic of Congo (DRC) and to make a complete analysis of the various parameters sought on the latter in a conventional brewery. Thus, we have selected two types of cereals traditionally used, sorghum (Sorghum Bicolor) and finger millet (Eleusine Coracana) and two other types of cereals conventionally used in brewing on an industrial scale, maize (Zea Mais) and Malt (Hordeum Vulgare). Different parameters such as density, turbidity, pH, coloring, filtration time, fat, humidity, saccharification and yield were sought and it emerges from the different results that the density of malts is found to be imposing by its extractable carbohydrate material compared to the selected test cereals, the turbidity was very acceptable in the two cereals including sorghum at 2.755 EBC and finger millet 2.39 EBC. Regarding pH, acidity was most noted in finger millet must 5.38; finger millet color was the highest of all samples, sorghum had a very long filtration time of 80 minutes, high moisture of 13.11% was found in semolina, fat was higher in the malt samples and finally, a conventional brew was performed to allow us to bring out the overall yield of 77.10% for the malt and that of 77.79%. These yields were quite high compared to those of the test cereals including finger millet with 55% and sorghum with 45.3%, but the yields obtained are still acceptable.

KEYWORDS: cereals, conventional brew, parameters, yields.

1 INTRODUCTION

Sorghum and finger millet are the staple food grains for several million people in the tropics of Africa, India and Asia [1], [2], [3]; these cereals are used directly or in malted and fermented form in the preparation of several traditional foods including porridge especially for children [5], [6], [7]., porridges and alcoholic and non-alcoholic drinks [4], [8], [9].,. In many regions of southern DR Congo and northern Zambia, their consumption is very widespread and the making of beverages constitutes an economic activity for many women in different cities such as Lubumbashi, Kipushi, Kasumbalesa, Chililabombwe, Kitwe, and Ndola [10], [11], [12]. They are consumer products and more accessible than industrial and imported beers [13], [14]. In rural areas, production for sale is also developed, but on a very small scale because a large part of the production is intended for self-consumption. The few studies carried out on these products have mainly concerned the reduction in the consumption of wood fuels in artisanal processing and in the industrial production of beer made from local cereals, particularly sorghum [14], [15], [16], [17]. The process for small businesses therefore remains traditional. There is not yet a traditional pasteurized beer allowing a wider consumption and a fairly developed distribution [18], [19], [20], [21]. The general objective of this work is to determine the physicochemical parameters of these cereals in order to develop the tools and methods for industrializing the manufacturing processes for craft drinks based on sorghum and finger millet; as a main goal, we want to complete the knowledge of the different parameters of a conventional micro-brewing in comparison with the cereals used industrially in brewing [5], [6], [7].

2 Materials And Methods

We will successively present the laboratory equipment, devices, chemicals and methods we used to obtain the results of this research.

2.1 Study Environment

The present work was carried out in the urban city of Lubumbashi, more precisely in the RUASHI Commune located in the North-East of the city of Lubumbashi, in the Democratic Republic of Congo. Said municipality is located at 11°37’46" South latitude and 27°32’46" East longitude.

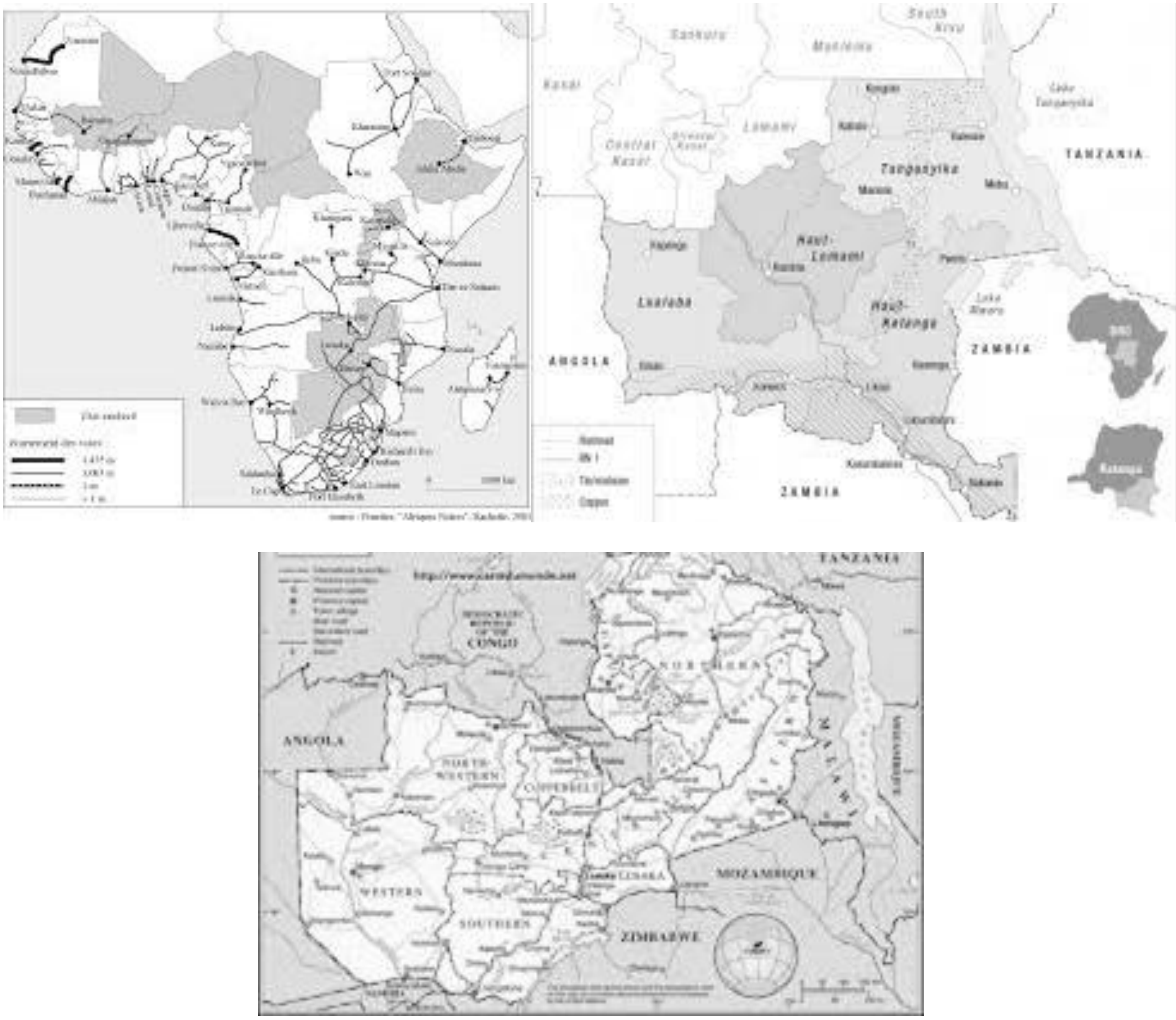

Fig. 1. Katanga (DR Congo) and Copperbelt (Zambia)

2.2 Obtaining And Conditioning Samples

Samples imported from the Republic of Zambia were purchased at the market called Zambia in RUASHI municipality (DR Congo), particularly in Ward 6; they were kept in Schott-Duran glass bottles, some for sorghum and others for Finger millet. They were then soaked and kept in a closed bag for 72 hours for germination, then dried in the sun for a day; finally they were finely ground before being used in the various investigations.

2.3 Experimental Setting

The analyzes made for this work were carried out at the central laboratory of the Simba brewery (BRASIMBA) located in the city of Lubumbashi on avenue N'Djamena N˚1200.

2.4 Materials, Devices And Reagents

The starchy materials used are sorghum and finger millet, in addition we have combined the cereals conventionally used in brewing including cornmeal and germinated and dried barley called Malt

2.4.1 Laboratory Equipment

Different glassware such as: funnel, calibrated flask of different capacities, metal jars, glass rod, Erlenmeyer flask of different capacities, Drygalski spatula, and beaker of different capacities, graduated and volumetric pipettes of different capacities were used.

2.4.2 Devices And Reagents

The following devices and reagents have been used: Inolab 7310 pH-meter, Anton Paar DMA 4500M density meter, Lochner micro-brewery type Labor + Technik model LB8-Electronic, Memmert oven, Präzitherm hot plate, Hach Lange DR 6000 spectrophotometer, Planschister sieve shaker type DLKP, Bühler Miag DLFU type mill, precision weighing scale from Sartorius, Iodine, distilled water and, trichloroethylene.

3 Methods

3.1 Conventional Brew

It consists of determining the amount of matter solubilized in the must during a conventional brewing process. This method is also used to determine saccharification time, odor, filtration rate, wort pH, color, viscosity, soluble nitrogen content and free amino nitrogen [22], [23], [24] [25].

3.2 Saccharification Speed

Determining the rate of starch hydrolysis during brewing is a method applicable to all malts. It consists of a reaction of a drop of maiche with a drop of iodine solution; the rate of saccharification is determined according to the disappearance of the blue color due to the starch-iodine complex [22], [23], [24] [25].

3.3 Wort Coloring

The method consists in determining the color of the most obtained in the laboratory by spectrophotometry, the absorbance of which is measured at 430 nm in a 10 mm cuvette. The method is applicable to all types of pale and dark malts after clarification of the obtained must [22], [23], [24] [25].

3.4 WORT Ph

The method is applicable to all types of laboratory must with the same principle of pH measurement using combined electrodes [23].

3.5 Turbidity Measurement

The turbidity of the beer is an important quality parameter as this affects the product shelf life and serves as acceptance criterion for the consumer, the Scattered light caused by haze particles is measured at 90° and 25° angles. A red light wavelength of 650 ± 30 nm as recommended by MEBAK [9], [23].

3.6 Determination Of Humidity

It consists in determining the water content of the malt. Grinding of the grains and measurement of the loss of mass of a sample after 3h30 of heating in an oven between 105 - 107°C [24], [25].

3.7 Determination Of Hot Fat

The principle is to subject the sample to extraction with trichlorethylene by heating under reflux using a soxhlet extractor. The extraction solvent is then evaporated off before weighing the residual fat [24], [25].

3.8 Presentation Of The Results And Discussion

This part will be devoted to the presentation of results obtained during all this research. These will be the results of Sorghum, malt; semolina and finger millet, the different parameters that we have determined are as follows: density, turbidity, pH, color, filtration time, humidity, yield, and saccharification.

Table 1. Results

Sample	Density	Turbidity	pH	Coloration	Filtration time	Humidity	Fat	Yield
Sorghum	5,29±0,02	2,75±0,06	5,54±0,02	5,33±0,09	80,50±2,12	9,96±0,21	0,88±0,01	45,3±0,07
Malt	8,65±0,25	5,07±0,25	5,94±0,00	5,21±0,19	32,50±10,61	0,04±0,00	1,33±0,03	77,10±0,57
Semolina	8,76±0,01	1,47±0,19	5,92±0,01	2,53±0,09	12,00±0,00	13,15±0,21	1,01±0,17	77,79±0,97
Eleusine	6,37±0,32	2,39±0,11	5,38±0,04	10,18±0,39	58,50±12,02	11,62±0,06	0,77±0,02	55,00±2,97

The results recorded above will be interpreted successively and represented graphically in the following lines; these will be the results of density, turbidity, pH, color, filtration time, humidity, yield and fat.

3.8.1 The Density

We noticed that the semolina and the malt had a high density respectively of 8.76°P and 8.65°P compared to the two test cereals including sorghum 5.29°P and finger millet 6.37°P, the values are shown graphically below.

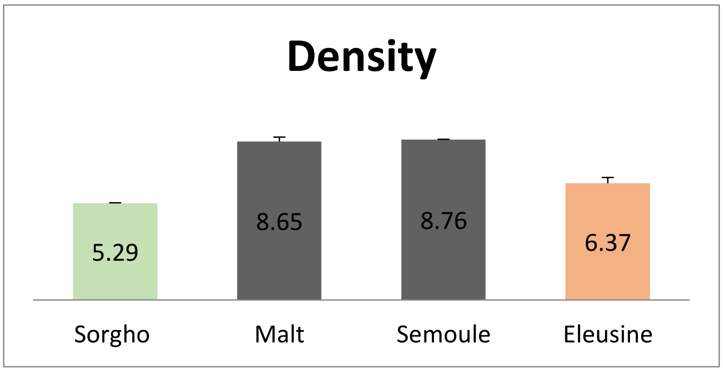

Fig. 2. Density values

3.8.2 Turbidity Expressed In EBC

After analysis, we found that the haze of the semolina wort was lower 1.47 EBC compared to other cereals including finger millet 2.39 EBC, sorghum 2.75 EBC and finally malt with the highest value of 5.07EBC disorder. The graph below clearly illustrates the observations.

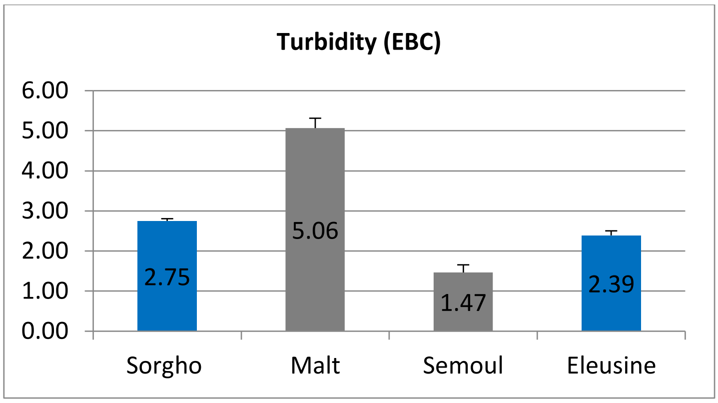

Fig. 3. Results of the different turbidities

3.8.3 PH

After the tests, we found that finger millet and sorghum had strong acidities of 5.38 and 5.54 respectively compared to other reference cereals including semolina 5.92 and malt 5.94; the graph successively represents the different values.

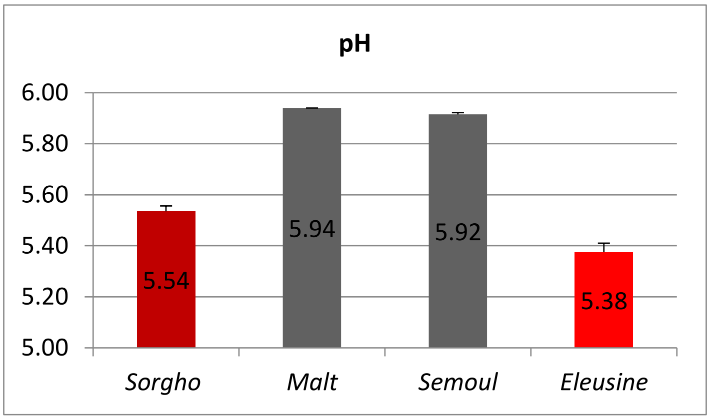

Fig. 4. pH values

3.8.4 COLORING

After analysis, we noticed that finger millet had an intense coloring of 10.18°EBC compared to other cereals sorghum 5.33°EBC and malt 5.21°EBC; the test cereals used as references had low color values, the values measured at the wavelength of 430 µm are expressed in °EBC as shown in Figure 5 below.

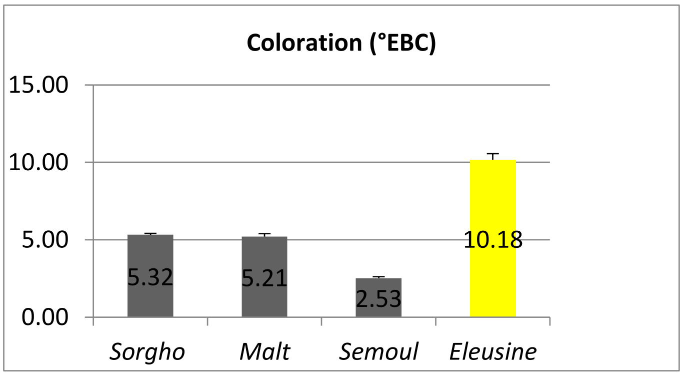

Fig. 5. The different coloring values

3.8.5 FILTRATION TIME

After analyzes, we found that the sorghum masche had a much slower filtration in the order of 80.50 minutes compared to other cereals including finger millet 58.50 minutes, malt at 32.50 minutes and semolina at 12.00 minutes which is the shortest filtration time compared to others.

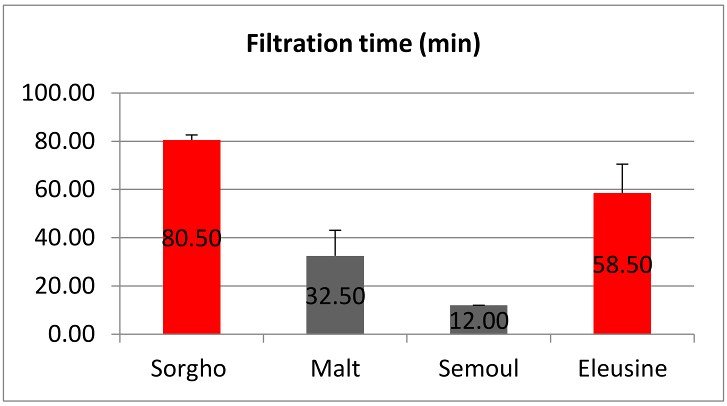

Fig. 6. filtration time

3.8.6 HUMIDITY

Regarding this point, we observed a low humidity in the Malt of 0.04% while the sorghum gave a content of 9.96% followed by finger millet with 11.62% in moisture content and the maximum content. 13.15% was observed in semolina.

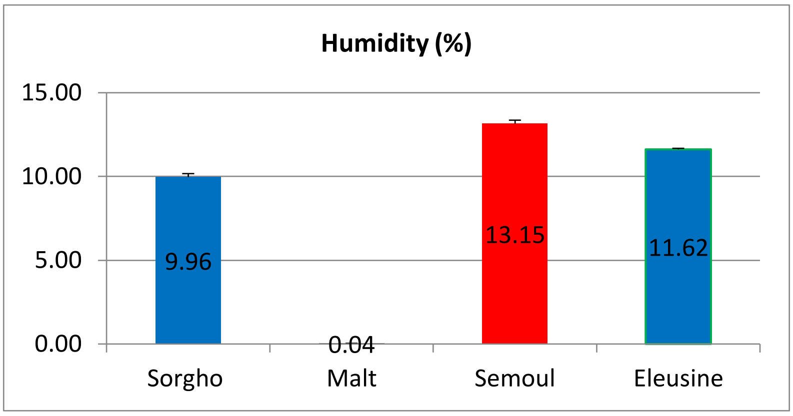

Fig. 7. Humidity

3.8.7 FATTY SUBSTANCES

We found that the two cereals tested had a fairly low fat content of 0.88% for sorghum and 0.77% for finger millet compared to the two reference cereals. The results are illustrated in the graph below.

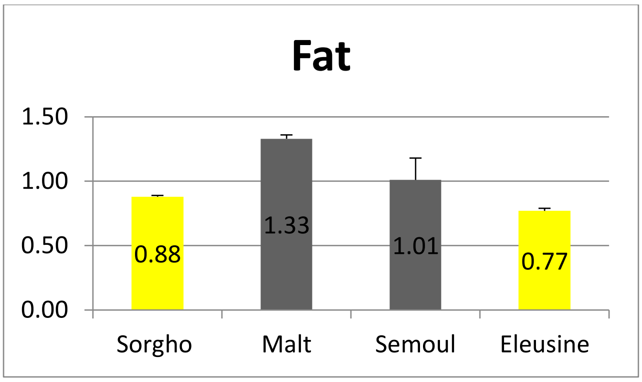

Fig. 8. Fat content

3.8.8 THE YIELD

These results show the possibilities of obtaining industrially acceptable quantities of sorghum at 45.30% and finger millet at 55.00% yield in extractable carbohydrate matter according to the conventional EBC mash compared to our two references which are semolina and malt.

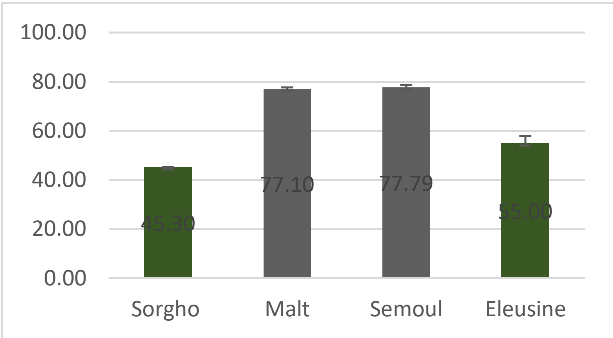

Fig. 9. The yield (Extract)

3.8.9 SACCHARIFICATION SPEED

The iodine test demonstrated that both study samples did not undergo adequate saccharification, as the transfer persisted for the first 10 minutes followed by testing after 15 minutes and 25 to 30 minutes.

This absence of saccharification indicates that the enzymatic reaction was not efficient and more precisely at the level of the malting of these samples, it is probable that the quantity of α-amylase was not sufficient during the malting to allow the β-amylase to continue with the saccharification reaction. The results are shown in Table 2 below:

Table 2. Results of the saccharification rate

Saccharification	10 to15 min	15 to 20min	20 to 25 min	25 to30 min
Sorghum 1	-	-	-	-
Sorghum 2	-	-	-	-
Malt 1	+	+	+	+
Malt 2	+	+	+	+
Eleusine 1	-	-	-	-
Eleusine 2	-	-	-	-

Sorghum density was observed to be the lowest and this confirms the studies by Palmer *et al*. 1989 and Ogbonna 2011. But this wort density content is not so low so as not to use these cereals in breweries, the values of 5.29°P and 6.37°P are also interesting for the process pilot scale tests, According to the work of Palmer and Ogbona (1989) explaining the problems of Sorghum as a brewing raw material, a low extract yield or low diastasic power, attribute to poor andosperm modification by comparing diastasic power with amylase 20, 0 Unit for Sorghum malt/wort and 80,0 for Barley malt/wort.

Unlike the test samples, we found a high haze content in the malt which is considered a benchmark but a low haze content in our samples compared to the reference samples, which is encouraging and proves that the final product will have an interesting clarity and will not require dilutions. We found that our samples had a low acidity of 5.38 for finger millet and 5.54 for sorghum. This shows that we can have beers with acceptable acidity. It was noticed that finger millet had an intense coloring of 10.18˚EBC, this intensity is not an alarming parameter compared to its use because it reassures us that we can use it for the manufacture of the products dark and dark beers. We know that sorghum has higher levels of dextrin and this causes filtration problems and we found that the sorghum sample took longer to filter so 80 minutes faster compared to other test samples. We noticed that our samples contained less percentage of fat including sorghum 0.88% and finger millet 0.77%, which confirms that we can have good beers without too much fat and therefore with persistent foams.

According to the studies of palmer in 1990; it shows us that the main enzyme of starch saccharification during reduction to malt is β-amylase and it is deficient in sorghum and therefore sorghum contains significantly lower levels of maltose which makes it less fermentable. This explains the low yield of sorghum that we obtained, which is 45.3%.

4 CONCLUSION

Our investigations aimed to assess the possibilities of industrialization of the various cereals commonly used in traditional beverage preparations. To do this, various indicator parameters were sought, among others density, turbidity, pH, coloring, filtration time, humidity, fat, yield and saccharification. Finger millet and sorghum gave quite low values compared to malt and semolina, but these values were not negligible, we noticed that sorghum and finger millet had low turbidity values compared to malt which was used as a reference; this confirms that our drink will have good clarity.

From our experiments, we can predict that the drinks produced will have significant acidity; we found that finger millet had an intense coloration; this means that it has colored molecules and with this we can envision the production of dark drinks. Our samples had high humidity and this can impact their performance. Regarding the fat, we found that our samples had a low content. Concerning the yield, our two cereals provided acceptable results. As a perspective, we recommend that researchers take these studies further by evaluating saccharification by other methods and go as far as experimenting with pilot-scale fermentation and analyzing the final results.

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