Vol. 23(5), pp.162-174, May 2024
DOI: 10.5897/AJB2022.17527
Article Number: 927EBF772144
ISSN: 1684-5315
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African Journal of Biotechnology

Full Length Research Paper

Effect of incorporating the pulp of the fruit of *Detarium microcarpum* Guill & Perr. on the quality of the traditional malt-based drinks in West Africa

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Received 6 October 2022; Accepted 13 February 2023

Detarium microcarpum **is a forest plant widely used in West Africa. However, it is little known and used for food. This study aims to assess the beneficial effect of incorporating the pulp of the fruit of *D. microcarpum* on the quality of the traditional malt-based drinks. Thus, the objective was to produce traditional drinks based on composite flour of *D. microcarpum* pulp and malt, then to characterize these drinks on biochemical, microbiological and sensory levels. Traditional drinks formulated with the incorporation of *D. microcarpum* pulp at 7, 10 and 13% are of good quality in relation to biochemical, microbiological, and sensory characteristics. For odor, acidity, color and aftertaste, statistical analysis shows significant differences between the controlled drinks produced with malt only and those from the formulations with the incorporation of the pulp of *D. microcarpum* at 10 and 7%. S90, S93, M90, and M93 obtained the best scores among unfermented drinks and MF93, SF93, MF90, and MF90 were those which were more appreciated taste wise among fermented drinks. These results showed that incorporation of 7 and 10% of the pulp of *D. microcarpum* in traditional malt-based drinks would be an asset to reduce acidity and improve the quality of traditional malt-based drinks.**

Key words: *Detarium microcarpum*, traditional drink, wild fruit processing, Dolo, Tchakpalo.

INTRODUCTION

In West Africa, the industrial sector is underdeveloped and a large part of agro-resources are transformed through food crafts. Traditional malt drinks are part of this product line (Nwaiwu et al., 2020; Jane and Ahmad, 2017; Dossou et al., 2015). These drinks take different designations according to the country of origin. In Western Africa (Burkina Faso, Mali and Ivory Coast), it is known as Dolo (Konfo et al., 2014). They are also called

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“Tchakpalo” or “Tchakparo” or “Tchapalo’’ or “Tchoukoutou’’ in Benin, Burkina Faso, Ivory Coast and Togo (Dossou et al., 2014). The malt-based drinks are very popular in West Africa and are often attached to the traditions of family hospitality and friendliness (Konfo et al., 2014; Kayode et al., 2007). Hence, they have a remarkable socio-economic character because they are used extensively during traditional ceremonies and constitute an important source of income for women who are the main producers in the sector (Kayodé et al., 2007). Sorghum and corn are the main cereals used for the production of these drinks (Dossou et al., 2014). However, an analysis of sorghum production in 2018 shows a drop in harvest of around 3 to 18% and the forecast yield of sorghum until 2025 (Kayode, 2018). These two situations could affect the sorghum supply chain and induce an increase in the production cost of these drinks. It is worth mentioning that the success of these traditional drinks is related to their relatively low price (Lyumugabe et al., 2012). Furthermore, corn, which should help resolve the constraint linked to sorghum, is in great demand because it is the staple cereal for population (Achigan-Dako, 2014). Therefore, it is becoming important to focus on alternative raw materials rich in fermentable sugars to replace, at least partially, sorghum or corn malt in the production of these traditional malt-based drinks. Fruits in general are an essential supplement to products based on cereals, starches, in particular poor in minerals and vitamins. Some of these fruits containing essential micronutrients (carbohydrates, potassium, iron, and beta-carotene) are still little known and exploited (Kouyate et al., 2009). This is the case of the fruits of *Detarium* species, which happen to be an ideal candidate as supplement but are little known and exploited (Houenon et al., 2021). The genus *Detarium* spp. belongs to the class of Magnoliopsida, subclass of Rosidae, order of Fabales, family of Fabaceae, subfamily of Caesalpinioideae, tribe of Detarieae (Kouyate, 2005). *Detarium* has several species including *Detarium microcarpum* Guill. & Perr. (Akah et al., 2012). *D. microcarpum* inhabits dry lands, wooded savannas, and open forests of the Sudano-Guinean and Sudano-Sahelian zones of the African continent (Arbonnier, 2002). *D. microcarpum* is a woody fruit species, widely found in the dense dry and clear forests in sub-Saharan Africa (Agbo et al., 2017). Its leaves and fruits are mainly used as human food and in traditional medicine (Tchatcha et al., 2022). It has anti-diabetic, antioxidant, and hepatitis C inhibitor properties and has been traditionally used in cancer treatment (Hassanin et al., 2018). In countries such as Nigeria and Sudan, a strong valuation of these fruits is made in human food, from the production of juices, syrups, marmalades, nectars, and ice cream to its use in sauces as a thickener (Tchatcha et al., 2022; Oibiokpa et al., 2014; Omokhua et al., 2013; Mariod et al., 2009). It is a fruit known to be very rich in vitamin C and sugars (Makalao et al., 2016; Diop et al., 2010). Recent developments studies in *D. microcarpum* have heightened the need to explore several areas for valorization of this fruit (Hassanin et al., 2018). However, according to FAO (2014), most of the wild fruit trees found in Africa (baobab, shea, tamarind, black plum, etc.) are often transformed into juice, syrup, jam, marmalade and butter (for the seeds). With a view to diversification and innovation with regard to the fields of application for the valorization of non-conventional fruits, this study has therefore directed its work towards traditional malt-based drinks. But a question remains: what is the effect of the incorporation of *D. microcarpum* pulp on the quality of traditional drinks made from corn or sorghum malt? This study provides additional information on the already existing information on the production of traditional malt-based drinks. This aims to assess the beneficial effect of incorporating the pulp of the fruit of *D. microcarpum* on the quality of the traditional malt-based drinks obtained.

MATERIALS AND METHODS

Raw material

The raw material used consists of grains of red sorghum (*Sorghum bicolour* [L.] Moench), grains of corn (*Zea mays* L.) purchased in local markets in southern Benin in 2020 and powdered pulp of fruits of *D. microcarpum*. The *D. microcarpum* samples were obtained from Tchaourou, in center Benin in 2020 and identified by YEDOMONHAN Hounnankpon under the number YH736HNB, at the Herbarium of Botany, University of Abomey-Calavi. These fruits were treated, and the pulp powdered and stored for the formulation of traditional malt-based drinks.

Preparation of sorghum and corn malt

Sorghum and corn kernels are sorted to remove visible impurities and broken kernels. The soaking of the grains is carried out by taking a kilogram (1 kg) of grains which was steeped in tap water for 24 h at room temperature (≈27-30°C). After soaking, the grains are spread out on jute bags on the ground and covered for 3 days with a sprinkling every 6 h, according to the traditional process described by Dossou et al. (2014). The sprouted grains are then dried in the sun for four days (96 h). After this drying process, the malt is freed from rootlets, soil and stored (Figure 1).

Production of traditional drinks

Preliminary tests have shown that the incorporation of the pulp of *D. microcarpum* at 10% in the production of traditional malt-based drinks would give good results (personal communication). Following these preliminary tests, ten formulations were applied in this study for the production of traditional fermented drinks and 10 formulations for traditional unfermented drinks (Table 1).

Production process of the traditional drinks

The production of the drinks was made according to the traditional process described by Dahouenon-Ahoussi et al. (2012) (Figure 2). 1 kg of mixed flour are weighed and introduced into a pot. 5 L of

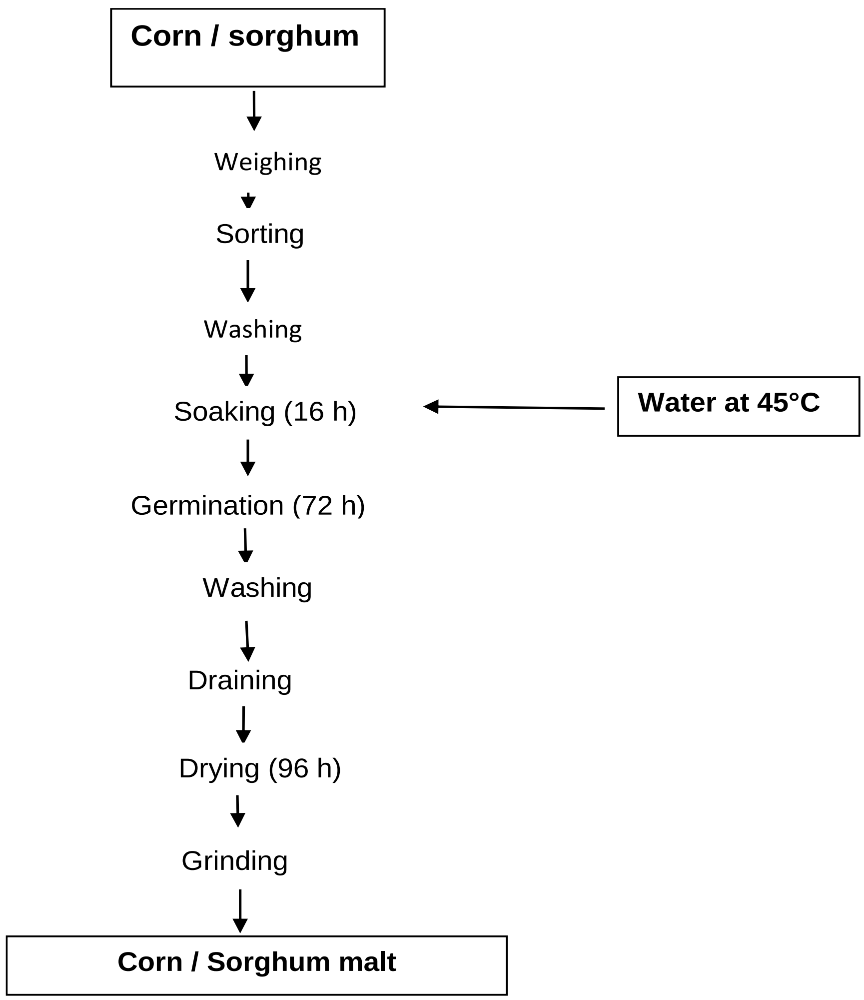

Figure 1. Diagram of production of orghum/corn malt.

fresh water was added and the solution is stirred with a paddle to prevent the formation of flakes. The solution is then heated at 45°C for 1 h with stirring every 5 min. Subsequently, the mixture is removed and left to settle for about 16 h. After decantation, the supernatant containing endogenous enzymes is removed and kept. The remainder is diluted with 3 L of fresh water, then gelatinized at around 100°C for 45 min with stirring every 5 min. After gelatinization, the mixture is brought to 65°C for further mixing. For the brewing step, the collected supernatant is added to the mixture and alternatively stirred every 5 min for 1 h. After this brewing step, the must is cooled, left to settle, and then filtered. The sweet wort obtained after the filtration is cooled either by leaving it in the open air or by successive transfers. After cooling, the must is introduced into plastic cans previously sterilized, then without adding any ferment, it is fermented for 72 h.

Biochemical analysis of traditional drinks produced

To characterize the drinks produced, many parameters such as the pH, the titratable acidity, the alcohol content, and the soluble solids content (°Brix) were determined. The determination of the soluble solids content (°Brix), the pH and the alcohol level, are performed by using the LH-T90 refractometer, the ATC type pH meter and the al-ambic Vinometer, respectively. The acidity was determined by titration according to the AFNOR method (AFNOR, 1982).

Assessment of the sanitary quality of the traditional drinks produced

Microbiological analyses were carried out on the various drinks after pasteurization, which aim is to stop the fermentation process and this is essential in stabilizing the drinks produced. All manipulations were carried out under the conditions of total asepsis. Standard microbiological analysis methods were used, and the parameters evaluated are total mesophilic flora at 30°C (ISO 6887-1 (09/1999)), *Staphylococcus aureus* at 37°C (NF ISO 6888-1), yeasts and moulds by AOAC 2005 method (Williams, 2005).

Sensory analysis of traditional drinks produced

The assessment of the organoleptic characteristics of the different drinks was carried out following the NF V09-002, 1995 method (AFNOR, 1995), from a pre-established technical sheet and a jury made up of ten testers trained to determine the sweet and sour tastes, colors, aromas and overall acceptability of the drinks produced.

Table 1. The different beverage formulations tested.

No.	Formulations	Fermented drinks	Unfermented drinks
1	100% Sorghum malt	SF100	S100
2	93% Sorghum malt + 7% *D. microcarpum* pulp	SF93	S93
3	90% Sorghum malt + 10% *D. microcarpum* pulp	SF90	S90
4	87% Sorghum malt + 13% *D. microcarpum* pulp	SF87	S87
5	83% Sorghum malt + 17% *D. microcarpum* pulp	SF83	S83
6	100% Corn malt	MF100	M100
7	93% Corn malt + 7% pulp of *D. microcarpum*	MF93	M93
8	90% Corn malt + 10% pulp of *D. microcarpum*	MF90	M90
9	87% Corn malt + 13% pulp of *D. microcarpum*	MF87	M87
10	83% Corn malt + 17% pulp of *D. microcarpum*	MF83	M83

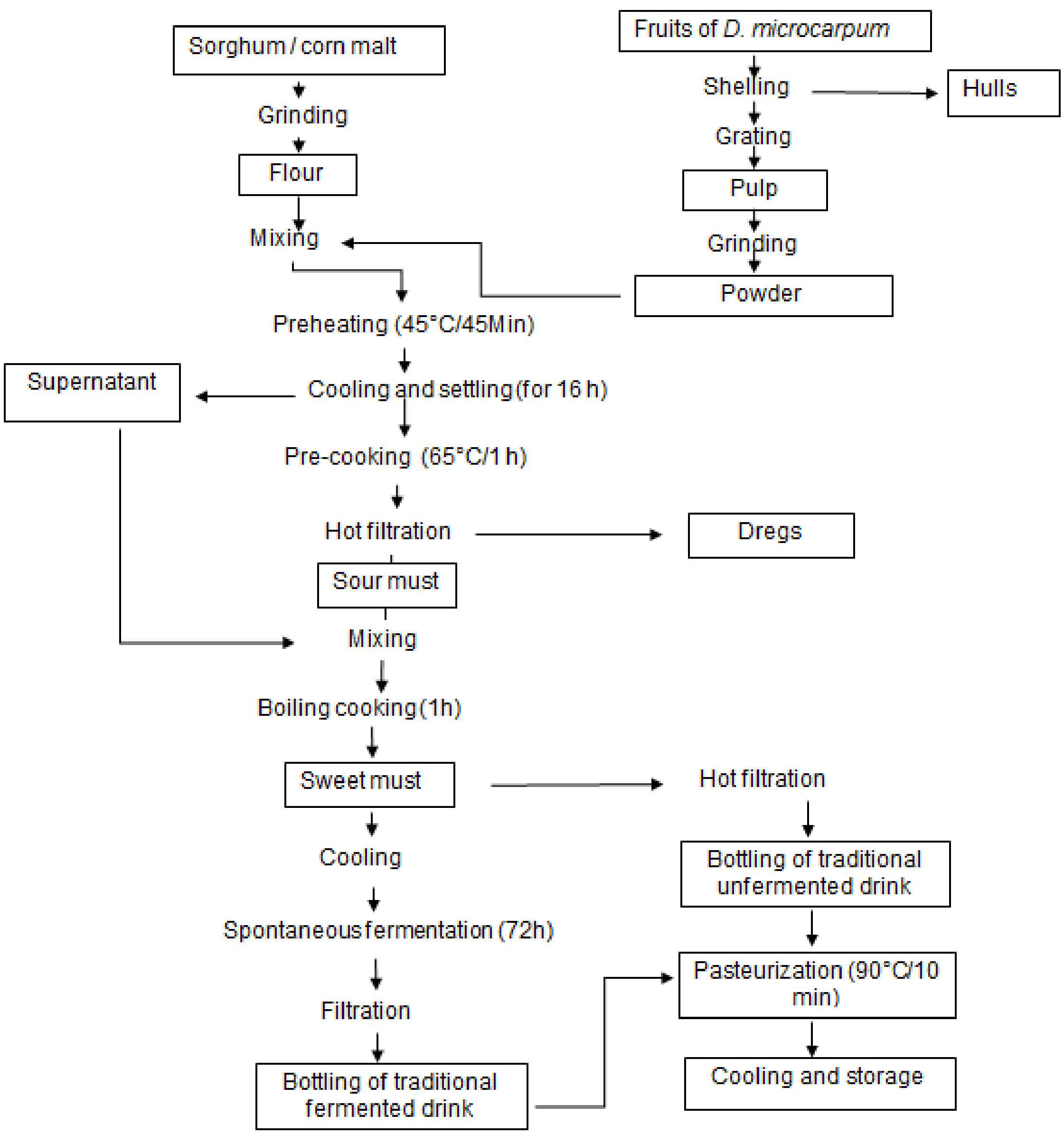

Figure 2. Diagram of production of traditional drinks.

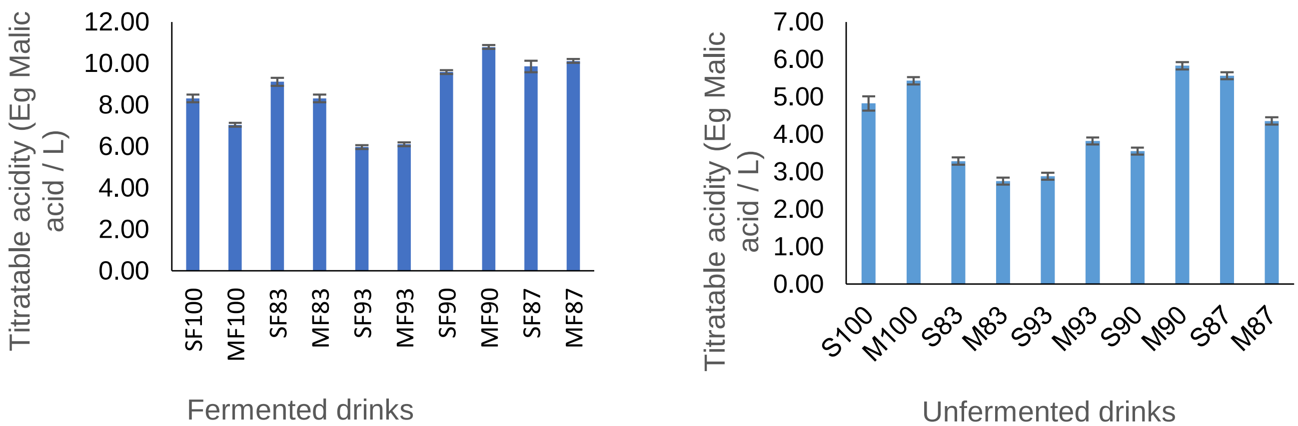

Figure 3. Titratable acidity of traditional fermented and unfermented drinks.

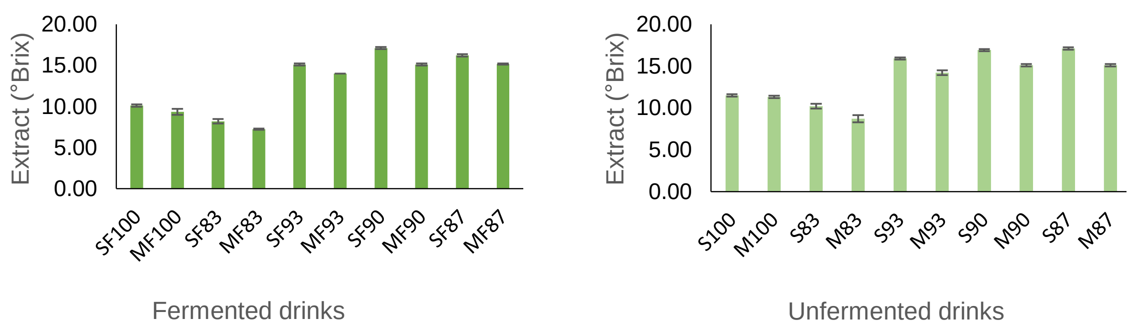

Figure 4. Soluble extract of fermented and unfermented drinks.

Statistical analyses

The results were organized using Microsoft Excel 2013 spreadsheet and processed with Minitab 14 software. Minitab software was used for data analysis for comparison of means and analysis of variance (ANOVA). The differences observed were considered statistically significant at $p<0.05$. Finally, to group the samples that show similarities, Principal Component Analysis (PCA) was performed using Minitab 14 software.

RESULTS

Biochemical characteristics of traditional drinks produced

Titratable acidity of traditional drinks produced

Figure 3 shows the titratable acidity of the traditional drinks produced. It can be seen that fermented drinks generally have the highest values. Formulation from corn malt in the category of non-fermented drinks and fermented drinks show the highest values. In all the formulations produced, we note that several drinks produced with incorporation of the pulp of *D. microcarpum* (S83, S93, S90, M83, M93, SF93 and MF93) have low acidity compared to formulations based on malt only (S100, M100, SF100 and MF100).

Soluble dry extract of traditional drinks produced

Figure 4 shows the soluble solids of the traditional drinks produced. Soluble dry extract indicates the amount of simple sugar produced in the drinks after hydrolysis of the starch. It emerges from this figure that the unfermented drinks S93, M93, S90, M90, S87, and M87 have a higher sugar level than the S100, M100, S83, and M83 formulations.

pH of traditional drinks produced

Figure 5 tells us about the pH of the traditional drinks produced. The pH of unfermented drinks varies from 4 to over 5. 100% malt drinks (S100 and M100) have the lowest pH and S87 drink has the highest. Regarding fermented drinks, the pH varies from 3.5 to 4.5 with the highest values coming from drinks SF93 and MF93.

Table 2. Evaluation of the microbial flora of produced traditional drinks.

Sample		FAMT (CFU/ml)	Yeast (CFU/ml)	Mold (CFU/ml)	*Staphylococcus aureus* (CFU/ml)
S100		0.4	0.7	0.46	Abs
M100		1.39	Abs	Abs	Abs
S93		1.43	1.4	0.42	Abs
M93		2.05	Abs	0.32	Abs
S90		0.45	Abs	0.9	Abs
M90		1.78	Abs	0.87	Abs
S83		1.08	0.1	0.51	Abs
M83		1.8	1.0	0.51	Abs
S87		0.45	Abs	0.3	Abs
M87		0.25	1	0.38	Abs
SF100		0.48	2.2	0.58	Abs
MF100		1.51	0.9	0.3	Abs
SF93		2.53	3.1	0.12	Abs
MF93		2.5	4.1	0.27	Abs
SF90		0.4	1.18	Abs	Abs
MF90		1.5	Abs	Abs	Abs
SF83		1.53	1.2	0.17	Abs
MF83		2.27	2.0	0.16	Abs
SF87		0.521	0.43	0.37	Abs
MF87		3.15	1.64	0.36	Abs
Standard F-054 Rev03	m	103 (CFU/ml)	103 (CFU/ml)	103 (CFU/ml)	Abs
	M	105 (CFU/ml)	104 (CFU/ml)	104 (CFU/ml)	Abs

FAMT = Total mesophilic aerobic flora; Abs = absence.

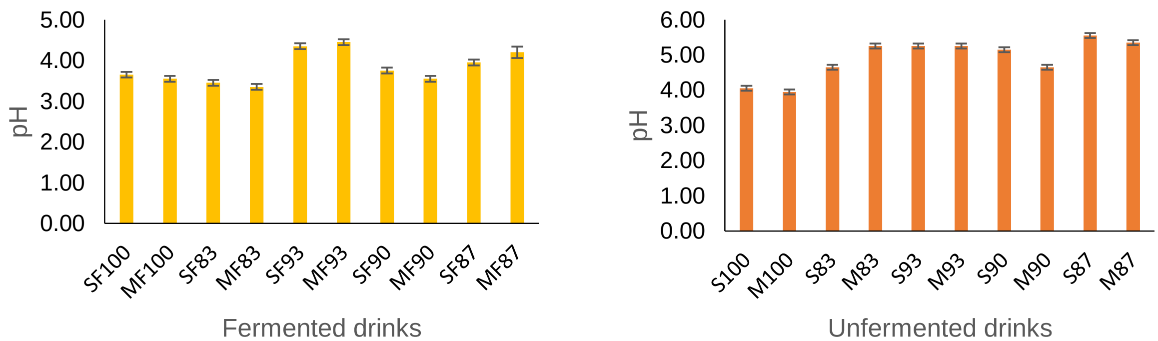

Figure 5. pH of traditional fermented and unfermented drinks.

Alcohol content of traditional fermented drinks produced

Figure 6 shows the alcohol content in the traditional drinks produced. This figure shows that corn-based productions have a high alcohol content of up to 5% v. Sorghum-based productions remain between 2.5 and 4% v. The drinks SF93, MF93, SF90, MF90, SF87, and MF87, respectively have the highest rates in the formulation with the incorporation of the pulp of *D. microcarpum*.

Microbiological characteristics of traditional drinks produced

Table 2 shows the results of the microbiological analysis of the traditional drinks produced. Analysis of this table reveals a total absence of *Staphylococcus aureus* in the various traditional drinks produced. The total mesophilic

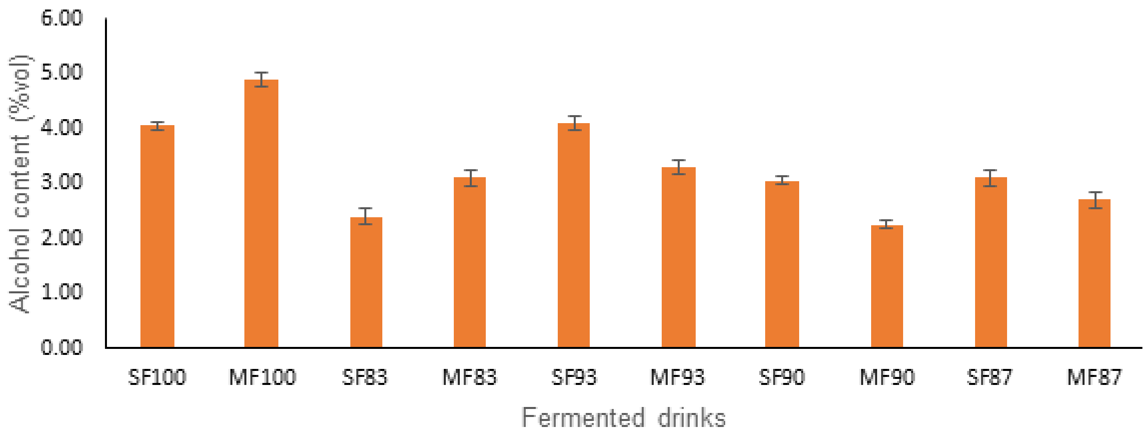

Figure 6. Alcohol content of traditional fermented drinks.

Table 3. Results of sensory analysis of traditional unfermented drinks.

Sample	Odor	Acidity	Flavor	Color	Aftertaste
S100	4.10 ± 0.28[a]	8.20 ± 0.44[a]	3.60 ± 0.19[a]	3.80 ± 0.21[a]	2.80 ± 0.15[a]
M93	4.80 ± 0.15[b]	10.00 ± 0.50[a]	5.80 ± 0.33[b]	2.80 ± 0.10[b]	3.40 ± 0.21[a]
S87	3.80 ± 0.21[a]	10.00 ± 0.50[a]	5.40 ± 0.31[b]	3.40 ± 0.17[a]	4.50 ± 0.26[b]
M87	2.40 ± 0.13[b]	8.20 ± 0.44[a]	3.80 ± 0.21[a]	5.40 ± 0.31[c]	6.60 ± 0.37[c]
S93	4.20 ± 0.05[a]	8.20 ± 0.44[a]	5.20 ± 0.30[b]	3.80 ± 0.13[a]	3.00 ± 0.13[a]
M83	4.40 ± 0.28[a]	8.20 ± 0.44[a]	2.80 ± 0.10[a]	4.60 ± 0.26[c]	4.20 ± 0.26[b]
S83	2.60 ± 0.06[b]	4.60 ± 0.26[b]	4.60 ± 0.26[a]	4.60 ± 0.26[c]	3.20 ± 0.19[a]
S90	5.20 ± 0.34[a]	8.20 ± 0.44[a]	6.80 ± 0.38[b]	3.60 ± 0.19[a]	3.80 ± 0.24[a]
M90	4.20 ± 0.26[a]	10.00 ± 0.50[a]	5.80 ± 0.33[b]	4.20 ± 0.24[a]	4.20 ± 0.24[b]
M100	2.20 ± 0.13[b]	8.20 ± 0.44[a]	5.20 ± 0.30[b]	3.00 ± 0.13[a]	3.60 ± 0.19[a]

In the same column, the values followed by a different letter are significantly different at the threshold $P < 0.05$.

aerobic flora was observed, with a low concentration in almost all the different productions. The 87% corn malt fermented drink (MF8) exhibited the highest microbial load (3.15 cfu/ml). This microbial load is less than (m = 1000), so the traditional drinks produced are of satisfactory microbiological quality. As for yeasts, their absence in beverages (M100, M93, S90, M90, S87, and MF90) and their presence in the other formulations is noted. The MF93 drink is more loaded with a value of 4.1 cfu/ml. Concerning moulds, drinks M100, SF90, and MF90 have total absence of germs and drink S90 has the highest microbial load (9 cfu/ml).

Sensory characteristics of traditional unfermented drinks produced

To evaluate the organoleptic characteristics of the traditional drinks produced, a sensory analysis on the odor, acidity, flavor, color and aftertaste characteristics was carried out. To this end, the results obtained are expressed in scores and presented in Table 3 for the unfermented drinks. The S90 formulation recorded the best odor score (5.20) while the M100 formulation obtained the lowest score (2.20). Statistical analysis shows a significant difference between the scores recorded. Regarding acidity, all the formulations had scores between 8 and 10 except for S83 formulation which obtained a low score (4.6). For most of the formulations that had scores between 8 and 10, their acidity was imperceptible. Flavor scores vary from 2.80 to 6.80 for drinks M83 and S90, respectively. A significant difference is observed between the flavor scores of the formulations based on malt alone (S100 and M100) and the formulations with the incorporation of the pulp of *D. microcarpum*. Furthermore, the color scores vary from 2.80 to 5.40, respectively for drinks M93 and M87. A significant difference is noted in the score of the drink M93 (2.80), while the scores obtained by the other formulations vary between 3.80 and 5.40. Formulated

Table 4. Correlation matrix between the variables of sensory analysis of traditional unfermented drinks.

Variable	PC1	PC2
Odor	0.004	-0.144
Acidity	**0.467**	**-0.556**
Flavor	**-0.411**	**0.433**
Color	**-0.671**	-0.266
Aftertaste	**-0.404**	**-0.642**

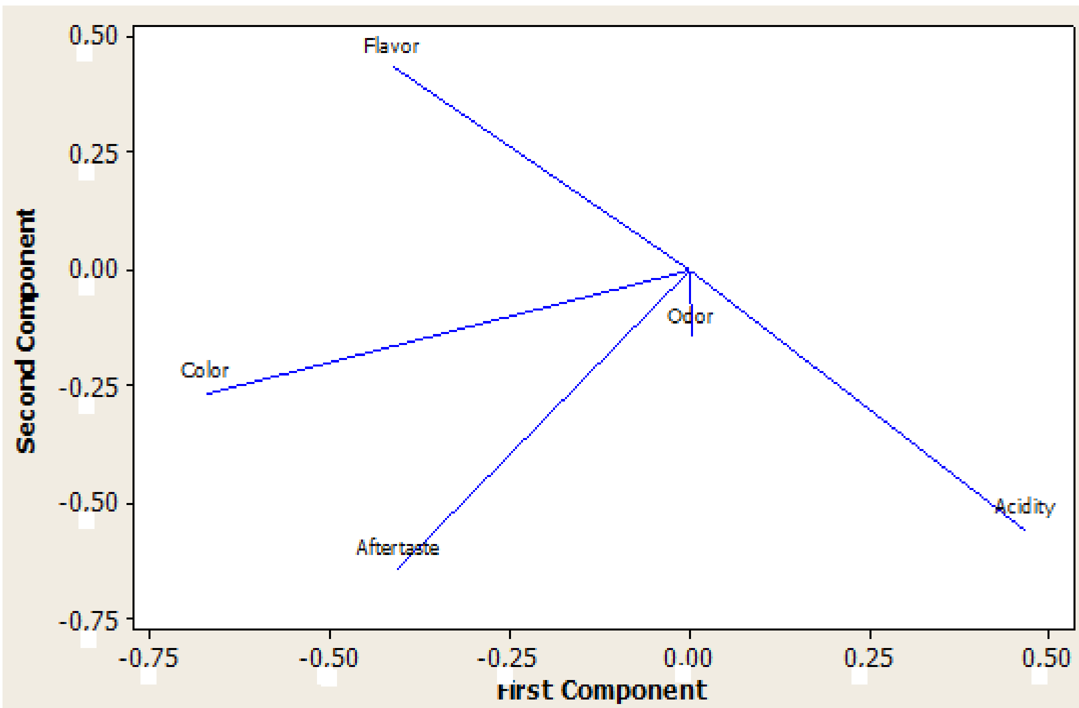

Figure 7. Projection of the variables in the factorial plane.

drink aftertaste scores range from 2.80 to 6.60 (for S100 and M87 drinks, respectively). A significant difference is observed in the scores obtained for the aftertaste.

Principal component analysis (PCA) of the results of the sensory evaluation of the traditional unfermented drinks produced

To better appreciate the different relationships that exist between the different sensory variables studied (odor, acidity, flavor, color and aftertaste) of traditional unfermented drinks, a main component analysis was carried out. The table of eigenvalues and the cumulus of information from the different components showed that the first component explains 35.7% of the information carried by the initial variables, the second component explains 29.3% and the third component explains 22.9%. The first and second components alone account for 65% of the total point cloud inertia. Therefore, a good analytical precision is guaranteed. Joint analysis of the correlation matrix between principal components and variables (Table 4) and of the graphic representation of the variables in the plane formed by the two axes (Figure 7) showed that four (4) variables are significantly correlated on the first component. Flavor, color and aftertaste are negatively correlated while acidity is positively correlated. These results tell us that as the acidity increases, the less flavor, color and aftertaste are appreciated. On the second major component, acidity and aftertaste are negatively correlated while flavor is positively correlated. So the flavor is most appreciated when the acidity and aftertaste decrease.

The projection of the samples in the factorial plane, made it possible to establish Table 5. Three large groups of beverage formulations were observed from this

Table 5. Distribution of samples on the principal components.

PC1	PC2
(+) S90 M100 S100 S93 M93	(+) S83
(-) M87 M83	(-) S87 M90

Table 6. Results of the sensory analysis of the traditional fermented drinks.

Sample	Odor	Acidity	Flavor	Color	Aftertaste
SF100	2.20 ± 0.08[a]	6.60 ± 0.37[a]	4.60 ± 0.26[a]	4.20 ± 0.24[a]	3.00 ± 0.17[a]
MF93	3.40 ± 0.21[b]	6.80 ± 0.38[a]	5.20 ± 0.30[a]	3.40 ± 0.17[a]	2.80 ± 0.10[a]
SF87	2.00 ± 0.17[a]	5.20 ± 0.44[b]	5.00 ± 0.29[a]	5.80 ± 0.33[b]	3.60 ± 0.19[b]
MF87	2.60 ± 0.22[a]	4.80 ± 0.38[b]	4.40 ± 0.25[b]	4.20 ± 0.44[c]	4.20 ± 0.26[b]
SF93	3.20 ± 0.05[b]	8.00 ± 0.24[c]	6.00 ± 0.13[c]	3.60 ± 0.19[a]	3.40 ± 0.21[b]
MF83	1.40 ± 0.33[c]	4.00 ± 0.50[b]	4.80 ± 0.33[a]	3.60 ± 0.37[a]	2.80 ± 0.10[a]
SF83	1.20 ± 0.10[c]	4.20 ± 0.24[b]	4.20 ± 0.30[a]	3.00 ± 0.13[a]	4.20 ± 0.27[b]
SF90	3.40 ± 0.14[b]	5.20 ± 0.30[b]	5.80 ± 0.31[a]	3.00 ± 0.13[a]	4.60 ± 0.26[b]
MF90	3.80 ± 0.10[b]	4.80 ± 0.21[b]	5.80 ± 0.33[a]	3.80 ± 0.21[a]	3.40 ± 0.21[b]
MF100	3.00 ± 0.17[b]	6.00 ± 0.50[b]	3.60 ± 0.19[c]	3.80 ± 0.21[a]	3.40 ± 0.17[b]

In the same column, the values followed by a different letter are significantly different at the threshold $P < 0.05$.

projection. Group 1, takes into account five (05) formulations (S90, M100, S100, S93, M93), essentially characterized by high appreciation scores for acidity and flavor, average for color, odor and aftertaste. Group 2, includes the formulations (M87 M83), which are characterized by high review scores for acidity and aftertaste, medium for color and low for flavor and odor. Group 3, includes the formulations (S87 and M90) which are characterized by very high ratings for acidity and medium ratings for odor, flavor, color, and aftertaste.

Sensory characteristics of the traditional fermented drinks produced

Table 6 shows the results of the sensory analysis of the fermented drinks produced. It emerges from this table that the formulations MF90, MF93, SF90, SF93 and MF100 recorded the highest scores (respectively 3.80, 3.40, 3.40, 3.20, and 3.0) while the MF83 and SF83 formulations exhibit the lowest scores. Regarding the acidity, only the formulation SF93 stood out with a score of 8.0 while the other formulations had scores between 4.0 and 6.60. For the flavor of fermented drinks produced, SF93 had the best score (6.0) while the other formulations had scores that ranged from 3.60 to 5.80. Scores obtained for the color of drinks produced are very similar (between 3 and 4). Only SF87 and MF87 stood out with scores of 5.80 and 4.20, respectively. SF90 had the best score for aftertaste (4.60) while MF83 had the lowest score (2.8) (Figure 8). Overall, it is observed that all formulations obtained higher scores for acidity and flavor than for odor, color, and aftertaste.

Principal component analysis (PCA) of the results of the sensory evaluation of the traditional fermented drinks produced

In order to fully appreciate the different relationships that exist between the variables (odor, acidity, flavor, color, aftertaste) of traditional fermented drinks produced on one hand and samples on the other hand, a main component analysis has been completed (Figure 9). Table 7 of eigenvalues and the accumulation of information from the different components showed that the first component explains 45.9% of the information carried by the initial variables, 22.9% explains the second component and 18, 3% explains that of the third component. The first two principal components alone explain 68.8% of the total inertia of the point cloud which give more information to make good analyses. According to the first axis CP1, three variables are significantly correlated. These are the smell, acidity and color that are negatively associated with the first component. This tells us that a bad odor rating results in a bad acidity score and a bad color score. On the second factorial axis, 02 variables (flavor and aftertaste) are significantly and negatively correlated. This second main component reveals that flavor and aftertaste are related and if the flavor scores poorly then the aftertaste also would have a poor appreciation score. The distribution of the samples

Table 7. Correlation matrix between the variables of sensory analysis of traditional fermented drinks.

Variable	PC1	PC2
Odor	**-0.584**	-0.225
Acidity	**-0.574**	0.193
Flavor	-0.070	**-0.772**
Color	**-0.480**	-0.185
Aftertaste	0.307	**-0.532**

Table 8. Distribution of samples of fermented drinks on the main components.

PC1	PC2
(-) SF87 MF83 MF87	(+) SF93 SF100 MF100 MF93
	(-) MF90 SF83 SF90

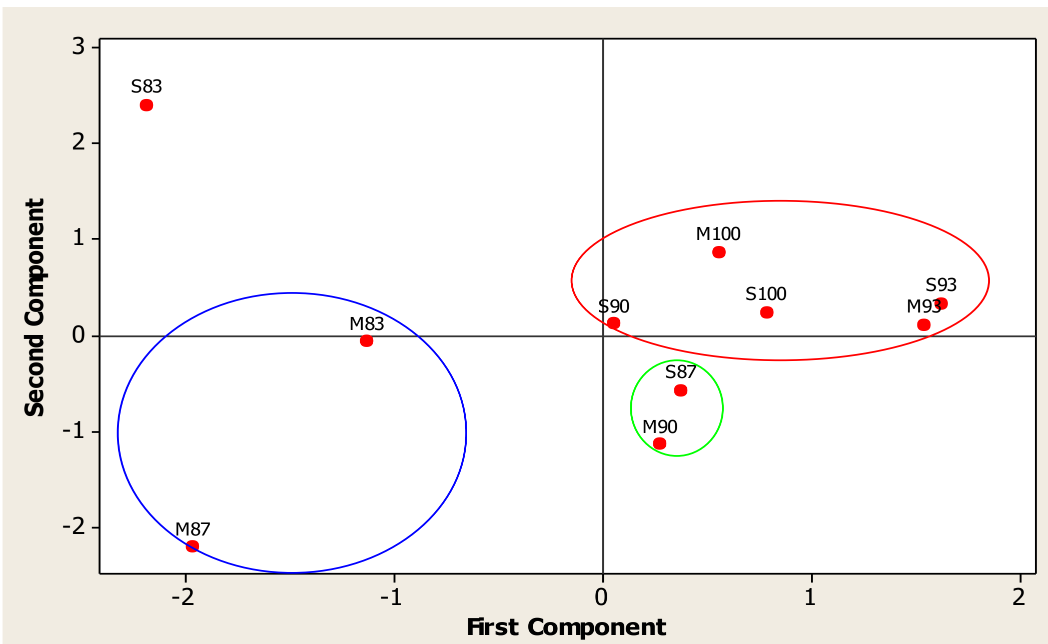

Figure 8. Projection of the samples in the factorial plane.

of fermented drinks on the main components (Table 8) made it possible to observe three (03) large groups. Group 1, consists of four (04) samples (SF93 SF100 MF100 MF93) which are characterized by high scores for acidity and flavor followed by average scores for color, odor and aftertaste. Group 2, consists of three samples (MF90, SF83, and SF90), characterized by high scores for flavor, acidity and aftertaste and average scores for color and odor (Figure 9). Group 3, also includes three samples (SF87, MF83, and MF87), characterized by low scores for odor and aftertaste, average scores for acidity, flavor and color (Figure 10).

DISCUSSION

This research aimed to assess the beneficial effect of incorporating the pulp of the fruit of *D. microcarpum* on the quality of the traditional malt-based drinks. To achieve the objectives of the study, the pulp of

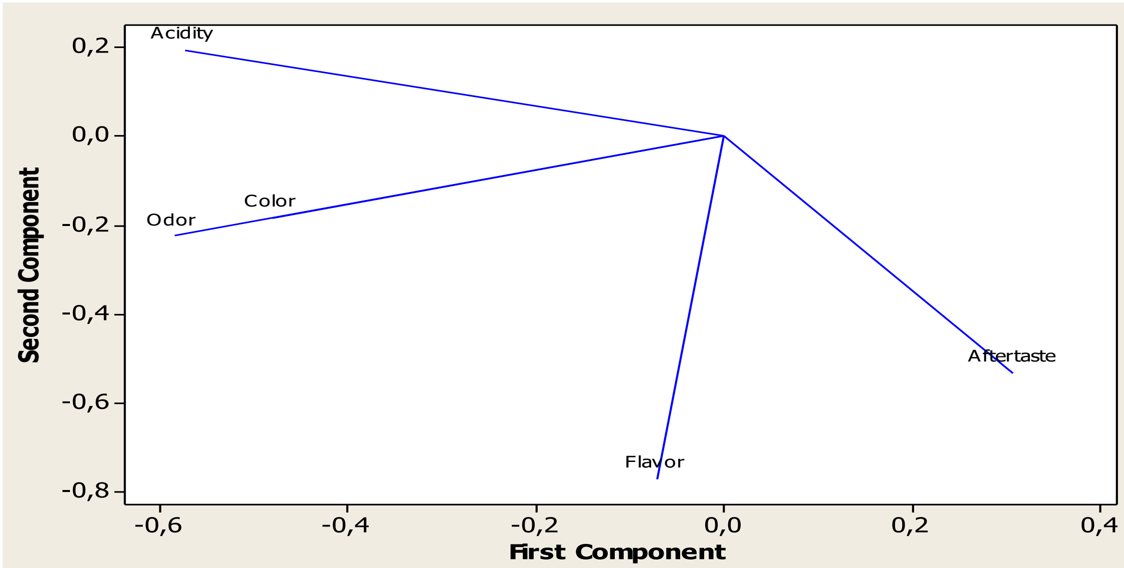

Figure 9. Projection of the variables in the factorial plane.

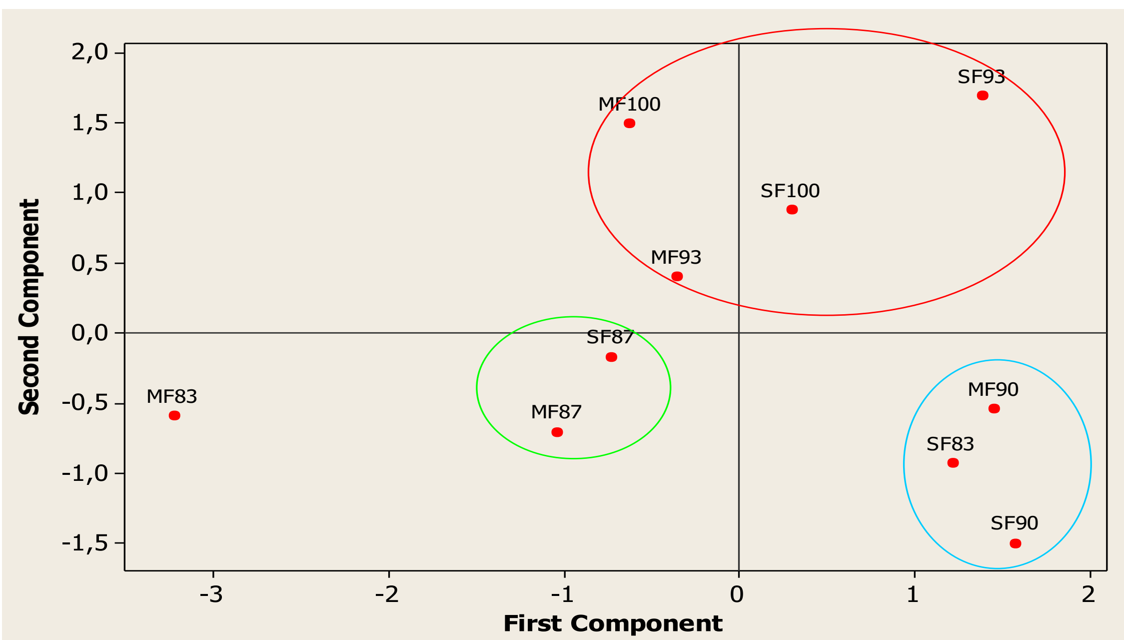

Figure 10. Projection of samples in the factorial plane.

D. microcarpum was incorporated into malt flour at rates of 7, 10 and 13% to produce traditional malt drinks. Fermented and unfermented beverages were produced and evaluated. The results obtained showed that drinks produced with the incorporation of *D. microcarpum* pulp have low acidity values compared to drinks without *D. microcarpum* pulp. But Anetoh et al. (2020) showed that consumers prefer malt drinks that have low acidity. This would therefore justify why tasters in this study preferred drinks based on *D. microcarpum* to the detriment of others. In addition, unfermented malt beverages produced with the incorporation of *D. microcarpum* pulp are sweeter (S87: soluble extract 17.1°Brix; M87: soluble extract 15.10°Brix) than those without *Detarium* (S100: soluble extract 11.5°Brix; M100: soluble extract 11.30°Brix). Thus, the use of *D. microcarpum* pulp in the production of traditional unfermented drinks allows the production of a quality natural product without adding sugar. Sensory analysis of beverages also showed that beverages produced with *Detarium* had a good smell, good flavor and attractive color, which was not the case for beverages without *Detarium*. Thus, the incorporation of the pulp of *D. microcarpum* has improved the visual and olfactory qualities of traditional malt drinks. Indeed, according to Anetoh et al. (2020), consumers make the decision whether or not to buy a malt-based drink based on its good visual and olfactory qualities. This would also mean that drinks produced with the pulp of *D. microcarpum*, once on the market, would be likely to be sold faster than drinks without *Detarium.* Therefore, the use of *D. microcarpum* fruits in the production of beverages could not only contribute to the improvement of the quality (reduction of the acidity and the aftertaste of the beverages when the pulp of *Detarium*) but also participate in its rapid sale on the market and in the reduction of the cost of production. Because according to Kayodé (2018), the production of sorghum in 2018 shows a drop in harvests of 3 to 18% and corn is increasingly in high demand (Achigan-Dako et al., 2014). However, the fruits of *D. microcarpum* are available at a lower cost (Agbo et al., 2018) in areas of large production and consumption of these drinks (Dossou et al., 2015). Thus, the use of *D. microcarpum* fruits in the production of traditional drinks would make it possible to keep the production cost relatively low to prevent these drinks from becoming very expensive, which would cause them to lose their character as "popular drinks", because according to Lyumugabe et al. (2012), the relative success of these traditional drinks with consumers is due to their relatively low price.

Conclusion

D. microcarpum is a little known species in West Africa. Its use relates to several organs of the plant (leaf, bark, wood, root, fruit, and flower), for food, medicinal, spiritual, artisanal, fodder, firewood and construction purposes. The incorporation of the pulp of the fruit of *D. microcarpum* in traditional drinks, fermented or not, is an opportunity to bring wild fruits into the local market for traditional drinks, which remains first in the sector in West Africa. Because of innovation, it, therefore, becomes necessary to deepen the study and popularize the results so that the fruits of *D. microcarpum* are valued and integrated into the daily diet of local populations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

This work received financial support from the Competitive Research Fund Program of the University of Abomey-Calavi (PFCR / UAC, 3rd phase) 2019-2021 and the Olga Triballat Institute through the project "Model of an endogenous enhancement of unconventional fruit resources: Case of *Detarium* species (ProDETOF)”.

REFERENCES

Achigan-Dako EG, Houdegbe AC, Glèlè M, Nono-Womdim R (2014). Analyse du système de production et de distribution des semences de maïs (*Zea mays* l.) au Sud-bénin. Biotechnology, Agronomy and Society and Environment 18(1):49-60.

Association Française de Normalisation (AFNOR) (1982). Recueil Des Normes Françaises Des Produits Dérivés Des Fruits et Légumes. 1è ed. Par. (AFNOR, ed.). AFNOR; 1982.

Association Française de Normalisation (AFNOR) (1995). Méthode de Détermination de l’acuité Gustative. Analyse Sensorielle (NF V09-002). 1995.

Agbo RI, Idohou R, Vihotogbé RAA, Dagba RA, Assogbadjo AE (2018). “Spatio-temporal dynamics of suitable habitats for Detarium microcarpum Guill. & Perr. (Caesalpiniaceae), a priority food tree species in Benin (West Africa). Modeling Earth Systems and Environment 5(2):595-604.

Agbo IR, Missihoun AA, Vihotogbe R, Assogbadjo EA, Ahanhanzo C, Agbangla C (2017). Impacts des usages traditionnels sur la vulnérabilité de *Detarium microcarpum* Guill. & Perr. (Caesalpiniaceae) dans le district phytogéographique Zou au Bénin (en Afrique de l’Ouest). International Journal of Biological and Chemical Sciences 11(2):730.

Akah P, Nworu C, Mbaoji F, Nwabunike I, Onyeto C (2012). Genus Detarium: ethnomedicinal, phytochemical and pharmacological profile. Phytopharmacology 2(3):367-375. http://inforesights.com/phytopharmacology/archive.html, (10/03/2021).

Anetoh JC, Nnabuko JO, Okolo VO, Anetoh VC (2020). Sensory attributes of malt drinks and consumer purchase decisions. Journal of Food Products Marketing 26(5):317-43.

Arbonnier MA (2002). Arbres, arbustes et lianes des zones sèches d’Afrique de l’Ouest. Volume 1. CIRAD. Montpellier, France.

Dahouenon-Ahoussi E, Degnon RG, Adjou ES, Sohounhloue DCK (2012). Stabilisation de la bière produite à partir de matières amylacées locales (Sorghum bicolor et Musa acuminata) par adjonction de l’huile essentielle de Cymbopogon citratus. Journal of Applied Biosciences 51:3596-3607. http://m.elewa.org/JABS/2012/51/6.pdf

Diop N, Ndiaye A, Cisse M, Dieme O, Dornier M, Sock O (2010). Le ditax (*Detarium senegalense* JF Gmel.): principales caractéristiques et utilisations au Sénégal. Fruits 65(5):293-306.

Dossou J, Ballogou V, Dabade D, Dakpo M (2015). Analyse économique de la production artisanale du chakpalo au Bénin : aspects sociaux et facteurs déterminants de la rentabilité financière de l’activité. Journal of Applied Biosciences 87(1):8065-8075.

Dossou J, Ballogou VY, Amoussou Fagla B, Akissoé N, Daïnou O, de Souza C (2014). Amélioration du procédé traditionnel de maltage du sorgho (*Sorghum bicolor*) pour la production du chakpalo au Bénin. Bulletin de la recherche agronomique du Bénin 76(Decembre):30-40. http://www.slire.net

FAO (2014). Stratégie nationale et plan d'actions de valorisation des Produits Forestiers Non Ligneux (PFNL) prioritaires du Bénin: Cas des fruitiers sauvages 136 p.

Hassanin HAM, Koko M, Abdalla M, Mu W, Jiang B (2018). *Detarium microcarpum*: a novel source of nutrition and medicine: a review. Food Chemistry 274:900-906.

Houenon GHA, Djossou AJ, Kouhinkpo EY, Salako KV, Tchobo FP, Adomou AC, Yedomonhan H (2021). Parataxonomy, perceived dynamics and diversity of uses of two Detarium species in Benin (West Africa). Genetic Resources and Crop Evolution 68:2627-2654.

Jane M, Ahmad C (2017). Traditional fermented foods and beverages of Namibia. Journal of Ethnic Foods 4(3):145-153. Doi: 10.1016/j.jef.2017.08.001

Kayodé APP (2018). Adoption de Variétés de Sorgho Résilientes Aux Changements Climatiques Au Bénin.; 2018. www.cta.int

Kayodé APP, Hounhouigan DJ, Nout MJR, Niehof A (2007). Household production of sorghum beer in Benin: technological and socio-economic aspects. International Journal of Consumer Studies 31(3):258-264.

Konfo CTR, Chabi NW, Agbadjizo J, Dahouenon-Ahoussi E, Soumanou MM, Sohounhloue DCK (2014). Influence of Hemizygia bracteosa (Benth) sheet on the quality of sorghum beer “tchakpalo” produced in Benin. International Journal of Innovation and Applied Studies 7(2):453-463.

Kouyaté AM, Van Damme P, De Meulenaer B, Diawara H (2009). Contribution des produits de cueillette dans l’alimentation humaine. Cas de Detarium microcarpum. Afrika Focus 22(1):77-88.

Kouyate AM (2005). Aspects ethnobotaniques et étude de la variabilité morphologique, biochimique et phénologique de Detarium microcarpum Guill. & Perr. au Mali. Thèse de doctorat 207 p: Ghent University (Belgique).

Lyumugabe F, Gros J, Nzungize J, Bajyana E, Thonart P (2012). Characteristics of African traditional beers brewed with sorghum malt – a review. Biotechnologie, Agronomie, Société et Environnement 16(4):509-530.

Makalao MM, Savadogo A, Cheikna Z, Traore A (2016). Composition nutritionnelle de 10 fruits sauvages consommés dans trois départements du Tchad. International Journal of Biological and Chemical Sciences 9(5):2385-2400.

Mariod AA, Mirghani MES, Abdul AB, Abdelwahab SI (2009). *Detarium microcarpum* Guill and Perr fruit proximate chemical analysis and sensory characteristics of concentrated juice and jam. African Journal of Biotechnology 8(17):4217-4221.

Nwaiwu O, Aduba CC, Igbokwe VC, Sam CE, Ukwuru MU (2020). Traditional and Artisanal Beverages in Nigeria: Microbial Diversity and Safety Issues. Beverages 6(3):53.

Oibiokpa FI, Adoga GI, Saidu AN, Shittu KO (2014). Nutritional composition of *Detarium microcarpum* fruit. African Journal of Food Science 8(6):342-350.

Omokhua GE, Abbey WM, Olaleye SM (2013). Use of indigenous technology in processing and utilization of non-timber forest product in south-eastern Nigeria. Journal of Agriculture and Social Research 13(2):68-75.

Tchatcha AD, Mureșan V, Djossou AJ, Păucean A, Tchobo FP, Mureșan A, Houndonougbo F, Soumanou MM (2022). *Detarium microcarpum* Guill. & Perr. Fruit properties, processing and food uses. A review. Biotechnology, Agronomy and Society and Environment 26(3):144-154.

Williams E (2005). Official Methods of Analysis of the Association of Official Analytical Chemists. 19th Ed. (AOAC, ed.). AOAC, Washington, D.C.