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Production and Characterisation of a Novel Dasheen (*Colocasia esculenta*) Alcoholic Fermented Beverage

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Abstract: *In this study, an alcoholic fermented beverage of acceptable quality characteristics was produced from two types of dasheen (Colocasia esculenta L. Schott) musts, A – boiled dasheen must and B – cooked dasheen with must, each at three total soluble solids (TSS) levels (18, 22 and 25 ˚Brix). Quality characteristics of pH, TSS, alcohol content, titratable acidity (TA), specific gravity (SG), and spectrophotometric, microbiological, and sensory evaluations were analysed in the fermented beverages. Fermentation caused pH, SG and TSS to decrease while simultaneously increased TA. Coliforms were not detected in any of the must and fermented beverage samples. The one-way ANOVA showed a significant difference ($p<0.05$) when the fermented beverage from musts A and B was compared on the final quality parameters of pH, SG, TSS, TA, a* component and sensory attributes (appearance, colour, taste, and mouthfeel). The beverage made from batch A, 25 ˚Brix was consumer acceptable based on sensory and physicochemical analyses with a pH of 3.12, SG of 1.0053, TSS of 10.13 ˚Brix, TA (% citric acid) of 0.75% and an alcohol content of 14.00 and 12.52% using the hydrometer and gas chromatography methods respectively. For the spectrophotometric analysis, the absorbance at 420 nm wavelength was 0.246 while the L* a* b* colour indices were 88.59, 0.13, and 1.36 respectively. The overall results indicate that this product can be beneficial to the Caribbean food and beverage industries.*

Keywords: *Dasheen (Colocasia esculenta), alcoholic fermentation, sensory attributes, colorimetry, spectrophotometry, gas chromatography-flame ionisation detector*

1. Introduction

Colocasia esculenta L. Schott commonly known as taro or dasheen is a tropical crop that belongs to the Araceae family or *Arum* genus (Deo et al., 2009). Dasheen production occurs yearly in many parts of the world, including Asia, Pacific, Africa, and the Caribbean (Ramantha Rao et al., 2010). However, the corms have a high moisture content, which can decrease its shelf life and contribute to spoilage, leading to significant postharvest wastage of the crop (Deo et al., 2009; Himeda et al., 2014). Fermented beverages from taro are generally unknown globally, however a recent study was reported on kefir-fermented beverage from the extract of *C. esculenta* with a shelf life of 21 days (Pinto et al., 2021). Alcoholic fermentation of the dasheen corm can increase its shelf life and add value to the product which can have immense economic and food security benefits.

Globally, there is a dearth of scientific reports on consumer acceptability and quality characteristics including physicochemical properties of fermented taro alcoholic beverages. Fiscal and Chavez (2016), produced a fermented alcoholic beverage from taro corms, but enhanced its flavor by the addition of calamansi (*Citrofortunella microcarpa*), santol (*Sandorium koetjape*), and dalanghita (*Citrus nobilis)* in the fermentation wort. The study revealed that the yeast quantity, fermentation temperature and duration, affected the pH while the fermentation temperature and duration, affected the alcohol and the total soluble solids content of the beverage. Another scientific report focused on ethanol production from dasheen or cocoyam fermentation, converting the starchy root crop into a fermentable sugar (wort) by a two-stage enzyme hydrolysis process (Braide and Nwaoguikpe, 2011).

In Trinidad and Tobago, homemade fermented alcoholic beverages are produced from dasheen corm as a by-product utilising the residue after boiling dasheen for consumption. The product has tremendous potential for commercial production, however, research and development is required to ensure consumer acceptability and quality standardisation of an acceptable product is achieved. This research is aimed to produce a fermented dasheen beverage that is acceptable to consumers through sensory evaluation and determine the physicochemical

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and microbial parameters required to maintain quality standards during commercial production.

The fermented beverages from the must of two batches were evaluated i.e. A-the must only from the strained cooked dasheen and B-the cooked dasheen with the must, at three total soluble solids levels of 18, 22 and 25 ˚Brix. Microbiological analyses were conducted throughout the fermentation process (from raw material to final product). Physicochemical parameters (pH, specific gravity, total soluble solids, titratable acidity) were evaluated during primary fermentation and at the finished product stage. Gas chromatography/Flame Ionisation Detection (GC/FID), spectrophotometry, colorimetry, microbiology, and physicochemical parameters of the final products were evaluated and compared to a commercial Dasheen alcoholic beverage manufactured in Tobago. After a ranking method confirmed the preferred sugar concentration, a sensory evaluation was conducted on the final products made from musts A and B to determine overall consumer acceptability.

2. Methods

2.1 Preparation of the Dasheen Must

Freshly harvested unbruised dasheen corms (*Colocasia esculenta* L. Schott) were washed, hand peeled and sliced into 6.0 mm rectangular wedges using a meat slicer (Hobart Model 1612). After washing and draining the wedges, a batch weighing 1.2 kg was boiled until cooked (15 min) in a sterilised stainless-steel pot containing 4.5 L of clean potable water. The mixture was then cooled to 37 ˚C and strained into an 8 L bucket to remove the dasheen from the water and dasheen must (Must A). For Must B, the mixture was not strained, and the dasheen was added to the 8 L bucket. At 37 ˚C, 0.29 g of the enzyme amylase (LD Carlson, OH, USA) was added. Then, the pH was reduced to 3.5 by adding a 50:50 (v/v) citric acid (Sigma Aldrich, Canada) solution. Granulated sugar (155.56 g L^{-1}) was used to increase the TSS to 18 ˚Brix. Yeast nutrients, 0.99 g L^{-1} of ammonium sulphate (SD Fine – Chem Limited, Mumbai, India) and 0.99 g L^{-1} of monobasic ammonium phosphate (Fisher Scientific, New Jersey, USA) were also added to the dasheen mixture.

To prevent proliferation of wild microorganisms, 0.14 g L^{-1} of sodium metabisulphite (HiMedia, Mumbai, India), (SMS) was added. Feiner (2006) noted that the sodium dioxide equivalent was 67% of the sodium metabisulphite added, which is lower (93.8 ppm) than the maximum permissible limit (100 ppm) prescribed in the Food and Drugs Act, Chapter 30:01 (Government of the Republic of Trinidad and Tobago (GORTT), 2022). The solution was covered and after 24 h, 1.11 g L^{-1} of dehydrated yeast, (Lalvin EC - 118 *Saccharomyces cerevisiae ex bayanus*) was added to the 4.5 L dasheen must batch. After 10 min, 15 mL of the pre-SMS and post-SMS yeast musts were collected for microbiological analysis. The solution was then allowed to undergo primary and secondary fermentation, pasteurisation and finally bottling.

The above process was repeated for Must A using 255.56 g L^{-1} and 277.78 g L^{-1} granulated sugar to increase the TSS to 22 and 25 ˚Brix respectively as illustrated in Figure 1. All other variables were held constant. Similarly, these steps were repeated for Must B resulting in six batches (3 sugar concentrations x 2 musts).

2.2 Preparation of Fermented Alcoholic Dasheen Beverage

The musts (A and B) for each sugar concentration (18, 22 and 25 ˚Brix) were fermented at 28 ˚C (monitored daily) for 7 days in 8 L buckets. Before pitching the yeast (1.11 g L^{-1}), the solution was stirred very well. On day 1 after yeasts addition (10^7 cfu mL^{-1}) to the musts, pH, total soluble solids (TSS), specific gravity (SG) and the titratable acidity (TA) measurements were taken. These parameters were measured daily for 7 days, to monitor the primary fermentation process, while on day 7, the alcohol content was measured. Racking involved siphoning the musts (A and B) from each sugar concentration into 4.5 L sanitised, glass carboys, leaving sediments in the 8 L buckets after 7 and 21 days respectively. Fermentation locks half-filled with distilled water were used to cover the mouth of the carboys for each racking. A third racking of the musts was done 21 days after the second racking. One week after the third racking, the six dasheen batches were pasteurised for 15 min at 60 ˚C by using a sterilised stainless-steel pot on a mild flame equipped with a digital thermometer (Thermo Works RT610B-24). A 15 mL sample of the musts from each racking and each batch were taken for microbiological analysis. The batches were cooled at 30 ˚C for 25 min and then transferred to pre-sterilised 750 mL glass bottles for further analyses.

2.3 Microbiological Analysis

Microbiological analysis was done to monitor the fermentation process, prevent microbial spoilage of the musts and ensure safety of the finished product (International Organisation of Vine and Wine (OIV), 2021). Plate count Agar (PCA), Dichloran Rose Bengal Chloramphenicol (DRBC) and Violet Red Bile Agar (VRBA) (Oxoid Limited, Hampshire, UK) were used to enumerate the total aerobic bacteria, yeasts and molds, and coliforms, respectively. The Butterfield's Phosphate-buffered dilution water (10 g sample in 90 mL diluent) was used to serially dilute the raw dasheen, musts, and final samples (Harrigan, 1998). Serial dilutions for the musts Pre-SMS (10^0 to 10^{-4}), Post-SMS (10^0 to 10^{-3}) and after the addition of yeasts (10^{-2} to 10^{-6}) were prepared while similar dilutions were prepared for each racking and for the final and commercial alcoholic beverages. The total aerobic bacteria, yeasts and molds and coliforms (cfu mL^{-1}) were calculated using the colony counter (Reichert, Model No: 3325, USA).

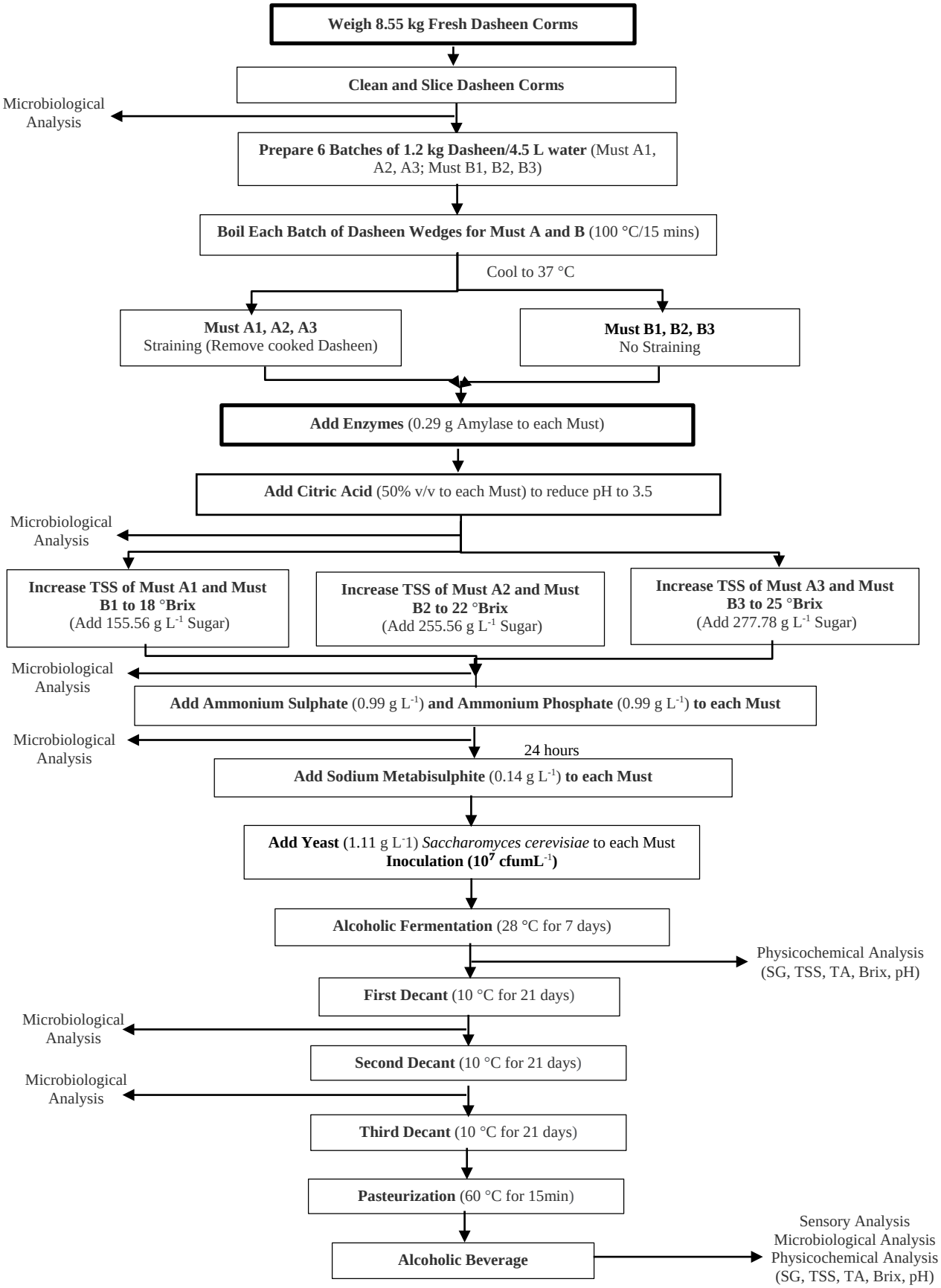

Figure 1. Process Flow Diagram and Microbiological Analysis for Preparation of Dasheen Alcoholic Beverage by Controlled Fermentation

2.4 Physicochemical Analysis

For the dasheen musts and fermented alcoholic beverages, the pH, specific gravity (SG), total soluble solids (TSS), titratable acidity (TA), and the alcohol content were determined using the analytical methods of the wine industry (Horwitz and Latimer, 2005; Ough and Amerine, 1988). The pH of the fermenting musts and the final products were monitored using a portable digital pH meter (Oakton Instruments 150, IL, USA). For the SG and potential alcohol content, a triple scale hydrometer (1983 EH 89 BT Ellaway Glass, Edinburgh, UK) with two scales was used to measure both the SG and the potential alcohol content (Jacobson, 2006). The TSS (˚Brix) was measured using a refractometer (Reichert, Analytical Instruments - 1452/62216/065). The TA was measured by the titration method with 0.1 N sodium hydroxide as the base and expressed as % citric acid (Jacobson, 2006).

2.5 Ethanol Concentration Analysis

The ethanol concentration of the fermented dasheen beverages was compared to that of a commercial dasheen fermented beverage using the gas chromatography method (Stackler and Christensen, 1974; Buckee and Mundy, 1993). An Agilent Technology (model 7890-A) GC system interfaced to an injector (7683-B series injector) with a Flame Ionised Detector (FID) at 250 ˚C was used to achieve chromatographic separation using 0.2 µL samples from 8 mL each of the commercial and the final fermented alcoholic beverages which were centrifuged (IEC Centra, USA model - CL4), at 6000 rpm for 15 min. The identification of the alcohol compounds was carried out by comparing their retention times with those of standards using a 5% propan-2-ol internal and ethanol standards (5%, 7.5%, 10%, 12.5%, 15%). The ethanol concentration mixtures were inserted into the GC storage sampler, followed by the final fermented product and commercial product mixtures. Two peaks were observed on each chromatogram, ethanol (longer peak) and propan-2-ol (shorter peak) and based on the retention times, peak areas quantified, and the alcohol content obtained (Stackler and Christensen, 1974).

2.6 Colour Analysis

A Thermo Scientific Evolution 60 s UV-Visible Spectrophotometer was used to determine the absorbance (A) of the finished products at 420 nm in triplicate (Blesic et al., 2013), while a Chroma meter (CR – 410, Konica Minolta Sensing, Inc; Ramsey, NJ, USA) was used to determine the Hunter values (L*, a*, b*) of the final and commercial products (Pathare et al., 2012).

2.7 Sensory Evaluation

The preferred sugar concentration was determined using a Preference Ranking Test to evaluate the samples, and these are ranked in order of preference. The three (3) samples from Must A were coded differently with 3-digit numbers and served to semi-trained individuals in a sensory evaluation booth. Respondents were required to indicate their preference for each product in the order from most liked sweetness (1) to moderately liked sweetness (2) to least liked sweetness (3) on a survey sheet provided. This procedure was repeated for the three (3) samples from Must B. Sensory evaluation of the final products made from the preferred sugar concentration for musts A (boiled dasheen must) and B (cooked dasheen and must) was then used to determine consumer acceptability and to evaluate whether the beverages from must A and B were discernable from each other.

The process involved training 30 panelists in sensory evaluation techniques including reducing biases and to distinguish the main characteristics of the beverage (Kilcast, 2000). The 30 semi-trained panelists were used to determine consumer acceptability by blind sampling and rating of the sensory attributes (appearance, colour, aroma, taste, and mouthfeel) of the beverage using a 5 – point hedonic scale from I like extremely (1), I like slightly (2), I neither like nor dislike (3), I dislike slightly (4) to I dislike extremely (5) (Fiscal and Chavez, 2016). A triangle test was used to determine whether there was a difference in the fermented beverage from Must A and Must B. In this test, respondents were asked to determine the odd sample from three (3) samples, where one sample was repeated twice (Hartley et al., 2022).

2.8 Statistical Analysis

All experiments were carried out in triplicate and the results expressed as the mean $\pm$ SD. The results were subjected to a one-way analysis of variance (ANOVA) using the IBM SPSS Statistics Data Editor (SPSS Inc., Chicago, IL, USA). Significant differences were established at the $p<0.05$ level.

3. Results and Discussion

3.1 Microbial Analysis of Musts and Fermented Beverages

Table 1 shows the microbial count throughout the fermentation of dasheen for both must types (A and B) and at the three TSS levels. The population of aerobic bacteria, yeasts and molds in raw ‘uncooked’ dasheen were 1.39 x 10^8, 2.1 x 10^8 and 29 cfu mL^{-1}, respectively. Generally, the microorganisms present on the raw dasheen samples allowed for the natural fermentation process to occur (Pambianchi, 1999). In the Pre-SMS stage, the microbial population decreased, as the dasheen was boiled in hot water. The B must, had a greater yield of aerobic bacteria than the A must, as it included the cooked dasheen wedges in the must. In the Post-SMS stage, the microbial population drastically declined, and this step was very crucial, to kill unwanted, bacteria and yeasts present in the original samples which could have contributed to unpalatable flavours. After inoculation of the must with the commercial wine yeast, primary fermentation commenced. Initially, it appeared that the yeast adapted to the new environment prior to cell division while

Table 1. Microbial Count of the Raw Dasheen and Must A and B during the Fermentation Process at 18, 22 and 25 °Brix

SAMPLE	TOTAL AEROBIC BACTERIA			YEASTS			MOLDS			COLIFORMS		
°BRIX	**18**	**22**	**25**	**18**	**22**	**25**	**18**	**22**	**25**	**18**	**22**	**25**
Mean values (cfu mL^{-1})												
Raw Dasheen	1.39×10^8	1.39×10^8	1.39×10^8	2.1×10^8	2.1×10^8	2.1×10^8	29	29	29	0	0	0
PRE-SMS												
A	1.26×10^7	1.17×10^7	1.05×10^7	1.61×10^7	1.79×10^7	1.93×10^7	21	15	9	0	0	0
B	1.35×10^7	1.28×10^7	1.13×10^7	1.72×10^7	1.85×10^7	2.07×10^7	38	22	13	0	0	0
POST-SMS												
A	12	10	6	32	25	13	3	1	3	0	0	0
B	21	14	10	41	34	21	10	2	4	0	0	0
MUST AFTER YEASTS ADDITION												
A	1.43×10^6	1.32×10^6	1.22×10^6	1.29×10^7	1.41×10^7	1.67×10^7	5	2	4	0	0	0
B	1.51×10^6	1.39×10^6	1.41×10^6	1.34×10^7	1.53×10^7	1.75×10^7	16	12	6	0	0	0
FIRST RACKING												
A	1.18×10^5	1.06×10^5	9.60×10^5	1.09×10^6	1.23×10^6	1.45×10^6	2	1	2	0	0	0
B	1.30×10^5	1.17×10^5	1.09×10^5	1.20×10^6	1.39×10^6	1.58×10^6	9	7	3	0	0	0
SECOND RACKING												
A	8.70×10^4	7.80×10^4	6.90×10^4	7.90×10^4	8.70×10^4	9.60×10^4	0	0	0	0	0	0
B	1.03×10^4	9.20×10^4	7.50×10^4	8.60×10^4	9.40×10^4	1.05×10^4	5	3	0	0	0	0
THIRD RACKING												
A	4.40×10^3	3.10×10^3	2.70×10^3	3.20×10^4	4.50×10^4	5.70×10^4	0	0	0	0	0	0
B	6.70×10^3	4.60×10^3	3.40×10^3	4.10×10^4	5.30×10^4	6.20×10^4	0	0	0	0	0	0
FINAL RACKING												
A	0	0	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0	0	0
COMMERCIAL WINE												
	2	2	2	0	0	0	0	0	0	0	0	0

simultaneously converting sugar to alcohol as described by Nobile et al. (2003). This process lasted for 7 days, whereby excessive amounts of energy were consumed as heat, oxygen, and increased temperature. Additionally, carbon dioxide (CO_2) was expelled through the bung, and this led to the rapid growth of yeast cells (exponential phase) (Braide and Nwaoguikpe, 2011).

After primary fermentation, the product was racked (secondary fermentation) and the microbial population continued to decline as shown in Table 1. During this stage, the rate of yeast multiplication declined since there were limited nutrients (sugars) for it to consume and the alcohol produced was toxic for yeast proliferation (Braide and Nwaoguikpe, 2011). A temperature decrease was noted since the energy produced was released by the fermentation tank (carboy) into the surroundings. The remainder of alcohol was produced at the secondary stage, which lasted between 7 to 14 days and the death rate of microbes was higher than the proliferation rate (Nobile et al., 2003). From the second into the third racking, most of the microbial population was killed and a few survivors (survival phase) probably remained. The final fermented alcoholic beverage was carefully pasteurised to destroy any remaining microorganisms, and to preserve its aroma and flavour. Coliforms were not detected in any of the must and fermented alcoholic samples as illustrated in Table 1.

3.2 Physicochemical Analysis of Musts and Fermented Beverages

During primary fermentation there was a general decline in the pH, SG and TSS while the TA (% citric acid) increased as shown in Figure 2, for the preferred 25 ˚Brix from must A and this trend was like reported studies (Braide and Nwaoguikpe, 2011; Ifie et al., 2012; Kiin-Kabari et al., 2019). Generally, the primary fermentation stage was characterised by a high fermentation rate, due to the available yeast nutrients at the start of the process and production and accumulation of organic acids (Nobile et al., 2003; Kiin-Kabari et al., 2019) while in the secondary stage, the fermentation rate slowed down because of alcohol concentration on yeast cells (Braide and Nwaoguikpe, 2011).

The initial pH decline during primary fermentation was indicative of a relatively good fermentation rate due to sugar utilisation by the yeast cells (Braide and Nwaoguikpe, 2011; Nobile et al., 2003) in an acidic medium. It demonstrated the yeast efficiency in alcohol production (Nobile et al., 2003; Ifie et al., 2012) which also caused the SG to decrease as illustrated in Figure 2 like previous studies (Braide and Nwaoguikpe, 2011; Nobile et al., 2003; Chilaka et al., 2010; Kiin-Kabari et al., 2019). Low pH and high acidity gave fermentation yeast a comparative advantage in natural acidic environments which inhibited spoilage microorganisms and created a favourable environment for the growth of desired organisms (Braide and Nwaoguikpe, 2011; Kiin-Kabari et al., 2019). The TSS declined during primary fermentation (see Figure 2) as the yeast consumed the sugars present in the must, producing ethanol and CO_2

which resulted in a decrease in SG (Ifie et al., 2012; Chilaka et al., 2010). The 25 ˚Brix A must had highest TSS levels during primary fermentation compared to the other must and sugar concentrations as noted in Figure 3.

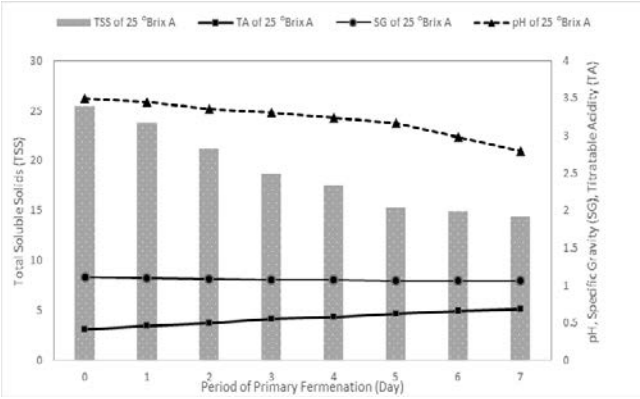

Figure 2. Changes in Quality Parameters during Week 1 of Primary Fermentation of Dasheen

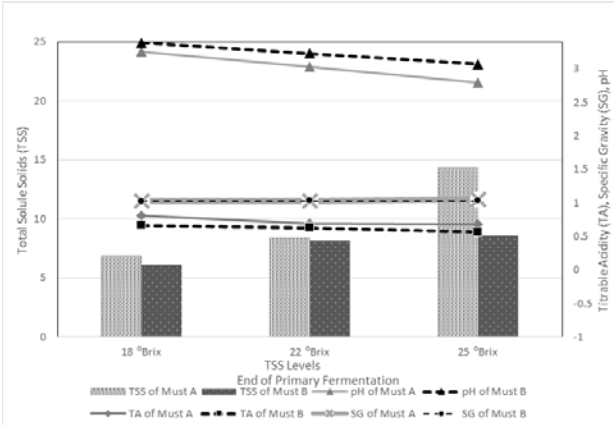

Figure 3. Quality Parameters of the Dasheen Musts for the Three TSS Levels at the end of Primary Fermentation

The TA (% citric acid) increased during primary fermentation (see Figure 2) and is like previous studies for pawpaw must, where an acidic medium encouraged optimum yeast activities resulting in organic acids accumulation during fermentation (Kiin-Kabari et al., 2019).

Table 2 shows the pH, SG, TSS and % citric acid data for the fermented dasheen alcoholic beverage from musts A and B for the three TSS levels (18, 22 and 25 ˚Brix). The type of must treatment significantly affected ($p<0.05$) the pH, SG, TSS and TA. An acidic pH was observed for all the six fermented alcoholic beverages, with the must A exhibiting a lower pH than the B must at the three TSS levels. Components that resulted in reducing the pH included esters, CO_2, phenolic compounds, and organic acids (lactic acid and acetic acid) via metabolic actions (Chilaka et al., 2010; Kiin-Kabari et al., 2019). The 25 ˚Brix A product was favoured with a pH of 3.12 which was within the pH range of 2.80 to 3.33 for alcoholic beverages (Fiscal and Chavez, 2016; Ifie et al., 2012) and was significantly lower ($p<0.05$) than the commercial fermented alcoholic beverage as noted in Table 6.

The final products SG ranged from 0.9933 to 1.0053 as shown in Table 2. Upon completion of fermentation, the SG was below 1.000 for the various ˚Brix concentrations and treatments (A and B) except for the 25 ˚Brix A and commercial wines probably because of their high TSS. The SG of the 25 ˚Brix A product averaged 1.0053 and was significantly lower ($p<0.05$) than the commercial product (see Table 6) as the density was increased by fermentable sugars and other substances (Ifie et al., 2012; Chilaka et al., 2010).

The final product TSS varied from 4.37 for the 18 ˚Brix B to 10.13 for the 25 ˚Brix A fermented products (see Table 2). The TSS for the 25 ˚Brix A fermented product, was significantly higher ($p<0.05$) than the B one but was significantly lower ($p<0.001$) than the commercial sample. The high TSS for the 25 ˚Brix A product was probably due to incomplete consumption of sugars by the yeasts during fermentation resulting in a semi – dry alcoholic beverage. The fermentation rate was slower, or probably ended earlier for this product compared to the commercial one which most probably was back sweetened.

Table 2. Physicochemical Analysis of the Final Fermented Alcoholic Beverages Produced from the Dasheen Must

Parameters	18 ˚Brix		22 ˚Brix		25 ˚Brix		*P*-value
	A	B	A	B	A	B	
pH	3.11 ± 0.06^{a}	3.42 ± 0.06^{b}	2.89 ± 0.06^{a}	3.10 ± 0.06^{b}	3.12 ± 0.06^{a}	3.34 ± 0.06^{b}	.001
SG	0.9973 ± 0.0012^{b}	0.9973 ± 0.0012^{b}	0.9993 ± 0.0012^{a}	0.9973 ± 0.0012^{a}	1.0053 ± 0.0012^{a}	0.9933 ± 0.0012^{b}	.005
TSS (˚Brix)	5.07 ± 0.06^{c}	4.37 ± 0.06^{c}	6.17 ± 0.06^{c}	6.27 ± 0.06^{c}	10.13 ± 0.06^{d}	6.57 ± 0.06^{c}	.009
TA (% citric acid)	0.86 ± 0.04^{f}	0.72 ± 0.00^{g}	0.75 ± 0.01^{f}	0.69 ± 0.00^{g}	0.75 ± 0.00^{f}	0.63 ± 0.00^{g}	.001
% Alcohol (hydrometer)	11.01 ± 0.19^{h}	9.92 ± 0.19^{h}	13.18 ± 0.19^{h}	12.64 ± 0.19^{h}	14.00 ± 0.19^{h}	13.72 ± 0.19^{h}	.504
% Ethanol (GC)	8.87 ± 0.02^{i}	8.59 ± 0.00^{i}	12.00 ± 0.00^{i}	10.81 ± 0.00^{i}	12.52 ± 0.01^{i}	12.36 ± 0.01^{i}	.599

Values are means ± SD for n=3; values within same row with different superscript differ significantly ($p<0.05$)

The TA of the final fermented products ranged from 0.63% to 0.86% as shown in Table 2 falling within reported levels of 0.38 to 1% (Chilaka et al., 2010; Kiin-Kabari et al., 2019) with the must A treatment TA significantly higher ($p<0.05$) than the B one. The 25 ˚Brix A finished product TA value of 0.75% was significantly higher ($p<0.05$) than the 0.22% for the commercial product.

3.3 Alcohol Content of Fermented Beverages from Gas Chromatography (GC) and Hydrometer Methods

The ratios of ethanol to propan-2-ol peak area in Table 3 were calculated for the commercial and final fermented samples and the alcohol content was interpolated from a linear graph of the mean ratio of the ethanol/propan-2-ol peak area of the standards against ethanol concentrations obtained from GC analysis. The first peak observed on the chromatogram was ethanol while the second peak was propan-2-ol, as shown in Figures 4 and 5 for the 25 ˚Brix A and B fermented products respectively.

Table 3. Ratios of the Ethanol to Propan-2-ol Peak Areas of the Commercial and Final Dasheen Alcoholic Beverages

Type of sample (˚Brix)	Ratio of Ethanol/Propan-2-ol (Mean ± SD)
Commercial Alcoholic Beverage	1.94 ± 0.00^{i}
18A	1.79 ± 0.00^{i}
18B	1.73 ± 0.00^{i}
22A	2.43 ± 0.00^{i}
22B	2.19 ± 0.00^{i}
25A	2.54 ± 0.00^{i}
25B	2.50 ± 0.00^{i}

Values are means ± SD for n=3; values within same column with different superscript differ significantly ($p<0.05$)

Table 2 shows the alcohol content of the final fermented samples from the GC and triple scale hydrometer which ranged from 8.59% (18 ˚Brix B) to 12.52% (25 ˚Brix A) with the GC method and with the hydrometer, the values ranged from 9.92% (18 ˚Brix B) to 14.00% (25 ˚Brix A). Samples from the A must for the various ˚Brix concentrations had higher alcohol levels than those from the B must because prior to fermentation (day zero) before yeasts were added, the TSS for the A must increased slightly over the B must. The higher alcohol levels could be attributed to higher amounts of available sugars and the capacity of the yeasts to convert the sugars to alcohol. The alcohol content of the 25 ˚Brix A final fermented samples was significantly higher ($p<0.05$) for both methods compared to the commercial sample (see Table 6). Reported alcohol levels in various fermented beverages ranged from 7.17% for taro corms (Fiscal and Chavez, 2016), to 9.6% for hibiscus (Nobile et al., 2003) and 8.00% and 7.69% for yellow and rose red pawpaw (Kiin-Kabari et al., 2019), respectively.

3.4 Spectrophotometric and Colour Analyses of Fermented Beverages

The dasheen final fermented samples were colourless (nearly white to light yellow) and categorised as white fermented beverage when a 420 nm wavelength was used to determine the propensity to yellow or brown, with the higher absorbances indicative of 'yellowing' of the white final fermented samples (Blesic et al., 2013).

Absorbance readings of the final fermented samples at 420 nm are shown in Table 4. The 25 ˚Brix B sample made from must with cooked dasheen exhibited the highest absorbance and the most 'yellow' character. The lowest absorbance and least 'yellow' noted was the 25 ˚Brix A. From Table 6, the commercial product had a significantly ($p<0.001$) higher absorbance value indicating more 'yellowing' than the 25 ˚Brix A one. Blesic et al. (2013), evaluated the absorbances at 420 nm between non-filtered and filtered white wines and found the non-filtered wines showed higher absorbances than the filtered wines, however, the absorbance values obtained for the non-filtered wines were lower than the range in this present study.

For colour analysis, higher L* values (whiteness) although not significant were noted for the 22 and 25 ˚Brix A fermented beverages (see Table 4) versus the B ones which were cloudier due to the type of must used. The a* and b* components were very low, (a* values were closer to zero), which meant that the alcoholic beverages did not reflect strong red and yellow hues, hence were colourless. The one-way ANOVA revealed a *P*-value of 0.003 for the a* component, which indicated a significant difference when products from both A and B musts were compared with a lower a* component (degree of redness) for the A products. From Table 6, the L*, a*, b* components were significantly different ($p<0.05$) for the 25 ˚Brix A and the commercial product in that the L* component was clearer than the commercial one while the a* component showed

Table 4. Colour Analysis of the Commercial and Fermented Alcoholic Beverages Produced from the Dasheen Must

Parameters	**˚Brix**						***P*-value**
	18 A	**18 B**	**22 A**	**22 B**	**25 A**	**25 B**	
λ = 420 nm	0.375 ± 0.002^{a}	0.351 ± 0.003^{a}	0.250 ± 0.002^{a}	0.458 ± 0.004^{a}	0.246 ± 0.002^{a}	0.506 ± 0.008^{a}	.509
$\mathbf{1}_{L^*}$	87.02 ± 0.27^{b}	88.63 ± 0.35^{b}	88.99 ± 0.03^{b}	88.10 ± 0.04^{b}	88.59 ± 0.01^{b}	87.99 ± 0.04^{b}	.901
$\mathbf{2}_{a^*}$	0.23 ± 0.00^{c}	0.41 ± 0.01^{d}	0.07 ± 0.01^{c}	0.24 ± 0.01^{d}	0.03 ± 0.00^{c}	0.20 ± 0.00^{d}	.003
$\mathbf{1}_{b^*}$	5.89 ± 0.07^{f}	1.57 ± 0.53^{f}	2.25 ± 0.00^{f}	1.69 ± 0.02^{f}	1.36 ± 0.01^{f}	1.93 ± 0.00^{f}	.057

Values are means ± SD, n=3; values within same row with different superscript differ significantly ($p<0.05$)

Table 5. Sensory Evaluation Comparison of the 25 ˚Brix Fermented Alcoholic Beverages

Final Alcoholic Beverages	Appearance	Colour	Aroma	Taste	Mouthfeel
25 ˚Brix A	1.63 ± 0.81^{a}	1.57 ± 77^{a}	1.70 ± 0.09^{a}	1.67 ± 0.18^{a}	2.07 ± 1.05^{a}
25 ˚Brix B	3.13 ± 1.01^{b}	3.07 ± 0.94^{b}	2.43 ± 0.19^{a}	3.33 ± 0.37^{b}	3.47 ± 1.28^{b}
***P*-value**	.001	.001	.056	.001	.001

Values are means ± SD for n=30; values within same column with different superscript differ significantly ($p<0.05$)

Table 6. Comparison between the 25 ˚Brix (A) Fermented Dasheen Beverage and the Commercial Dasheen Beverage

Wine Property	25 ˚Brix (A) mean (SD)	Commercial mean (SD)	*P*-value
pH	$3.12\ (0.06)^{a}$	$3.77\ (0.06)^{c}$	.002
SG	$1.0053\ (0.0012)^{a}$	$1.0720\ (0.0012)^{c}$	≤ .001
TSS (˚Brix)	$10.13\ (0.06)^{d}$	$23.37\ (0.06)^{e}$	≤ .001
TA (% citric acid)	$0.75\ (0.00)^{f}$	$0.22\ (0.01)^{h}$	.001
Alcohol Content (%) - Hydrometer	$14.00\ (0.19)^{h}$	$11.50\ (0.15)^{i}$	.009
Absorbance at 420 nm	$0.246\ (0.002)^{j}$	$0.384\ (0.002)^{k}$	≤ .001
Alcohol Content (%) - GC Analysis	$12.50\ (0.01)^{l}$	$9.59\ (0.01)^{m}$	.001
L*	$88.59\ (0.01)^{n}$	$87.06\ (0.05)^{o}$	.005
a*	$0.13\ (0.00)^{p}$	$0.31\ (0.01)^{q}$	≤ .001
b*	$1.36\ (0.01)^{r}$	$3.06\ (0.10)^{s}$	.005

Values are means ± SD for n=3; values within same column with different superscript differ significantly ($p<0.05$)

a lower red hue and the b*component a lower yellow hue compared to the commercial product.

3.5 Sensory Analysis

Dasheen fermented alcoholic beverages made from the two musts (A and B) were significantly different ($p \leq 0.05$) on the sensory attributes for mouthfeel, taste, appearance, and colour. The 25 ˚Brix A product was preferred over the 25 ˚Brix B one, based on the lower sensory evaluation scores (highly liked) in Table 5. The 25 ˚Brix A product was also preferred because of its improved clarity (higher L*), the lower absorbance reading, indicating a lighter, less opaque wine (see Table 4), the higher alcohol levels obtained from GC and hydrometer methods (see Table 2) and the higher TSS readings compared to the B product (see Table 2). Even though final products from both musts were acidic, the 25 ˚Brix A was more acidic due to the lower pH value of 3.12 and similarly when compared to the commercial wine, the 25 ˚Brix A was more acidic (see Table 6). Overall, the data showed the 25 ˚Brix A final product as the ideal, acceptable product.

Dasheen is not high in compounds such as anthocyanins and polyphenols which add a heightened nutrient content compared to wines made from grapes, papaya and purple sweet potato and other highly pigmented fruits or storage roots as described in the literature (Ray et al., 2011). Recently, fermented tubers such as yam (Batista et al., 2019) and cassava (Yuwa-Amornpitak et al., 2012; Coelho et al., 2020) have been investigated. However, Batista et al. (2019) used lactobacillus instead of yeast. Since these crops are inherently low in flavour, infusions were done to ameliorate the sensory profile and increase the antioxidant content. In our study, amylase was also used to increase the available reducing sugars for fermentation.

While the flavour of the beverage made in this study may not be as dynamic and not as nutrient enriched, it may find utility as a cheaper alternative for a cooking wine. Additionally, the beverage developed can also be an alternative as a base ingredient, for the production of other alcoholic beverages in gastronomy such as cocktails and other preparations, such as alcoholic truffles, for example.

4. Conclusion

From the sensory evaluation, the 25 ˚Brix A final product was consumer acceptable with a pH, SG, TA and TSS reading of 3.12, 1.0053, 0.75% and 10.13 respectively. The alcohol content from the GC method was 12.52% versus 14% with the triple scale hydrometer. The absorbance reading at 420 nm was 0.246 with L*, a*, b* values of 88.59, 0.13 and 1.36 respectively.

The manufacture of an alcoholic fermented beverage eliminates wastage of this perishable crop, which is available yearlong, particularly when there is a glut in the market and offers opportunities for economic benefits to farmers and entrepreneurs. The product marketability can be improved with larger scale manufacturing since there is knowledge of the quality characteristics to make a standardised dasheen fermented alcoholic beverage. In advanced studies, the starchy dasheen corms can be gelatinised to produce a high glucose/sugar content before fermentation and without adjuncts can be used to produce distilled alcoholic beverages such as vodka. Further research is warranted using dasheen as the main fermentable sugar via enzymatic digestion in order to increase flavour and aroma from its own characteristic by the distillation process that is used for spirits.

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