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Research Article

Optimization of Low-Cyanide Cassava Adjuncts in Production of Dark Stout Using Sorghum Malts at Varying Concentrations

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ABSTRACT: *Optimization of low-cyanide TMS31/00110 (var. cassava) adjunct for the production of dark stout using two varieties of sorghum malts was carried out at varying concentrations. The malted sorghum varieties and the processed low cyanide cassava adjunct were separately milled into moderately coarse size using Institute of Brewing method. The Exogenous enzymes used include Alpha Amylase (Termamyl), Bioprotease, β-glucanase, Beta Amylase (Promalt) and Alpha Amylase (Bioferm). Worts of different concentrations were obtained with the aid of upward infusion mashing system. Three hundred milliliters (300ml) of tap water was used to dilute 50g of the mixed concentrated grist for the dark stout samples respectively. After complete saccharification from the mashing for about 2 1/6 hr, each mash was filtered to obtain clear sweet wort which was immediately subjected to various analyses. The clear worts obtained were boiled with hops for 45min, followed by cooling at15°C for pitching. The pitched worts were fermented for 6 days. Caramel (5mls) was added to improve the colour of the liquors. Colour intensities were determined for the stout samples using spectrophotometer according to European Brewing Convention method. Sensory evaluation tests were carried out on the stout samples using ten panelists, their judgment through questionnaires were statistically analyzed. The characterized worts showed that the original gravity ranged from 1046 to 1048°ρ, for prospective dark stout using sorghum CSR-02 Variety. The original gravity of dark stout ranged from 1046 to 1048 °ρ with sorghum ICSV-400. The wort pH ranged from 5.21 to 5.30, viscosities from 1.09 to 1.12CP for prospective stout samples from sorghum CSR-02 and ICSV-400 varieties. For reducing sugars, maltoses were 178.30 – 196.20mg/l; glucoses were 109.30 - 120.30. The cyanide content reduced from 4.50mg/l to between 0.03 and 0.00mg/l. The young stout beer obtained had the specific gravity ranging from 1015 to 1016°ρ, and 1011 to 1013°ρ. pH ranged from 4.68 to 4.78 and 4.28 to 4.32; % alcohol of 3.87 to 4.13% and 4.26 to 4.77%. The apparent fermentability was 3.15 to 3.53% at 22°C. The beer colour was 29 EBC. The Null Hypothesis was accepted since there was no significant difference among the samples produced at P≤0.05 level of significance.*

KEYWORDS: Cassava, Concentrations, Cyanide, Dark, Malts, Optimization, Sorghum, Stout,

I. INTRODUCTION

Beer is the world's most widely consumed alcoholic beverage; it is the third most popular drink after water and tea [1]. Beer is an alcoholic product obtained from the fermentation by yeast culture of the solution prepared from a mash of malted barley (or any other cereals) and hops or hops products with or without the addition of other malted or unmalted cereals or other suitable carbohydrate source.

When other cereals are used in beer production (unqualified), references shall be made based on barley and hops [2]. Beer made exclusively from other cereals sources shall be qualified; for example rice beer from rice and sorghum beer from sorghum [3]

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Although, barley has been the major grain malted for the brewing industries all over the world. However, the South African have tried some local brewing using sorghum cereal (*Sorghum vulgare*) for the purpose of producing an opaque beer called "kaffir" beer as recorded by [4]

In Nigeria, lager and ale (stout) beers have been produced from Nigerian sorghum comparable to the one made from barley. Ever since those trials, the interest of Nigerian government was stimulated to encourage the replacement of barley malt with sorghum malt. As a result, local farmers boost sorghum production. The benefits derived from these innovations of brewing industry outside the laws made in most European countries over the use of only barley malt, hops and water as the only raw materials include; (i) Reduction in dependency on other countries as all cereals have similar chemical compositions (ii) Reduction in cost as different countries have decided to utilize their local cereals in the brewing industry. (iii) In addition, job creation and employment opportunities are enhanced as people now go on cereal cultivation. (iv) The last but not the least, conservation of foreign exchange earnings of the countries [5].

Some limitations do exist with sorghum utilization in brewing, such as low enzyme complement and high gelatinization temperature [6]. The former can be removed through the use or addition of exogenous enzymes while the later can be managed by gelatinizing the grain in a separate mash tun with the addition of malt enzymes before incorporating it into the main mash. Cassava could also be used as adjunct in beer production because it provides carbohydrate which can ultimately be broken down into fermentable sugars at cheaper price. It reduces the soluble nitrogen content of wort and produces beer of better physical stability [7]

The problem of hydrogen cyanide of cassava can be corrected by stepping in water for 24 – 48 hours which dissolves the pyrussic acid in water thereby detoxifying it [4]. In addition, the level of hydrogen cyanide can be reduced to a greater extent during wort boiling and drying of the cassava due to the volatile nature of this pyrussic acid [7],[8]

There are different varieties of beers, among which lager, ale and stout are the most popular. Ale, which is often described as robust, fruity and hearty is made from top fermenting yeast. Stout, which is richly flavoured, dark and heavy, is made from pale malt, caramel malt and unmalted barley.

Research interests especially by many African scholars have tried to provide solution to some of the setbacks which would have frustrated the maximum use of sorghum grain in brewing [4]and [9]

II. MATERIALS AND METHODS

2.1 Materials

The materials used for this work include:

i. Improved varieties of sorghum:-CSR-O2 variety and ICSV 400 variety of sorghum.
ii. TMS81/00110 variety of cassava
iii. Hop pellets

Number i and ii above were obtained from National Research Institute, Zaria and National Root crops Research Institute, Umudike respectively.

2.2 Yeast strain

Strain of *Saccharomyces cerevisiae* obtained from Consolidated Breweries Awo-omama, Imo State was used.

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Reagents and chemicals used include:

i. Fehling Solutions A and B
ii. Methylene blue
iii. Iodine Solution
iv. Sodium carbonate
v. KCN solution, H_2O_2
vi. HCL
vii. H_2O_2

2.3. Methods

The methods used were: The Methods of Analysis of the Institute of Brewing [10] The Recommended Methods of Analysis of the American Society of Brewing Chemists and Alkaline Picrate Method (Wang and Filled Method) of cyanide determination. While samples packagings were done using the Principles of Food Packaging by [11]. Beer style Guidelines by Guidelines by [12] were also adopted.

2.4. Malting of sorghum varieties

Floor malting techniques were employed in this research.

The two varieties of sorghum CSR-O2 and ICSV-400 were thoroughly cleaned, soaked in tap water for the period of 8h, after which the steep waters were removed followed by 2 hours air-resting period. The same procedures were repeated until the completion of 40 total hours of steeping with the corresponding 2 hours of air-rest after each change of water.

The steeped grains were casted for 24h where the grains were heaped on sac bags and covered with banana leaves in order to generate heat which quickened germination rate. After casting, the grains were allowed to germinate for 4 days at room temperature by spreading on the same sac bags; where water was sprinkled at intervals of twice a day in order to avoid dryness of the surface grains. Occasional turning of the grains was observed to avoid "malting" during germination.

The germinated grains were kilned at the temperature of 48ºC for 24h to reduce the moisture contents.

The kilned malts were de rooted by abrasive method.

2.5 Steeping of the Cassava

The cassava variety was peeled, thoroughly washed and sliced into uniform chip-sizes. The chips were soaked in distilled water for 24hours; with the steep water was changed at 12 hours interval. The essence of steeping was to allow the hydrolysis of hydrogen cyanide thereby reducing its level in the cassava. This procedure was immediately followed by oven drying of the chips at the temperature of 56^{o}C.

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III. GRAIN ANALYSIS

3.1. Determination of Moisture content.

Twenty grams (20g) of each of the sorghum varieties were weighed out and moderate coarsely ground with the aid of laboratory milling machine. Five grammes (5g) of each sample were placed in a moisture dish and covered. The entire content was weighed to 0.001gm accuracy. The cover was then removed and the dish placed in an oven preheated at a temperature of 105ºC, for 3hours. The dish was then covered with the lid and then placed in desiccators to cool for about 30mins to the temperature of about 30ºC. The dish was then reweighed to 0.001gm. The moisture content (MC) for each of the samples was then calculated as follows:

$$MC = \frac{W1 - W2}{W1} \times \frac{100}{1}$$

Where W1= weight of samples before drying

W2= weight of sample after drying

3.1.1. Germinative capacity

Zero point five percent (0.75%) of H_2O_2 was freshly prepared, i.e 5ml of 30% H_2O_2 in 100ml of distilled water. Two lots of 200 corns were obtained after excluding foreign matter like debris and stones including broken corns. Each lot was steeped in 200ml of fresh solution for 48hours in the first instance. The steep liquor was then changed with a fresh 200ml H_2O_2 (Hydrogen peroxide) solution for another 24hours. The solution was finally strained off and the corns counted for those that have chitted or developed either rootlets or acrospires.

3.2.2. Germinative Energy

This was determined by placing two filter papers (whatman size 2) in the bottom of petri dishes and wetted with 3ml of distilled water. One hundred corns from each sample were separately added in the petri dish and allowed to stand for 72 hrs. The numbers of germinated corns were counted after 24 hours, 48 hours, and 72 hours, respectively.

G.E (%) = 100-n

Where; n = number not chitted after 72hrs.

Mashing, and hop boiling cum fermentation were carried out in accordance with the procedure of Priest and Campbell (2003), Society of Brewing Chemists and the procedures by the European Brewing Convention.

Milling of the malted sorghum varieties and the processed cassava variety:

Each of the samples of sorghum varieties was dry-milled into moderately coarse sizes (IOB recommendation), using laboratory grinder. The grists were carefully weighed according to the specified adjunct concentrations to make up a total of 50g in 300ml of tap water in accordance to IOB recommendations.

3.3. Mashing

Infusion mashing system was done to obtain worts of varying concentrations which were subjected to further analysis according to IOB methods.

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3.3.1. Procedure for infusion Mashing used

The grist (mixture of malted sorghum grist with the corresponding adjunct concentrations) was poured into 5 conical flasks for ale samples, and another 5 conical flasks for the stout samples. The same procedure was repeated for another variety of sorghum; making it up to a total of twenty conical flasks.

Fifty grammes (50g) of the grist were poured into the conical flasks already labeled according to the different concentrations used. Three hundred millilitre (300mls) of tap was measured and gradually poured each to each conical flask and thoroughly stirred.

Zero point eight millilitre (0.8ml) of exogenous enzymes) was added into the mixture in each flask, containing the grist and water. The enzymes added (at room temperature) include; Termamyl, Bioprotease, β-glucanase, Promalt, and Bioferm

Temperature of the mash was increased to 35-40ºC and maintained for 30mins, and increased to 40-45ºC, and maintained for another 30mins.

The mash was placed on hold at the temperature of 45-50ºC for 30mins, after that it was increased to 60-63ºC for another 1 hour.

The mash was finally held at 70-74ºC and maintained for 30mins, while checking for saccharification. The mash was boiled at 100ºC for 10mins to mash off.

3.3.2. Saccharification test

Two milliliters (2ml) of each wort samples were measured out into properly labeled test tubes. Then, two drops of iodine solution were added into the test tubes. Colour changes were immediately noted. A brown purple colouration showed that complete saccharification had been achieved.

3.3.3. Wort Filteration

The mash was filtered for each sample using muslin filter cloth to obtain clear sweet wort in readiness for analysis with subsequent wort boiling with hops.

3.4.Wort Analysis

i. **Determination of original gravity:** After obtaining the clear sweet worts, they were allowed to cool for 30mins. Then, the samples were poured each into 100ml measuring cylinder. A saccharometer was dipped slightly into the solution while readings were immediately taken and recorded accordingly. Same was repeated for specific gravity.
ii. **Determination of Total reducing sugars.** A starch was obtained by mixing 10ml of the wort in 100ml of water to obtain 10% dilution for each sample. The diluted worts were poured into a burette, one after the other. About 12.5ml each of Fehling's solution A and B were mixed together, and poured into 250ml volumetric flask. One drop of methylene blue was added as an indicator. The diluted wort samples were titrated against the mixed Fehling's solutions and immediately boiled. The titration and heating continued until the reaction changed colour to orange brick red end point (precipitate): Reduction of copper from Cu^{2+} to Cu^{+}. Titre values were noted and recorded accordingly.
iii. **Determination of pH:** The pH of each wort sample was determined by pouring each in 250ml round bottom flask, and the pH meter slightly dipped into the samples while readings were taken and appropriately recorded. Same procedure was used to check pH.

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iv. **Determination of wort viscosity/flow rate:** One hundred milliliters (100ml) of each wort samples was poured into 200ml measuring cylinder. Ostwald viscometer was gently dipped into the content while readings were taken and appropriately recorded.
v. **Determination of wort/beer temperatures:** Temperatures were determined by dipping thermometer into each sample, while readings were taken and recorded accordingly.

3.4.1. Wort Boiling/Clarification

Three and five pellets (capsules-like size) of hop pellets were added each to each ale and stout respectively and boiled for 45mins. The hopped worts were clarified with the aid of Kieselghur filter, (after wort cooling).

3.4.2. Wort Cooling

The hot hopped worts were allowed to cool to the barest temperature for yeast activities. This was done by placing the hot wort flasks in cold water and there was gradual reduction in temperature in readiness for pitching prior to the commencement for fermentation.

3.5 Preparation of Yeast Innoculum Cum Pitching

The yeast strain, *Saccharomyces cerevisiae* was reconstituted from its dormant state to the active state by weighing 10g of it together with 5g of glucose-D into an air-tight container. The content was mixed with 100ml of distilled water. Zero point two grams (0.2g) of ammonium sulphate (yeast protein) were added. The mixture was shaken for about 7minutes until there was evolution of carbon (iv) oxide on opening the container. The evolution of CO_2 connotes awaken of the yeast cells.

Finally, 10ml of the yeast innoculum was pitched in each fermenting vessel for the commencement of primary fermentation.

3.6. Primary Fermentation

Primary fermentation commenced as soon as the pitching was done, and lasted for 7days at room temperature.

At the end of 7^{th} day green beers were decanted for the stout samples and finally clarified before some parameters were determined. The parameters of the green beers include: pH, fall in gravities, percentage alcohol and apparent fermentability. Readings were taken and appropriately recorded for each of the parameters.

3.7 Beer analysis

Determination of percentage Alcohol.

The alcoholic content was determined using the formula

(Original gravity – Specific gravity) × 0.129

(IOB, 1977)

3.7.1 Determination of Apparent Fermentability

Apparent fermentability was determined for each of the samples with the aid of stated titrimetric methods of analysis of The Institute of Brewing using the formula:

$$\frac{\text{(Original gravity – Specific gravity)} \times 0.129}{\text{Original gravity}}$$

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3.7.2 Determination of HCN (Cyanide) content of the Samples.

Alkaline Picrate Method (Wang and filled method) was used in determining the HCN contents of the samples; starting from the raw samples to the final beer samples.

Procedures

Steps:

i. **Extraction of cyanide sample:**

About 5g of sample were ground into a paste. The paste was dissolved with 50ml of water in a conical flask for each sample.

The cyanide extraction was allowed to stay overnight.

The extract was filtered, while the filtrates from each sample were used for the determination.

ii. **Preparation of alkaline picrate solution;**

One gramme (1g) of picrate and 5g of sodium carbonate was dissolved in minimally warm water. The volume was made up to 200ml with distilled water.

iii. **Cyanide determination:**

Four milliliters of alkaline picrate were added to 1ml of the sample filterate in a corked test tube and incubated in a water bath for 5mins. After colour development (reddish brown colour), the absorbance of the corked test tube was read in Spectrophotometre at 490nm.

Also, the Absorbance of the blank containing only 1ml distilled water and 4ml alkaline picrate solution was read.

The cyanide contents were extrapolated from a cyanide standard curve.

3.7.3. Preparation of a cyanide standard curve.

Different concentrations of KCN (Potassium Cyanide) solution containing 5 to 50kg cyanide in a 500ml conical flask were prepared. Twenty five milliliters (25mls) of HCL were added to the content. The cyanide standard curve was prepared using the different concentrations.

Note: The above procedures were repeated for determining the cyanide content of the raw samples, wort samples, and beer samples respectively.

3.8.Addition of Caramel

The dark colour of the stout samples were aided by addition of 5ml of the caramel syrup in the stout samples.

The colour intensity was determined using spectrophotometer, (EBC)

3.8.1. Colour Determination

Colour was determined for each of the samples using spectrophotometer.

For accurate results, measurement of the wavelength was shifted to a value of 550nm. That caused (like at dilution) lower absorption values. A correlation factor (f) was used because of the lower absorption of the beer samples at that wavelength.

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$EBC_{Colour} = (E_{550} \times 25) - (E_{770} \times 25) \times f$

IV. RESULTS

The grain analyses values of the sorghum varieties used in this study are shown in the Table 1 below. CSR-02 had higher values in all the parameters checked. Although, there was no significant difference in germinative energy values at $P \leq 0.05$.

Table 1: Grain Analyses Values of the two sorghum varieties (CSR-02 and ICSV400).

Parameters	**Samples**	
	CSR-02	ICSV400
Moisture Content (%)	7.3	6.7
Germinative Capacity (%)	96	93
Germinative Energy (%)	94	93

Table 2: Physicochemical Properties of the sweet worts

S/N	Samples	O.G ($^{o}\rho$)	pH	Viscosity (CP)	Flow Rate (sec.)	Reducing Sugars (mg/l)		Temperature (^{o}C)	HCN (mg/l)
						Maltose	Glucose		
1.	0B1	1046	5.28	1.10	24.67	196.20	120.30	29.00	0.00
2.	5B1	1048	5.28	1.12	25.04	178.30	109.30	29.00	0.00
3.	10B1	1047	5.28	1.12	25.00	178.30	109.30	29.00	0.00
4.	15B1	1047	5.28	1.10	24.72	196.20	120.30	29.00	0.00
5.	20B1	1047	5.25	1.10	24.68	196.20	120.30	29.00	0.02
6.	0B2	1046	5.26	1.10	24.60	196.20	120.30	29.00	0.00
7.	5B2	1048	5.24	1.12	25.02	178.30	109.30	29.00	0.00
8.	10B2	1047	5.30	1.12	25.50	196.20	120.30	29.00	0.00
9.	15B2	1047	5.21	1.11	24.80	196.20	120.30	29.00	0.00
10.	20B2	1047	5.25	1.09	24.50	196.20	120.30	29.00	0.03
11.	Distilled Water	1000	6.90	1.00	23.45	NA	NA	29.00	

KEY:

0B1= Stout beer (0% cassava with CSR-02 var. sorghum)
5B1= Stout beer (5% cassava with CSR-02 var. sorghum)
10B1= Stout beer (10% cassava with CSR-02 var. sorghum)
15B1= Stout beer (15% cassava with CSR-02 var. sorghum)
20B1= Stout beer (20% cassava with CSR-02 var. sorghum)

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0B2= Stout beer (0% cassava with ICSV400 var. sorghum)
5B2= Stout beer (5% cassava with ICSV400 var. sorghum)
10B2= Stout beer (10% cassava with ICSV400 var. sorghum)
15B2= Stout beer (15% cassava with ICSV400 var. sorghum)
20B2= Stout beer (20% cassava with ICSV400 var. sorghum)
Var. = Variety
Cassava variety used: TMS81/00110
NA: Not Available
HCN content of the raw cassava variety = 4.50mg/100g

Table 3: Kinetic Properties of the fermenting worts at day 3

Samples	Parameters				
	Specific gravity ($^{o}\rho$)	pH	%Alcohol	Apparent fermentability (%)	Temperature °C
0B1	1016	4.73	3.87	2.87	23
5B1	1016	4.71	4.13	3.05	23
10B1	1016	4.72	3.99	2.96	23
15B1	1015	4.72	4.13	3.06	23
20B1	1016	4.70	3.99	2.96	23
0B2	1016	4.75	3.87	2.87	23
5B2	1016	4.68	4.13	3.05	23
10B2	1016	4.67	3.99	2.96	23
15B2	1015	4.78	4.13	2.68	23
20B2	1016	4.73	3.99	2.96	23

Table 4: Physiochemical parameters of the stout beers after day 7

Samples	Parameters					
	Final gravity ($^{o}\rho$)	pH	%Alcohol	Apparent fermentability (%)	Temp (^{O}C)	Colour (EBC)
0b1	1013	4.32	4.26	3.15	22	29
50B1	1011	4.31	4.77	3.53	22	29
10B1	1012	4.31	4.52	3.34	22	29
15B1	1012	4.31	4.52	3.34	22	29
20B1	1013	4.32	4.39	3.25	22	29
0B2	1012	4.31	4.39	3.25	22	29
5B2	1012	4.30	4.64	3.44	22	29
10B2	1013	4.31	4.39	3.25	22	29
15B2	1012	4.28	4.52	3.34	22	29
20B2	1012	4.34	4.52	3.34	22	29

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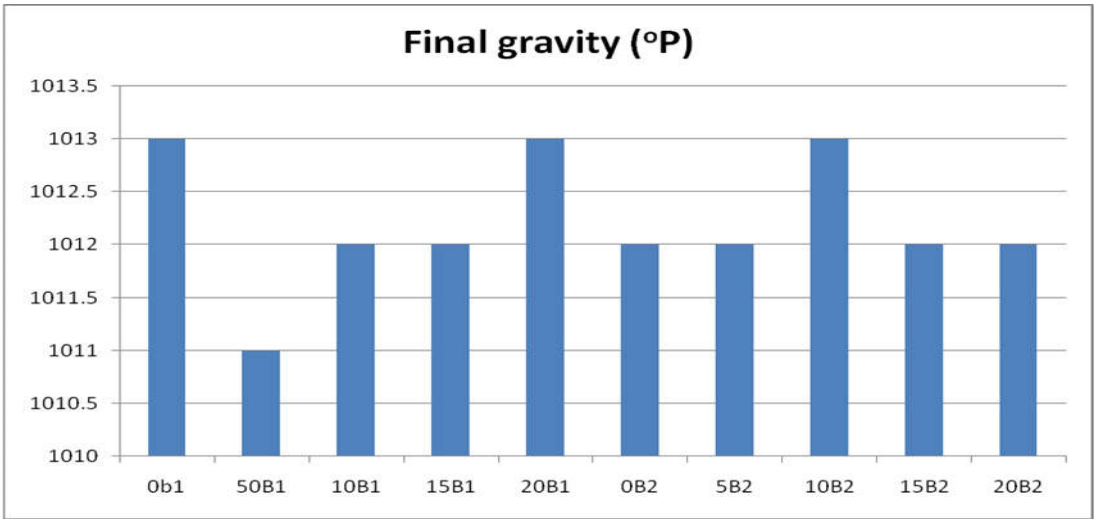

Fig 1: Final Gravity values for Stout Samples.

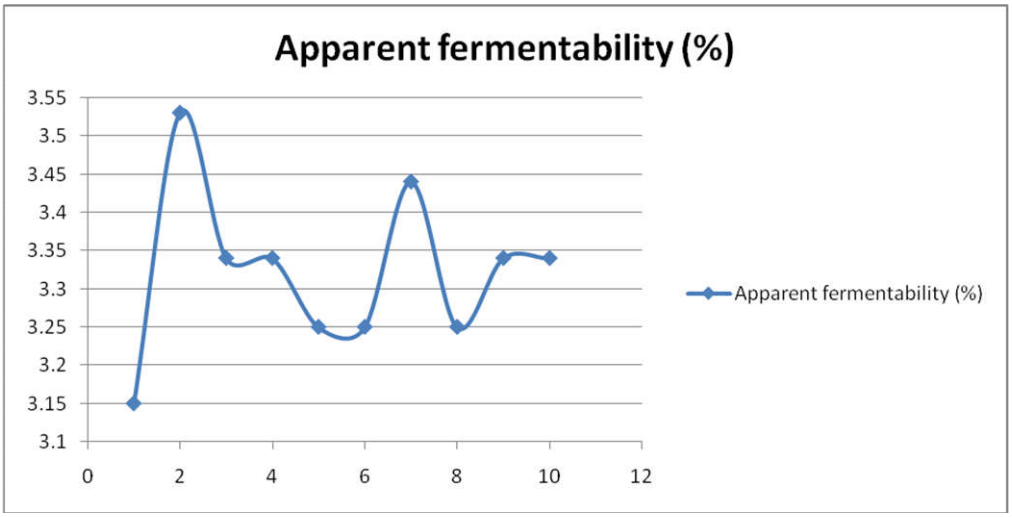

FIG 2: APPARENT FERMENTABILITY VALUES FOR STOUT SAMPLES.

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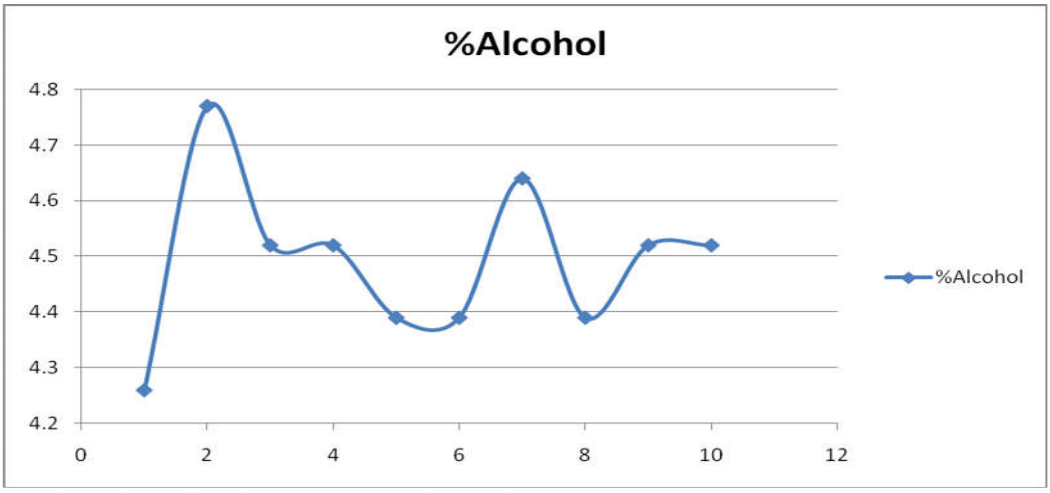

FIG 3: %ALCOHOL VALUES FOR STOUT SAMPLES

TABLE 5: Sensory Evaluation for Dark Stout Beers

	Colour	Taste	Mouth feel	General Acceptability
F-Calculated	1.87	1.93	1.67	1.30
F-Table values	2.87	2.87	2.87	2.87
Least Significant Difference	0.82	0.81	0.78	0.96

V. DISCUSSION

Grain analyses: The results of grain analyses showed in Table 1 where CSR-02 variety of sorghum had 7.3% moisture content, 96% germinative capacity and 94% germinative energy. On the other hand, sorghum variety ICSV-400 had lower values in the same parameters above as 6.7%, 93% and 93% respectively for moisture content, germinative energy and germinative capacity. The recorded values were comparable to the reference values as documented by [6].

Table 2 showed the physiochemical properties of the sweet worts.

The original gravities ranged from 1045-1046°ρ for all the ale samples with the exception of 5.0A2 (sample containing 5% cassava adjunct for ICSV-400 for sorghum variety), which had 1048°ρ at room temperature of 29°C. Wort viscosities were similar at 1.08-1.12 centipoise. Easy flow rate/ fast flow rate and high extract yields were all attributed to the activeness of the exogenous enzymes in conjunction with the high concentrations used. Although, low β-glucan level of the sorghum varieties also contributed to the low wort viscosity [6].

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Mashing procedures helped in drastic reduction of cyanide content of the cassava used. Further wort boiling with hops for 45 minutes aided easy evaporation; even to the insignificant level of the cyanide while majority of the content had initially been removed during steeping of the cassava, knowing fully that pyrussic acid (hydrogen cyanide) is soluble in water.

At the end of infusion mashing system, the reduction in the cyanide level was recorded to be 0.03-0.00mg/100g. However, the FAO/WHO recommendation safe limit of HCN in human food is 50mg/100g.

Extract yield form the mashes gave maltose (178.30-196.20)mg/l, glucose (109.30-120.30)mg/l. The values obtained were normal and appropriate for normal gravity wort according to the specifications of the Institute of Brewing.

4.1. Analysis of the Fermenting Worts

Table 3 showed the kinetic properties of the fermenting worts at day 3 for the samples under investigations. For CSR-02 var. sorghum, the gravity reduced to 1015-1016°ρ. For ICSV-400 var. sorghum, the gravity was 1015-1016°ρ.

There was a reduction in the pH value for the samples which ranged from 4.71-4.80, at the specified temperature of 23°C. The % alcohol appreciated to 3.87-4.13% v/wt due to active fermentation. Apparent fermentability cordially increased to 2.68-3.06% as a sign of activities of yeasts on the sweet wort. At 5% concentration of cassava adjunct for both sorghum varieties, there was highest records for apparent fermentability. Likewise highest % alcohol was recorded for samples with 5% and 15% concentrations respectively.

4.2. Beer Analyses

Table 4 show the physiochemical parameters of the dark stout samples with the final gravity of 1011-1013°ρ, the pH ranged from 4.28-4.34, at a temperature of 22°C. Higher alcoholic contents were recorded for the dark stout (4.26-4.77) %v/wt. Apparent fermentability rose to 3.15-3.53%. It could be deduced that increase in apparent fermentability is increase in % alcohol; on the other hand, decrease or fall in gravity as shown in Tables 2-4. The recorded values were compliance with the works of [7]

V. CONCLUSION

Conclusively, satisfactory beer could be produced from improved varieties of Nigerian sorghum with low cyanide cassava adjunct up to 20% concentration without posing health hazard on the consumers. The two sorghum varieties had similar properties as investigated from this work. Although, there was a slight difference in the grain analysis in terms of germinative energy (93 and 94) %, germinative capacity (93 and 96)%, and moisture content (6.7 and 7.3)%.

These differences had insignificant effect on the yields from the wort samples. Sensory evaluations of the samples showed that they are comparable to each other since there was no significant difference at $P \leq 0.05$ level of significance.

The hazards expected from cyanide could be avoided by appropriate steeping of cassava for a period of 24hrs with occasional changing of steep water half way the steeping period. Reasonable amounts of the pyrussic acids were removed during wort boiling with hops. At the end of fermentation, almost all the cyanide had been

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removed to the lowest level 0.03-0.00mg/l. This is far less than the recommended range of cyanide in any consumable food as stated by FA0/WHO (50mg/100g).

VI. RECOMMEMDATIONS

- Production of dark stout beers using CSR-02 and ICSV400 varieties of sorghum in conjunction with TMS 81/00110 variety of cassava adjunct is recommended to the brewing industries in Nigeria.
- Steeping of cassava is recommended to reduce its cyanide content to the barest minimum. Although, variety of cassava under investigation had acceptable level (below the hazard limit).
- It is recommended that farmers should embark on mass production of these varieties of sorghum likewise the cassava variety to ensure that they are readily available to reduce the high cost of using both local and foreign cereal grains as adjuncts.
- Satisfactory beers could be produced using TMS 81/00110 Variety of Cassava up to 20% without posing any health hazards on the consumers.

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