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Comparative Study of Experimental Beers Brewed from Millet, Sorghum and Barley Malts

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Lager beers brewed from millet and sorghum malts were darker in colour and had a different flavour from beer brewed with barley malt. These qualities, which seem to be inherent properties of millet and sorghum, may be associated with the production of opaque beers from these cereals. Millet beer had a better foam (head) retention than sorghum beer, but the alcohol content of sorghum beer was higher than that of millet beer. In all the parameters assessed, barley beer outscored the beers brewed from millet and sorghum.

INTRODUCTION

Beer has been defined as a beverage obtained from alcoholic fermentation of a malted cereal, usually barley malt, with or without starchy materials and to which hops have been added.[1] Hoyrup[2] defined lager beer as a brew from barley malt which is stored for a period of time for clarification and maturing, but beer is also considered as the generic term for all malt liquors variously called beer, ale, stout, porter and lager.[3] The first two definitions indicate the general use of cereal malts in brewing practice, but the high enzyme level of barley malt, as well as extensive research studies conducted on barley,[4,5] has earned barley a unique position as the preferred cereal for brewing beer.

Barley, a temperate crop, used to be imported into Nigeria from Europe. A ban in 1988 on the import of barley malt has resulted in sorghum and maize being used as the only cereals for local beer production. Early studies by Skinner,[6] Okafor and Aniche[7,8] suggested that lager beers could be brewed from sorghum. Similar studies on beer production using a Nigerian millet variety, *Pennisetum maiwa*, were also reported.[9]

The emphasis on the use of local cereals such as millet and sorghum for brewing lager beer did not take cognizance of the fact that breweries, like other food industries, are conservative and will strongly resist change.

In this paper, comparative assessments (sensory evaluation) of laboratory-brewed lager beers using millet, sorghum and barley malts, as well as lager beers brewed from three local breweries prior to the effective substitution of barley malt in Nigeria, are reported.

MATERIALS AND METHODS

Raw materials

Barley malt samples were kindly supplied by the Olympic Company Limited, Abagana. Four kilo-

grammes each of millet variety *Pennisetum maiwa* and sorghum variety *Sorghum bicolor* were malted as described earlier,[10] except that malting additives were not applied at steep out.

Mashing procedure
A modified upward-infusion mashing method was employed in wort production from millet, sorghum and barley malts for uniformity in analysing the results, since no standard, commercial mashing procedure has been developed when brewing from malted sorghum and millet. These cereals are used commercially as unmalted cereals with enzymes added to effect the breakdown of starch, etc.

Millet, sorghum and barley malt samples were milled to different particle sizes using a Thomas–Wiley mill. Equal weights (~ 2·4 kg) of each sample were divided into two parts. Each half (~ 1·2 kg) was separately mixed with 4·8 litres of tap water (43°C) in aluminium pots to obtain two sets of millet, sorghum and barley mashes. The temperature in one set of the mash was raised to 53°C, then to 63°C in 15 min and then allowed a rest period of 10 min at 63°C, after which the temperature was raised to 100°C. The hot millet, sorghum and barley mashes were transferred to their other respective mashes held at 43°C, with a resultant increase in temperature to 63° ± 1°C. The combined mashes were held at 63° ± 1°C for 30 min, after which the temperatures were raised to 73° ± 1°C, held for 25 min at that temperature and then mashed off at 78°C.

Wort production from breweries
The mashing procedure described above for wort production is the method employed by one of the local breweries.

Mash boiling with hops
The hops added to the mash (without filtration) and the quantity calculated according to the American Society of Brewing Chemists' (ASBC) recommendations[11] (0·65% of total weight of malt) resulted in bulky, hot breaks, and a fast wort filtration after 2 h of boiling. The hops were added in a two-stage process in equal amounts (at the beginning and at the end of the boiling process) after which the mash was filtered; first through a muslin cloth, and finally through a cotton gauze. The spargings from the spent grains (water temperature; 80°C) were added to their respective worts to obtain specific gravities of 1·040, 1·042 and 1·044, respectively for millet, sorghum and barley worts.

Fermentation studies
The wort produced (approximately 6 litres in each case) was pitched with *Saccharomyces uvarum*, supplied by a local brewery at 11°C (pitching rate; 3 g fresh weight per litre of wort) after propagating the yeast in yeast-extract dextrose broth.[12] The green beer was lagered for 21 days at 5°C in a thermostat-refrigerator for maturing after a 5 day primary fermentation.

Beer analysis
The beer was analysed for pH, colour, specific gravity and alcohol, following the Institute of Brewing (IOB)[13] and Association of Official Analytical Chemists (AOAC)[14] recommendations.

Sensory evaluation
A total of 20 tasters evaluated the beers for comparative analyses. The parameters used for sensory evaluation were colour, foam, bitterness and flavour, and the scores based on a scale of 1–5.

RESULTS AND DISCUSSION

The properties of worts obtained after mashing the different cereal malts are presented in Table 1. Barley-derived wort gave higher values for extract (11°P) and attenuation limit (88·0%) and the filtration rate was very fast. For millet and sorghum-derived worts, the respective values for extract (10·0°P and 10·5°P) and attenuation limit (66·8% and 71·2%) obtained after mashing were lower than those of barley wort. These differences are

Table 1. Properties of the worts obtained from millet, sorghum and barley malts

Parameters	*Millet wort*	*Sorghum wort*	*Barley wort*
Colour (°EBC)	10·5	9·5	7·0
pH	5·4	5·4	5·5
Specific gravity (20°C/20°C)	1·040	1·042	1·044
Extract (°P)	10·0	10·5	11·0
Iodine colour	+ve	+ve	+ve
Attenuation limit (%)	66·8	71·2	88·0
Filtration rate (ml min^{-1})	Fast	Fast	Very fast

due mainly to the varying levels of hydrolytic enzymes of the different cereal malts for which barley is quite unique. The poor filtration rates recorded for millet and sorghum were due to low β-glucanase developed in these cereals during malting, even though it has been reported that this enzyme is developed more in millet than in sorghum malts.[15,16]

In Table 2, the fermentation profiles of the laboratory worts from millet, sorghum and barley malts are compared with those from a local brewery producing beer with barley malt during the transition period prior to complete switching over to sorghum and maize for beer production. The extract yield from the brewery (12°P) was higher than that obtained in the laboratory barley mash (11°P) due probably to inadequate control of the brewing parameters in the laboratory. Similar fermentation patterns were observed with all worts and they agreed with the properties reported for barley-wort fermentations.[17] In all the cases, fermentation was complete after 5 days, with some lactic fermentation resulting in a slight sour taste of the beers.

The data for the properties of the green beer from the different cereal malts are summarized in Table 3. The barley malt beer yielded the highest alcohol concentration (3·65 wt %) followed by sorghum beer (3·09 wt %) and then millet beer (2·55 wt %) for similar falls in specific gravity. It is possible that the low level of alcohol production from millet is due to the small size of the endosperm available for extract production, even though equal weights of cereals were used in this study. It is not quite clear why high colour values were obtained for millet and sorghum, but it is possible that it is a property of millet and sorghum grains (probably due to high tannins) which are also involved in the production of opaque beers from these cereals.[6–9] Okafor and Aniche reported that it is the technique of production that is responsible for obtaining opaque beers.[8]

The sensory evaluation of the laboratory-brewed lager beers are presented in Table 4, while Table 5 summarizes the values of similar evaluations obtained from commercial beers. In all the parameters assessed, laboratory-brewed barley beers outscored those of millet and sorghum beers (Table 4). The scores obtained from sorghum beers were better than those from millet beers except for foam (head) retention for which millet beer was rated up to 75%, compared with 64·8% for sorghum beer. However, while this value may be typical for sorghum,[18–27] the value for millet may not be representative and further work is required.

Both millet and sorghum beers had low scores for colour (62·7% and 77·6%, respectively) compared with barley beer (87·5%) confirming the assertion that millet and sorghum produce opaque

Table 3. Properties of the green beer from the millet, sorghum and barley malts

Variables	*Millet beer*	*Sorghum beer*	*Barley beer*
Specific gravity (20°C/20°C)	1·012	1·015	1·017
pH	4·4	4·0	4·6
Total acidity (as lactic acid %)	0·16	0·14	0·13
Alcohol (wt %)	2·55	3·09	3·65
Colour (°EBC)	11·0	10·5	8·0
Iodine reaction	Yellowish	Yellowish	Yellowish
Extract of original wort (°P)	10·0	10·5	11·0
Real extract (°P)	3·04	3·75	4·25

Table 2. Fermentation profiles of worts derived from millet, sorghum and barley malts

Fermentation period (days)	*Barley wort**		*pH profile*	*Millet wort†*		*pH profile*	*Sorghum wort†*		*pH profile*	*Barley wort†*		*pH profile*
	SG profile	*Extract drop (°P)*		*SG profile*	*Extract drop (°P)*		*SG profile*	*Extract drop (°P)*		*SG profile*	*Extract drop (°P)*	
0	1048	12·0	5·4	1040	10·0	5·4	1042	10·5	5·4	1044	11·0	5·5
1	1036	9·0	5·3	1030	7·5	4·9	1035	8·75	5·0	1034	8·5	5·1
2	1028	7·0	5·1	1023	5·75	4·7	1030	7·5	4·8	1024	6·0	4·9
3	1021	5·25	4·9	1018	4·75	4·6	1025	6·25	4·6	1021	5·25	4·8
4	1016	4·0	4·5	1015	3·75	4·5	1020	5·0	4·4	1019	4·75	4·7
5	1014	3·5	4·3	1012	3·04	4·4	1015	3·75	4·0	1017	4·25	4·6

*Fermentation profile data from a brewery.
†Fermentation profile data from laboratory brews.

Table 4. Sensory evaluation of the laboratory-brewed beers from millet, sorghum and barley malts

Parameters	*No. of tasters*			*Rank total*			*Percentage acceptance (%)*		
	*MB**	*SB†*	*BB‡*	*MB**	*SB†*	*BB‡*	*MB**	*SB†*	*BB‡*
Colour	20	20	19	51(32)	58(45)	64(56)	62·7	77·6	87·5
Foam	20	19	20	64(48)	54(35)	68(58)	75·0	64·8	85·3
Bitterness	20	19	19	46(26)	52(32)	60(45)	56·5	61·5	75·0
Flavour	20	20	20	39(17)	44(30)	62(56)	43·6	68·2	90·3

*MB, millet beer; †SB, sorghum beer; ‡BB, barley beer. Score is based on a scale of 1–5. Values in brackets are rank total (3–5) that accepted the beer as fair, good and very good.

Table 5. Sensory evaluation of commercial beer samples brewed by three different breweries using barley malt

Parameters	*No. of tasters*			*Rank total*			*Percentage acceptance (%)*		
	$*B_1$	*$^{\dagger}B_2$*	*$^{\ddagger}B_3$*	*$*B_1$*	*$^{\dagger}B_2$*	*$^{\ddagger}B_3$*	*$*B_1$*	*$^{\dagger}B_2$*	*$^{\ddagger}B_3$*
Colour	19	19	20	81(79)	68(66)	77(75)	97·5	97·1	97·4
Foam	19	20	19	70(67)	70(65)	76(76)	95·7	92·9	100
Bitterness	18	19	19	63(60)	64(62)	74(72)	95·2	96·9	97·3
Flavour	19	20	20	73(72)	69(68)	73(67)	98·6	98·6	91·8

*B_1, brewery one; †B_2, brewery two; ‡B_3, brewery three. Score is based on a scale of 1–5. Values in brackets are rank total (3–5) that accepted the beer as fair, good and very good.

beers which may be a property of the cereal and not due to the production technique. The poor flavour recorded for millet (43·6%) may also be a property of this cereal. The bitterness values obtained for the various beers may be a result of the hopping method, which may be adjusted during the brewing process when different grains are used.

The three commercial beers, brewed from barley, scored very high on all the parameters (Table 5) confirming the superiority of barley to millet and sorghum, as well as the skill of the tasters.

CONCLUSION

In Nigeria today, sorghum and maize (unmalted) are being used by all the functional breweries to produce large quantities of beers, even though it is with the aid of external enzymes. Some of the breweries have perfected beer production from these cereal grains, while others are still reporting problems, especially with flavour. The major problem encountered by almost all the breweries is poor foam (head) retention, which collapses very fast.

Our further studies confirm the foam retention potentials of millet and it is possible that a brew would be obtained from a combined mashing of sorghum and millet, which would be completely acceptable to consumers.

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