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PRODUCTION OF ALE WITH SOME VARIETIES OF SORGHUM MALTS USING CASSAVA AS ADJUNCTS AT DIFFERENT LEVELS OF SUBSTITUTION

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Key words: *sorghum, beer, beer production, adjunct, cassava and cyanide*

ABSTRACT: *The sweet sorghum varieties (Sorghum bicolor) were screened for their suitability for beer production using low cyanide cassava TME 419 as adjunct. However the use of cassava as an adjunct in brewing has not received much attention. This work therefore sought to establish the suitability of cassava starch as an adjunct in brewing. The percentages adjunct used were 0%, 5%, 10%, 15% and 20% respectively. The varieties of sorghum used in the course of the practical are; Samsorg 40 (ICSV 400), Samsorg 41 (ICSVIII) and Samsorg 14 (ICSV 8). The germinative capacity of the grains was accessed prior to malting in other to ascertain the physiological state of the grain. Malting commenced with soaking of the grain for 48hours with 2hours air rest, 24hours of casting was observed before the four days germination period after which the grain is sun-dried for 48hours before kilning in the oven at the temperature of 55°C for 24-48hours then both were mashed with the help of exogenous enzymes to obtain worts. The resulting wort were analyzed for original gravity (OG), viscosity and total reducing sugar before boiling with isomerised hops. The carbohydrate level of the grain is good enough for brewing purpose, and the original gravity of wort was 1031-1036 ^{0}p and the wort viscosity is between 1.0- 1.04$_{c}$p. The worts were boiled with hops and then left to ferment with the yeast sccharomyces cerevisiea to produce some liquor with alcoholic content of 3.10 – 4.39%v/v. The HCN content of the sweet worts were in the range of 0.80 – 1.68 mg/L, which disappeared after wort boiling with hops showing that the adjuncts used were low HCN carbohydrates. The sensory evaluation test showed that the resulting liquors were not significantly different in all the parameters tested colour, taste, mouth feel and general acceptability*

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when compared with existing liquor in the shelf. Thus the liquor (ales) from low cyanide cassava adjuncts can be useful in beverage industries like breweries in future in Nigeria.

INTRODUCTION

Worldwide, the brewing industry is registering growth in both volumes and profits year on year. Nigeria is no exception to this global phenomenon. Over the last two years, the biggest brewing industries in Nigeria, Nigerian Breweries Limited (NBL) and Guinness Breweries Limited (GBL) have made enviable strides, both in volume turnover and profit margins. The potential for the industry to grow has become unquestionable. The challenge therefore is how the brewing industry can reduce the cost of production by using low-cost sources of raw materials such as malts and hops. Many brewing industries have taken remedial steps to accommodate the ever-soaring prices of these raw materials by the introduction of low-cost sources of carbohydrate as adjuncts in their recipes. The important role adjuncts play in brewing has been stressed by many authors (Jones, 2006). Nobody envisages a dramatic shift in grist materials used in the current beer market. Some brewers have shifted from sizeable use of adjuncts to grists that are largely composed of premium malted as they are convinced that this offers genuine quality. However, there remains a clear justification for many brewers to use adjunct materials, since they offer unique product attributes such as flavour and colour. The quality characteristics of some of the world's leading global beer brands are heavily based on the adjunct used in their formulation (Goode and Arendt, 2005). The foregoing underpins the employment opportunities this may offer to inhabitants in areas where brewing industries are vibrant and are endowed with cereals that are commonly used as brewing adjuncts.

Brewing adjuncts are materials other than original malts that bring added sources of carbohydrate and protein into wort. Adjuncts have largely been limited to cereals such as corn, rice, sorghum, wheat and barley with little contribution coming from cane sugar. Globally, the use of adjuncts from roots and tubers has however received relatively little attention. The Bavarian purity law (Reinheitsgebot) defines an adjunct as "anything that is not malt, yeast, hops or water". However the definition is much broader today.

The United Kingdom food standards committee interprets adjuncts to be "Any carbohydrate source other than malted barley which contributes sugars to the wort". The latter definitions seem to embrace roots and tubers alike that can provide sources of carbohydrate, which can meet the requirements for brewing. It has been reported (Bamforth, 2003) that when the total cost of beer production is taken into consideration (from raw material purchase and processing through to packaging, sales and taxation), then malts costs in general have been estimated to represent just approximately 3.5% of the total cost.

Therefore, it becomes seeming that the costs of grain represent only a relatively minor contribution to the overall cost of producing

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beer. The foregoing raises the question, why replace malted barley with an unmodified substrate "adjunct"? In less developed countries, malting facilities and malting conditions are quite often less than optimal.

Therefore, because of its lower price, locally made adjuncts can be used to complement malts (Grujic, 1999). Apart from the direct cost advantages of using cheaper raw materials, indirect costs (much greater than the direct costs) can also influence raw material selection. Cassava could also be used as an 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.

The problem of hydrogen cyanide of cassava can be amended by soaking in water for 24 – 48 hr which dissolves the pyrussic acid in water thereby detoxifying it. 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. In Kenya, for example, beer is made from malted grain, (Cege et al., 1999).

Kenyan brewers are therefore encouraged to develop beer from exclusively non-malted grain (mainly raw barley). Likewise in Japan, much lower rate taxation is applied to products containing high adjuncts levels (Happoshu) (Brewers Association of Japan; Shimizu et al., 2002). Therefore, Japan's brewers have a great incentive to brew products from grists containing adjunct levels in excess of 50%.

Likewise, in Nigeria a 1988 government economic decision to ban the importation of malted barley forced local brewers to develop alternative brewing techniques to utilize locally grown sorghum and maize crops (Hallgren, 1995; Little, 1994). Additionally, factors associated with product quality, tradition and consumer product expectations can be the decisive reason to use adjuncts, such as the impact that rice has on flavour, colour and colloidal stability of an American pale lager, or the role that wheat plays in the taste and appearance of a Belgian or German style wheat beer (Delvaux et al., 2001).

Also the use of liquid adjunct materials in today's high gravity brewing culture can increase production output and considerably reduce production costs, whilst contributing to product character. In the past, the main drivers for the usage of brewing adjuncts have been cheaper cost of raw materials, together with opportunities of increasing product output capacity without the necessity of increasing brew house capacities (addition of syrups).

In addition, usage of certain adjuncts has offered the brewer more control over product quality with regard to flavour, colour and colloidal stability. Likewise, governmental political decisions have encouraged the use of adjuncts; hence the manufacture of lager beer from unmalted sorghum and maize in Nigeria, the manufacture of barley beer in Kenya and more recently the manufacture of happoshu in Japan.

There are other drivers, which have the potential to increase adjunct usage. Very recent research efforts (Brauer *et al.,* 2005; NicPhiarais *et al.,* 2005; Wijngaard *et al.,*

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2005; Zarnkow *et al.,* 2005) have concentrated on developing alternative beers and cereal-based beverages with the aim of fulfilling current consumers health needs and expectations. Two such beverages where both traditional and non-traditional adjunct materials will in the future play an important role in their recipe formulations are gluten-free beers and health promoting functional beers.

Statement of Problem

Beer is being sold costly in Nigeria, because barley cereal used is not grown in Nigeria. Locally grown cereals like sorghum could be used for the production of beer in absence of barley cereal. However, the use of cassava as an adjunct in brewing has not received much attention. Cassava adjunct in malted sorghum beer production helps to beef up the sugar content of the worth. This help in the production of beer that will compare to those produced with imported materials and bring the unit cost of the product low.

Aim

This study was to evaluate the suitability of low-cyanide cassava starch as adjunct in the brewing of beer.

Objectives

- To determine the sorghum fermentative qualities
- To produce fermentable wort from sorghum
- To prepare cassava flour from the tuber
- To produce Ale through fermentation with cassava as adjunct

MATERIALS AND METHODS

Sources of Raw Materials

The raw materials used for the study are sorghum (Samsorg 40 (ICSV 400), Samsorg 41 (ICSV III) and Samsorg 14 (ICSV 8) were sourced from Ahmadu Bello University Zaria. The adjunct used is improved variety of cassava (TME 419) obtained from National Roots Crops Research Institute Umudike, Abia State. The yeast used is *saccharomyces Cerevisiae* was supplied by the Department and the hops was sent from International Centre for Brewing and Distilling (ICBD) Herriot Natt University, Edinburgh.

Methods

The methods used includes: the Methods of Analysis of the Institute of Brewing, alkaline Picrate method (Wang and Filled Method) of cyanide determination, the principles of food packaging and beer style guidelines.

Grain Analysis

The germinative energy, germinative capacity and moisture content were determined using the Methods of Analysis of the Institute of Brewing

Malting of Sorghum

Malting processes include the following methods

Cleaning and weighing

↓

Steeping of grains in water for 40hrs with change of water every 8hrs and 2hrs air-rest.

↓

Casting on sac bag for 24hrs

↓

Germination of the grains for about 4 days

↓

Sun drying/ kilning at 45°C for 24hrs

↓

De-rooting and cleaning of malt

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↓
Malt

After removing the rootlets, the grains were milled using a grinder. The grains were milled in a coarse form to aid filtration.

Preparation of Cassava flakes

TME 419 cassava variety obtained from National Root Crop Research Institute Umudike was peeled, thoroughly washed and sliced into uniform chip-sizes. The chips were soaked in distilled water for 24hr; with the steep water changed at 12hr 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°C. The dried flakes were then coarsely milled using a blender to produce cassava flour. This was used as adjunct for this study.

Table 3.1: Malt and Adjunct Mixtures

Malt	Cassava	Total % Adjunct
50.00g	0.0g	0%
47.5g	2.5g	5%
45g	5g	10%
42.5g	7.5g	15%
40g	10g	20%

Mashing Process

The type of mashing used was infusion mashing technique. Five conical flasks were labelled properly and used for mashing. Three hundred and sixty milliliters (360ml) of clean water was added to each of the conical flask. Each of the measured grist samples were added into corresponding mashing flasks containing 360ml of water followed by addition of 2mls of exogenous enzyme (Termamyl, Bio protease, Beta-glucanase, Pro-malt and Bioferm) each. The content of the flasks were stirred properly and covered with foil. The grists mashed in at 25 – 30°C. The temperature was raised in a water bath to 40-45°C and allowed to rest for 30 minutes for proteolysis. It was followed by a gradual increase in temperature from 60-62°C and kept at rest for 1hrs for β-amylase activities. Finally, the temperature was increased from 70-72°C for alpha-amylase activities after which saccharification test was carried out. The temperature was increased to 80°C and heating continued till saccharification was achieved. This was followed by aggressive boiling for about 10 minutes to mash off. The samples were allowed to cool for 30minutes and filtered using muslin cloth to obtain the worts of various concentrations and spent grain.

Wort Analysis

The parameters determined were original gravity (O.G) (°ρ), sugar (°Brix), pH, flow rate (sec), viscosity (cp), temperature (°C) and reducing sugar (glucose and maltose). This was done using the method of the Methods of Analysis of the Institute of Brewing

Wort Boiling with Hops

The wort was poured in a 500ml conical flask and arranged in a pot on a burning gas

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cylinder. Hops (isomerised) was added and boiled for $1^1/_2$ hrs.

Wort Cooling and Filtration

The hopped boiled worts were cooled to room temperature using heat exchanger technique by placing the conical flasks in a big basin containing cold water. The separation of hop debris and the coagulant protein (trub) from the wort was done with the help of sterile muslin cloth and filter.

Preparation of Yeast Inoculum Cum Pitching and Fermentation

The yeast strain, *Saccharomyces cerevisiae* was reconstituted from its dormant state to the active state by weighing 10g of dry yeast 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 vigorously for about 7min 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 inoculum was pitched in each fermenting vessel for the commencement of primary fermentation which lasted 7 days.

Analysis of the Liquor (ALE)

Determination of Percentage Alcohol

The percentage alcohol by weight of each green beer sample was determined by subtracting the final gravity of the beer from the original gravity of wort.

Calculation

% Alcohol = (Original gravity of wort – Final gravity of beer) x 0.129.

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:

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

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:

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 gram (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.

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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 (25ml) of HCL were added to the content. The cyanide standard curve was prepared using the different concentrations.

Addition of Caramel

The dark colour of the ale samples were aided by addition of 3ml of the caramel syrup in the ale samples. The colour intensity was determined using spectrophotometer, (EBC)

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.

EBC Colour= $(E550\times25)- (E770\times25)\times f$

Sensory Evaluation

The liquors were subjected to organoleptic assessment by a 10 member panel. Clean cups were provided for each of the samples, each panelist was requested to taste the samples one after the other and to indicate their degree of likeness or preference for the sample on the questionnaire provided. The samples were evaluated for colour, taste, mouth feel and general acceptability.

Statistical analysis

The experimental data was analyzed using Analysis of Variance (ANOVA) to determine significant difference between the means and these were expressed as mean ± standard deviation (SD). The level of significance was set at $P\leq 0.05$.

RESULTS

Table 1: The Grain Analysis of three varieties of Sorghum.

Parameters	Sample ICSV 400	Sample ICSV III	Sample ICSV 8
Moisture Content (%)	6.7	7.3	8.5
Germinative Capacity (%)	93	84	83
Germinative Energy (%)	93	94	95

Table 2: Beer Analysis of Samsorg ICSV III and adjunct (cassava)

Samples	Original gravity	Final Viscosity	Approximate alcoholic content %
A_1	1038	1005	4.3
A_2	1030	1005	3.3
A_3	1031	1005	3.4

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A_4	1030	1006	3.3
A_5	1034	1005	3.8

Key: A_1: 50g of sorghum malt + 0g of cassava adjunct, A_2: 47.5g of sorghum malt + 2.5g of cassava adjunct, A_3: 45.0g of sorghum malt +5g of cassava adjunct, A_4: 42.5g of sorghum malt + 7.5g of cassava adjunct and A_5: 40g of sorghum malt + 10g of cassava adjunct.

Table 3: Beer Analysis of Samorgh ICSV 8 and Adjunct (cassava)

Samples	Original gravity	Final Viscosity	Approximate alcoholic content %
B_1	1037	1005	4.2
B_2	1032	1006	3.4
B_3	1032	1008	3.2
B_4	1032	1005	3.6
B_5	1032	1004	3.7

Key: B_1: 50g of sorghum malt + Og of cassava adjunct, B_2: 47.5g of sorghum malt + 2.5g of cassava adjunct, B_3: 45.0g of sorghum malt +5g of cassava adjunct, B_4: 42.5g of sorghum malt + 7.5g of cassava adjunct and B_5: 40g of sorghum malt + 10g of cassava adjunct

Table 4: Beer Analysis of Samsorgh ICSV400 and Adjunct (cassava)

Samples	Original gravity	Final Viscosity	Approximate alcoholic content (%)
C_1	1036	1003	4.4
C_2	1032	1005	3.6
C_3	1032	1004	3.6
C_4	1032	1008	3.6
C_5	1031	1005	3.4

Key: C_1: 50g of sorghum malt + Og of cassava adjunct, C_2: 47.5g of sorghum malt + 2.5g of cassava adjunct, C_3: 45.0g of sorghum malt +5g of cassava adjunct, C_4: 42.5g of sorghum malt + 7.5g of cassava adjunct and C_5: 40g of sorghum malt + 10g of cassava adjunct.

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Table 5: Physicochemical Properties of the Sweet Worts

Samples	O.G. (°P)	pH	Viscosity (CP)	Flow Rate (sec)	Reducing (mg/I) Sugar		Temperature (°C)	HCN (Mg/I)
					Glucose	Maltose		
0A	1044	5.21	1.08	24.50	196.20	120.30	29.00	0.80
5A	1046	5.21	1.09	24.50	196.20	120.30	29.00	0.81
10A	1048	5.20	1.12	25.00	178.30	109.30	29.00	0.82
15A	1046	5.20	1.10	24.56	196.20	120.30	29.00	0.83
20A	1045	5.20	1.09	24.40	196.20	120.30	29.00	0.86
0B	1034	5.56	1.10	24.50	196.20	120.30	29.00	0.96
5B	1035	5.55	1.12	24.50	196.20	120.30	29.00	1.32
10B	1031	5.56	1.12	25.00	178.30	109.30	29.00	1.35
15B	1032	5.55	1.10	24.56	196.20	120.30	29.00	1.42
20B	1035	5.59	1.10	24.40	196.20	120.30	29.00	1.45
0C	1031	5.57	1.09	24.86	196.20	120.30	29.00	1.48
5C	1031	5.57	1.10	24.50	196.20	120.30	29.00	1.51
10C	1036	5.55	1.10	25.00	178.30	109.30	29.00	1.54
15C	1035	5.57	1.10	24.56	196.20	120.30	29.00	1.57
20C	1036	5.56	1.10	24.40	196.20	120.30	29.00	1.68
Distilled water	1000	6.90	1.00	23.45	NA	NA	29.00	

KEY: 0A= Ale beer (0% cassava with ICSV400 var. sorghum), 5A= Ale beer (2.5% cassava with ICSV400 var. sorghum), 10A= Ale beer (5.0% cassava with ICSV400 var. sorghum), 15A= Ale beer (7.5% cassava with ICSV400 var. sorghum), 20A= Ale beer (10% cassava with ICSV400 var. sorghum), 0B= Ale beer (0% cassava with ICSVIII var. sorghum), 5B= Ale

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beer (2.5% cassava with ICSVIII var. sorghum), 10B= Ale beer (5.0% cassava with ICSVIII var. sorghum), 15B= Ale beer (7.5% cassava with ICSVIII var. sorghum), 20B= Ale beer (10% cassava with ICSVIII var. sorghum), 0C= Ale beer (0% cassava with ICSV8 var. sorghum), 5C= Ale beer (2.5% cassava with ICSV8 var. sorghum), 10C= Ale beer (5.0% cassava with ICSV8 var. sorghum), 15C= Ale beer (7.5% cassava with ICSV8 var. sorghum), 20C= Ale beer (10% cassava with ICSV8 var. sorghum); Var. = Cassava variety used: TME 419. NA: Not Available HCN content of the raw cassava variety = 4.50mg/100g.

Table 6: Kinetic Properties of Fermenting Worts at Day 3 (Main ALE Samples) Parameters

Samples	Specific gravity (°P)	pH	% Alcohol	Apparent fermentability (%)	Temperature (°C)
0A	1017	4.72	3.61	2.68	23
5A	1017	4.72	3.79	2.77	23
10A	1016	4.70	3.87	2.87	23
15A	1016	4.71	3.87	2.87	23
20A	1016	4.71	3.87	2.87	23
0B	1011	4.54	3.61	2.68	23
5B	1011	4.56	3.79	2.77	23
10B	1012	4.57	3.87	2.87	23
15B	1013	4.60	3.87	2.87	23
20B	1012	4.62	3.87	2.87	23
0C	1011	5.57	3.10	1.94	23
5C	1011	5.57	3.10	1.75	23
10C	1012	5.56	3.87	2.41	23
15C	1013	5.57	3.74	2.32	23
20C	1012	5.56	3.61	2.32	23

Table 7: Physicochemical Parameters of the Ale Beers After Day 7 (Primary Fermentation) Parameters

Samples	Final gravity (°P)	pH	% Alcohol	Apparent Fermentability (%)	Temp (°C)	Colour (EBC)
0A	1015	4.40	3.87	2.87	22	27
5A	1014	4.40	4.12	3.06	22	27
10A	1014	4.51	4.13	3.06	22	27

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15A	1014	4.42	4.13	3.06	22	27
20A	1014	4.50	4.13	3.06	22	27
0B	1011	4.51	4.39	2.21	22	27
5B	1011	4.50	4.12	2.96	22	27
10B	1012	4.43	3.99	3.02	22	27
15B	1013	4.41	4.13	3.05	22	27
20B	1012	4.42	4.39	3.04	22	27
0C	1011	4.50	3.99	3.06	22	27
5C	1013	4.48	3.89	2.87	22	27
10C	1011	4.51	4.13	3.06	22	27
15C	1011	4.50	4.13	2.96	22	27
20C	1012	4.51	4.39	2.21	22	27

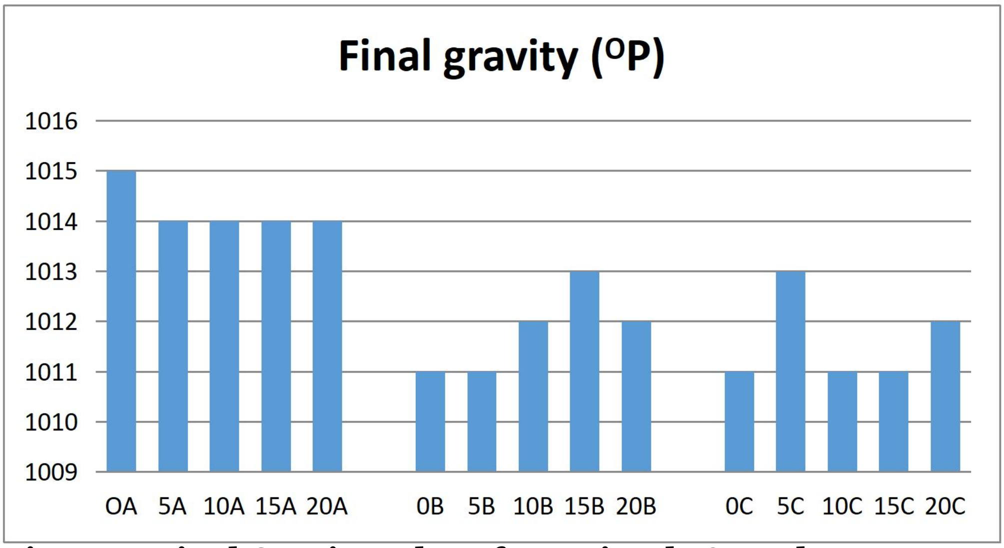

Figure 1: Final Gravity values for Main Ale Samples

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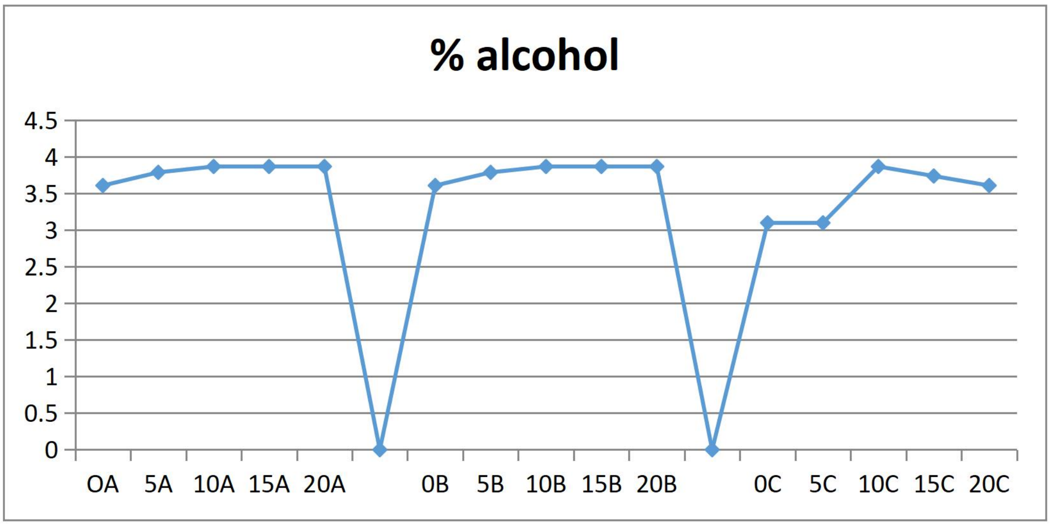

Figure 2: Alcohol values for Main Ale Samples

Table 8: Sensory Evaluation for Ale beers

	Colour	**Taste**	**Mouth feel**	**General acceptability**
F-Calculated	0.77	1.61	0.10	0.62
F-Table values	2.87	2.87	2.87	2.87
Least Significant Difference	0.82	0.81	0.78	0.96

The sensory evaluation test showed no significant difference since all the calculated values (0.10-1.61) are less than (≤) the table values (2.87) at 5% (0.05) level of significance. Therefore, the Null Hypothesis (Ho) was accepted.

Discussion

This present studies has shown that the results of grain analyses of ICSV III variety of sorghum had 8.5% moisture content, 83% germinative capacity and 95% germinative energy (Table 1). On the other hand, sorghum variety ICSV-400 and ICSV 8 had lower values as 6.7%, 93% and 93% respectively for moisture content, germinative energy and germinative capacity (Table 1).

The recorded values were similar to the reference values as documented by Ogu et al. Works by different scientists had shown that physiologically, sorghum malt contains significantly lower levels of salt soluble proteins which influence some of the biochemical modifications that take place during malting (Okolo and Ezeagu, 1996).

Furthermore, the possibility of enhancing the enzyme activity through improvement in malting methods such as alkaline steep and air rest cycle is necessary.

Table 2 showed the physiochemical characteristics of the sweet worts. The original gravities ranged from 1045-1046oP for all the ale samples with the exception of 5.0A2

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(sample containing 5% cassava adjunct for ICSV-400 for sorghum variety), which had 10480P at room temperature of 290C. 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 ß-glucan level of the sorghum varieties also contributed to the low wort viscosity. Mashing procedures helped in drastic reduction of cyanide content of the cassava used.
Further wort boiling with hops for 45 min 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.
Table 3 showed the kinetic properties of the fermenting worts at day 3 for the samples under investigations. For ICSV III varierty of sorghum, the gravity reduced to 1016-10170P same for ICSV-400 var. sorghum; the gravity was 1016-10170P of ale.
There was a reduction in the pH value for the samples which ranged from 4.70-4.80, at the specified temperature of 230C. The % alcohol appreciated to 3.61-3.99% v/wt due to active fermentation. Apparent fermentability cordially increased to 2.68-2.96% 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. In addition, beers were produced after primary fermentation that lasted for 5 days, the results of green beer analysis were shown (Table 4.). The final gravity ranged from 1014-10150P for the two varieties of sorghum under investigation. An increase in % alcohol (3.87-4.39)% v/wt brought about gradual reduction in pH which ranged between 4.40-4.51. Apparent fermentability (2.21-3.24) % was favoured by suitable temperature of fermentation (220C).
The physiochemical conditions affecting fermentation rate (like pH, temperature, yeast availability, etc) were optimally available. The values obtained agreed with the recorded values. The organoleptic test carried out on the beer produced for colour, taste and general acceptability at P= 0.05. The results obtained are available on ANOVA table as shown in the Table 18-33 above.
There were significant effect on the following beer produced: Sample A colour, mouth feel, taste and general acceptability. Sample B colour, mouth feel, taste and general acceptability. Sample C mouth feel, taste and general acceptability.

Conclusion

In conclusion, satisfactory Ale 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 three sorghum varieties had similar properties as investigated from this work. Although, there was a minor difference in the grain analysis in terms of germinative energy (93, 94 and 95)%,

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germinative capacity (83, 84 and 93)%, and moisture content (6.7 and 7.3 and 8.5)%. These differences had insignificant effect on the yields from both worts. Sensory evaluations of the samples showed that they are comparable to each other since there was no significant difference at P=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. After fermentation, almost all the cyanide had been removed to the lowest level 0.03-0.00mg/l. This was lesser than the recommended range of cyanide in any consumable food (10mg/kg).

Recommendations

Production of ale using ICSV III, ICSV 8 and ICSV400 varieties of sorghum in conjunction with TMS 419 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 commence 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 Ale could be produced using TMS 419 Variety of Cassava up to 20% without posing any health hazards on the consumers.

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