International Journal of Multidisciplinary Research and Growth Evaluation.

Valorization of Mandrakwa and Musururu traditional fermented drinks from North Kivu, DR Congo

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Article Info

ISSN (online): 2582-7138
Volume: 04
Issue: 03
May-June 2023
Received: 21-03-2023;
Accepted: 11-04-2023
Page No: 192-197

Abstract
After the description of the methods of preparation of two traditional beers of the Congolese province of North Kivu, Mandrakwa and Musururu, it is reported in this study the food value, the physicochemical and microbiological properties of these two fermented drinks of the DR Congo.

DOI: https://doi.org/10.54660/.IJMRGE.2023.4.3.192-197

Keywords: Traditional beers, Mandrakwa and Musururu, fermentation

1. Introduction

Within the framework of the project relating to the valorization of vegetables and fermented drinks from the DRC, initiated at the Chemistry Department of Higher Pedagogical Institute of Lubumbashi, several studies have been already realized. The last related publication concerned two traditional fermented drinks from the province of Haut-Katanga, Katata and Katubi beers [1]. Continuing the investigations on local fermented beverages, in this paper we are interested in two other brewing specificities of another Congolese province, Mandrakwa and Musururu beers from North Kivu brewed respectively from corn and sorghum. By examining the literature, we realized that the two drinks under study had already been the subject of some studies, especially in the province of North Kivu. This is particularly the case of two end-of-studies dissertations for the first cycle and the second university cycle which were carried out in 2011 and 2007 respectively [2, 3]. Unlike the results reported in the works cited, we carried out a double filtration of the freshly prepared beers, on filter paper and on an activated earth, the Kieselguhr, reflecting the influence of the duration of fermentation during the preparation of the two traditional beers previously mentioned on their physico-chemical parameters. In addition, we also examined the effect of reducing the duration of burial in the soil of germinated maize seeds, in the case of Mandrakwa beer, on the same physico-chemical parameters.

2. Materials and Methods

2.1. Laboratories

Three laboratories in the city of Lubumbashi were called upon for the physic-chemical and microbiological analyses: the Biology and Chemistry laboratories of the Higher Pedagogical Institute of Lubumbashi as well as that of the SIMBA Brewery (BRASIMBA).

2.2. Operational modes

2.2.1. Preparation of Mandrakwa beer

The preparation of Mandrakwa drink took place according to the steps listed below:

- **Malting and burial**

5 kg of maize seeds are soaked in water for 7 days. They are full of water, germinate and are then washed with water to reduce the bad smell from soaking. Then they are coarsely pounded in a wooden mortar before being wrapped in a plastic bag and buried for 30 days.

After the 30 days of burial in the ground, the maize seeds dug up and giving off a foul smell are dried in the sun for 4 days and ground to obtain the sprouted maize flour, i.e. the flour corn malt.

- **Cooking and obtaining the must**

To 3.5 liters of boiled water, 1.5 kg of corn malt flour thus prepared are gradually added while kneading until a homogeneous and solid paste is obtained. The cooking period lasts about 3 to 5 minutes and the dough obtained is cooled in the open air for two hours. After cooling, the paste added to 4 liters of cold water is crushed with the hand until a homogeneous porridge is obtained, the must.

- **Addition of finger millet malt to the wort and fermentation**

Along with the maize treatment, 2.5 kg of carefully winnowed finger millet seeds are soaked in water for 24 hours. This soaking has the role of facilitating the germination of the seeds.

The seeds removed from the water are spread in a dish rack lined with banana leaves to facilitate germination. After 3 days of germination, the seeds are dried in the sun for 3 days and then ground on a stone wheel or a mill to obtain the germinated finger millet flour, the flour of finger millet malt. Mix 150 g of finger millet malt flour with the maize mash in the fermenter, which is covered with a plastic bag thus creating the anaerobic conditions. This quantity of finger millet malt flour can also be added in two steps: one part during the first day of fermentation and another part during the second day of fermentation.

Traditionally, the fermenter is opened on the third day of fermentation and the foaming beer immediately delivered to consumers is called Mandrakwa.

2.2.2. Preparation of Musururu (or Musululu) beer

- **Malting**

6.2 kg of carefully winnowed red sorghum seeds are soaked in water mixed with ashes for one day (the ashes are used to make the red color of the sorghum dark red). Removed from the water, the seeds are spread in a dish rack lined with banana leaves to facilitate germination conditions.

After 3 days of germination, the germinated and sun-dried sorghum for 3 days is ground on a stone grinder or in a mill to obtain sorghum malt flour.

- **Cooking**

To 6 liters of water is added one kilogram of sprouted sorghum flour. Heat the mixture while homogenizing, remove from heat before boiling and cool before placing in a fermenter (a plastic bucket).

- **Fermentation**

Cover the fermenter and place it in the warmest place in the house, usually the kitchen, to facilitate fermentation. After a day of fermentation, sprinkle the must with 340 g of sprouted sorghum flour on the first day, 330 g on the second day, 330 g on the third day of fermentation and observe the formation of air bubbles on the drink. On the fifth day of fermentation, the drink is ready for consumption, it is Musururu (or Musululu) beer.

2.2.3. Physicochemical analyzes

Acidity was determined using a pH meter. While the measurements of density and alcoholic degree were made by injecting a previously filtered sample into the Alcoholyser Beer Anton DMA 4500 M densimeter. The measurement of the coloring or clarity of the samples of the beers studied was carried out for its part, using a Hach Lange DR 6000 spectrophotometer at 430 nm.

2.2.4. Microbiological analyzes

The microbiological analyzes were carried out on four solid culture media: Wallerstein Laboratories Nutrient (WLN) for determining the presence of total germs, yeasts and molds; WLN-differential with added cycloheximide (WLD) for bacteria only; Yeast and Mold Agar (YMAgar/Agar yeast and Mushrooms) for the isolation and enumeration of wild yeasts and moulds; From Man Rogosa and Sharp (MRS), supplemented with cycloheximide (Actidione) for the isolation and enumeration of lactic acid bacteria. Then, a PCR (Polymerase Chain Reaction) analysis using the Genedisc technology developed by Pall Corporation was requested for the characterization of the germs.

3. Results and Discussion

3.1. Results

3.1.1. Physicochemical and microbiological analyzes

A. Physicochemical analyzes

- **Effect of filtration**

Before being analyzed, the two beers, Mandrakwa and Musururu, had been double filtered, on filter paper and on an activated earth, Kieselguhr. By comparing the samples of beers filtered by simple sieving with those having undergone the aforementioned double filtration, it was observed that in the first case the drinks were dark gray in color and that in the second case they were transparent yellow and pleasant to the sight. Furthermore, the yellow color of Mandrakwa beer was less dense than that of Musururu beer.

- **Physicochemical parameters analyzed**

The results recorded in the first table below relate to the Mandrakwa and Musururu drinks having been made available to consumers respectively after three and five days of fermentation, that is to say as it is traditionally done.

Table 1: Physico-chemical analyzes of Mandrakwa beverages and Musururu prepared according to traditional methods and having been double filtered (on filter paper and Kieselguhr)

N°	Analysis	Mandrakwa	Musururu
01	pH	3.88	3.54
02	Primitive extract (°Plato or °P)	10.41	9.79
03	Apparent extract (°Plato or °P)	1.17	1.08
04	Alcohol (% by mass)	4.44	3.58
05	Alcohol (% by volume)	**5.61**	**4.55**
06	Fermentation yield (%)	80.13	88.99
07	Density	1.00456	1.0041
08	Total titratable acidity (meq/l)	0.40	1.05
09	Coloring (°EBC)	2.15	4.36

Legend: °EBC= European Brewing Convention Degree

The examination of the results gathered in this first table showed that if the pH, the density and the sugar contents in the initial and terminal phases were very similar, this was not the case for the alcohol content, the fermentation yield, color and acidity. Moreover, it clearly appeared that the alcohol content of Mandrakwa (5.6%) was higher than that of Musururu (4.6%). Conversely, the fermentation yield of the latter beer (89%) exceeded that of Mandrakwa beer (80%). The second table of results relates to the influence of fermentation time on the physico-chemical parameters considered.

Table 2: Influence of fermentation time on the physico-chemical parameters of Mandrakwa and Musururu beverages prepared according to traditional procedures

Fermentation time (days)	Analysis						
	pH	Prim.E (°P)	E.app (°P)	% Alc m/m	% Alc v/v	R.ferm	Density
Mandrakwa							
1	-	-	11.92	-	-	-	1.04804
2	4.13	8.28	4.63	3.34	4.28	50.54	1.01819
3	3.88	10.41	1.17	4.44	**5.61**	80.13	1.00456
4	3.54	11.06	0.05	4.57	5.78	91.25	1.00021
5	3.51	11.04	0.05	4.59	5.82	91.27	1.00021
Musururu							
1	-	-	8.77	-	-	-	1.03496
2	4.04	896	8.55	0.17	0.22	4.57	1.03327
3	3.82	8.89	8.37	0.25	0.33	6.91	1.03327
4	3.72	9.50	4.82	1.64	2.11	40.91	1.01895
5	3.54	9.79	1.08	3.58	**4.55**	88.99	1.0041
6	3.43	10.20	0.83	3.87	4.91	91.91	1.0041

Legend: E=extract; prim =primary; app=apparent; Alc=alcohol; R=yield; ferm=fermentation

Four main observations can be drawn from Table 2. These are the sugar content in the final phase, the alcohol content, the fermentation yield and the pH.

On the second day of fermentation, the alcohol content in the Mandrakwa drink already amounted to 4.28% alcohol by the time in the Musururu drink it had remained below 0.5% during the second day and the third day of fermentation. The alcoholic degree recorded on the third day of fermentation in the Mandrakwa (5.6% by volume) and on the fifth day of fermentation in the Musururu (4.6% by volume) remained in each case practically identical to those noted on the following days.

Regarding the maximum fermentation yield, on the fourth and fifth days in the Mandrakwa and on the fifth and sixth days in the Musururu, it was around 90% in the two drinks. In addition, it was also interesting to note that this particular fermentation yield corresponded, in each drink, to the minimum presence of sugar in the final phase: 0.05° plato in the Mandrakwa, 1.08 and 0.8° plato in Musururu.

As for the pH, it had remained acidic from the second to the last day of fermentation while decreasing slightly: in the Mandrakwa, it had varied from 4.12 on the second day to 3.51 on the fifth day of fermentation and in the Musururu, from 4.04 on the second day to 3.43 on the sixth day of fermentation.

- **Reduced burial time**

The duration of burial of germinated corn seeds in the ground for 30 days (4 weeks) during the traditional preparation of the Mandrakwa drink having seemed to us very long, we tried to reduce it to 14 and 21 days, it is i.e. at two and three weeks. The results obtained are summarized in Table 3.

Table 3: Determination of the physico-chemical parameters of Mandrakwa drink after the reduction of the duration of burial in the ground of the seeds of germinated maize

D. of ferm (days)	Physico-chemical parameters						
	pH	P. extr (°plato)	*A. extr* (°plato)	% Alcohol (m/m)	%Alcohol (v/v)	Ferm. Yield (%)	Density
14 days corn malt landfill							
2	4.24	11.06	10.97	0.04	0.05	0.80	1.0440
3	4.11	11.23	10.25	0.40	0.53	8.72	1.0410
4	4.00	11.50	6.55	1.77	2.28	37.04	1.0259
5	3.75	11.64	4.46	2.98	3.84	61.70	1.0175
6	3.58	11.71	1.96	4.05	**5.17**	83.25	1.0076
21 days corn malt landfill							
2	4.18	11.51	11.39	0.05	0.07	1.05	1.0457
3	4.05	10.71	9.47	0.51	0.67	11.62	1.0377
4	3.89	11.13	4.94	2.40	3.20	52.35	1.0194
5	3.50	11.08	1.39	4.15	**5.28**	87.82	1.0053
6	3.36	11.38	1.06	4.29	5.45	90.92	1.0041
30 days corn malt landfill							
2	4.12	8.28	4.63	3.34	4.28	50.54	1.01819
3	3.88	10.41	1.17	4.44	**5.61**	80.13	1.00456
4	3.54	11.06	0.05	4.57	5.78	91.25	1.00021
5	3.51	11.04	0.05	4.59	5.82	91.27	1.00021

Legend: P. extr= Primary extract*; A. extr.*= Apparent extract*; Alc= Alcohol ; D = duration*
Rdt ferm= Fermentation yield

The reduction of the duration of burial of sprouted ma ize seeds to 14 and 21 days during the manufacture of the Mandrakwa drink made it possible to identify the following:
1°. a great slowdown in the yield of the fermentation and a strong reduction in the alcoholic degree compared to the results obtained when the duration of burial was 30 days and the drink made available to consumers on the third day of fermentation. Indeed, at the time when the fermentation yield and the alcoholic degree amounted respectively to 80.13% and 5.61% by volume on the third day when the fermentation period was 30 days, by reducing this period to 14 and 21 days, on the third day of fermentation, about 10% of the fermentation rate and an alcohol content of less than 1% were recorded in both cases.
2°. The fermentation yield and the alcoholic degree practically identical to those recorded on the third day of fermentation under traditional conditions (80.13% and 5.16%) were obtained on the sixth day of fermentation when the burial time was 14 days (5.17%) and on the fifth day when it was 21 days (5.28%).

A. Microbiological analysis

Before looking at the nutritional value of Mandrakwa and Musururu beers, we looked for some germs in said freshly brewed drinks.

Table 4: Detection of some germs in beers freshly prepared Mandrakwa and Musururu

N°	Germs wanted	Mandrakwa	Musururu
01	Total coliforms	0	0
02	Molds	13	34
03	Wild yeasts	21	>50
04	Lactobacillus group	0	0

If the microbiological analyzes thus carried out did not report any presence of total coliforms and lactobacillus group, on the other hand they highlighted that of wild yeasts and molds, especially in Musururu beer.

3.1.2. Food Value

Table 5: Dietary value of Mandrakwa beers and Musururu from North Kivu Province, DR Congo

N°	Analysis	Mandrakwa	Musururu
01	Total sugars (g/100ml)	13	11.1
02	Humidity (%)	92.22	86.06
03	Nitrogen (g/100ml)	0.56	1.08
04	Protein (g/100ml)	3.46	6.73
05	Calcium (ppm)	130	206
06	Iron (ppm)	8.16	12
07	Vitamin C (mg/100ml)	9.9	10.54
08	Vitamin B1 (mg/100ml)	18.32	15.67
09	Vitamin B2 (mg/100ml)	11.12	0.84
10	Vitamin B6 (mg/100ml)	8.5	7,2
11	Vitamin B12 (mg/100ml)	0.29	2.4
12	Polyphenols (mg/l)	43	78

The latest results we recorded related to the nutritional value of the traditional Congolese beers under study, Mandrakwa and Musururu from North Kivu.

The overall examination of Table 5 shows that the two beers of Congolese origin concerned by the present study also contained, apart from total sugars, iron, calcium and proteins, polyphenols and vitamins C, B1, B2, B6 and B12.

However, in a comparative manner, it appeared that the contents of certain substances analyzed were quite similar in the two beers. This is the case of total sugars (13 g/100 ml in Mandrakwa and 11.1 g/100 ml in Musururu), iron (8.16 ppm in Mandrakwa and 12 ppm in Musururu), vitamins C, B1, B2 and B6 (respectively 8.16; 18.32 and 8.5 mg/100 ml in Mandrakwa and 12; 15.67 and 7.2 mg/100 ml in Musururu).

As for the other substances, they were four times more abundant in Musururu than in Mandrakwa. These are proteins (6.73 g / 100 ml against 3.46), calcium (206 ppm against 130), vitamins and B12 (2.4 mg / 100 ml against 0.29) and polyphenols (78 mg/l against 43). On the other hand, the opposite situation was observed in a single case, that of vitamin B2: 11.12 mg/100 ml in Mandrakwa against 0.84 mg/100 ml in Musururu.

3.2. Discussion

3.2.1. Effect of filtration

By comparing the organoleptic aspects of our two drinks before and after filtration, it clearly jumps to the eyes that unlike Mandrakwa and Musururu beers of gray color having undergone only sieving before being made available to consumers, those that we have filtered were characterized by a visually pleasing appearance, i.e. a yellow color and superior transparency. This state results from the interruption of several particles in suspension which, under traditional conditions, are not retained by the meshes of the sieve used. This means that the filtered beer is far lighter than that obtained under traditional conditions. As for the yellow color, it is generally attributable to the presence of flavonoids which, as we know, are polyphenols [4].

3.2.2. Effect of fermentation time

The acidic pHs oscillating between 4.0 and 3.4 in the two traditional beers of the DR Congo under study corroborate the data of the literature according to which the usual pHs of commercial beers vary between 3.8 and 4.4 [5].

But the fact that the pHs of our two beers are more acidic than that of SIMBA industrial beer also agrees with the literature which shows that spontaneous fermentation produces beers that are low in alcohol and have a pronounced acidity [6].

Furthermore, our results indicated that the long fermentation time increased both the fermentation yield and the alcohol content (Table 2). This is normal because the higher the degree of fermentation, the greater the quantity of glucose obtained beforehand from the hydrolysis of starch under the effect of α, β amylases and maltase to be transformed into alcohol.

However, if it has been observed that the pH decreases slightly with the duration of fermentation, it is because in the medium other fermentations occur, mainly lactic fermentation which was highlighted in a previous similar study. [7].

By comparing the alcohol content in the two traditional beers under study, we understood the fact that if traditionally Mandrakwa and Musururu are released to consumers respectively on the third and fifth days of fermentation, it is because at these times that the highest alcohol content is practically reached in each case: 5.6% by volume in the Mandrakwa and 4.6% by volume in the Musururu. It should also be noted that the alcohol content of 4.3% of Katata and Katubi beers from Haut-Katanga reported in the literature [1] is practically the same as that of Musururu beer (4.6%). It is not impossible that the superiority of the alcohol content of Mandrakwa beer compared to Musururu, Katata and Katubi beers results, if only partially, from the double malting and the phenomenon of the burial of corn malt in the ground for 30 days.

3.2.3. Effect of the duration of maize malt burial in the soil

By reducing to 14 and 21 days the usual duration of burial of maize malt intended, after drying and grinding, to obtain a mash to which finger millet malt will be added for the fermentation leading to Mandrakwa beer, we realized (Table 4) that this reduction in duration considerably slowed down the rate of fermentation and greatly reduced the alcohol content during the first three days of fermentation. However, it is on the third day of fermentation that the traditionally prepared drink is served to consumers when the burial in the ground of the germinated corn seeds is spread over 30 days.

As it is during germination that the α and β amylases appear responsible for the hydrolysis of starch into maltose which leads to glucose under the enzymatic effect of maltase and it is this monosaccharide, glucose, which, under our operating conditions, is converted into ethanol under the spontaneous action of wild yeasts, one can think that the mobilization of the latter is optimal at four weeks of burial in the ground. As we know, these yeasts, like Saccharomyces cerevisiae, are optional anaerobes [8]: in the presence and absence of oxygen, they find the energy necessary for their life. In one case, energy is released during the oxidation of sugars into carbon dioxide and water. In the other, it is supplied in small amounts as ATP from glycolysis.

3.2.4. Microbiological analysis

The absence of total coliforms and bacteria of the Lactobacillus group in the beers under study, Mandrakwa and Musururu, is an indication of the good hygienic conditions observed during the preparation and storage of these two drinks. On the other hand, the presence of yeasts and molds indicates the inadequacy of the clarifying filtration technique used which, in modern breweries, is supplemented by pasteurization or by fine or sterilizing filtration. Also called post-filtration, the latter has, among its many advantages, the safe elimination of yeasts and bacteria without heat treatment [9].

3.2.5. Food value

The presence of several group B vitamins in beer makes it qualify as a cocktail of said vitamins provided by malt and yeast. B vitamins have a great effect on the metabolism of carbohydrates and proteins. While vitamin C is an antioxidant that plays a role in the immune system and in the metabolism of iron as a promoter of its absorption at the intestinal level in divalent hemenic form (Fe^{2+}) resulting from the reduction of trivalent non-hemenic iron (Fe^{3+}) [10]. As it appears, the moderate consumption of beer can also provide part of our daily vitamin needs.

With regard to polyphenols, it is reported in previous studies cited by Valérie Arnaudinaud *et al*. in their work on wine

polyphenols [4] that a diet rich in these natural substances reduced the risk of cardiovascular or neurodegenerative diseases by more than 50%. And the aforementioned studies have also shown that polyphenols have anti-inflammatory, anticancer and antiplatelet properties [11, 12, 13].

4. Conclusion

This study, which focused on two traditional beers from the Congolese province of North Kivu, Mandrakwa and Musururu, showed that their physicochemical and microbiological properties could be significantly improved. The transparent yellow appearance resulting from good filtration, the food value highlighted through in particular the presence of vitamins C and group B, polyphenols, proteins and carbohydrates as well as the alcoholic degree of 5.6% in the Mandrakwa and 4.6% in Musururu constitute parameters which can be exploited in the valorization of traditional fermented drinks of the DR Congo under study.

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