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Sugars Content of Pearl Millet as Diversed among Cultivars and Affected by Germination

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Abstract: Ten pearl millet (*Pennisetum americanum*) cultivars were germinated along with one sorghum cultivar for 96 h. Various sugars were determined at intervals of 24 h over a total of 96 h. The germinated grains were dried and polished. The polished pearl millet malt was milled, defatted and the sugars extracted with 80% ethanol for 6 h. The quantities of individual soluble sugars were estimated with high performance liquid chromatography. The sucrose, maltose, glucose and fructose contents of the grains increased significantly ($p < 0.05$) with increase in germination time. The maltose content of unmalted LCRI-IC 9701, ICMV-IS 94208, GWAGWA, G.1-14.9, GB 8735 and GI-297-1 was not detected. Most of the grains reached their various optimum sugar levels at 72 h of germination. SOSAT C-88 had higher ($p < 0.05$) various sugar levels, followed by ZANGO, G.I-14.9 and G.I-297.1. Therefore, these pearl millet cultivars have been found to be good source of sucrose, maltose, glucose and fructose.

Key words: malting, maltose, pearl millet, sorghum, sugar

Pearl millet is an important cereal grain for people living in the semi-arid tropics of India and Africa.[1)] The grain can be processed into many products one of which is malt. Malting of pearl millet lowers the tannin content, thereby improving enzyme activity.[2)] It also improves *in vitro*-starch digestibility[3–5)] due to the activation of amylases that occurs during germination.[6)] As a result of amylase activities, there is increase in the concentration of total soluble sugars, both reducing and non-reducing sugars (major products of amylase activities) in malted pearl millet grains.[2,7)]

Generally, a lot of enzymes are either synthesized or are set free during germination. As a result, malted grains are very important and could be used as brewer malt, distillers' malt, malt sugars and malt flour which are used in preparation of beer, breakfast cereals, bakery products, pharmaceuticals, infant foods, weaning foods and as enzyme rich flours.[8)]

The various sugars that are obtained in malted pearl millet grain may be one of the factors imparting taste and flavor to the food products and may play a significant role in determining the end use. Hence, there is the need to evaluate the quantity of these sugars and determine the optimum germination time and cultivars that could give the maximum yield. The most frequently studied sugars of cereal grains are glucose, fructose, sucrose, maltose and lactose.[9)] This information could serve as a guide in screening the pearl millet cultivars to obtain those that are most suitable for producing glucose, fructose, sucrose and maltose.

Sugars of unmalted sorghum and pearl millet have been reported by other scientists around the world[10,11)] but such information is scanty in this environment, especially on the effect of germination time on the quantity of these sugars. Therefore, the objective of this study was to determine the effect of germination time and cultivar on the concentration of various sugars of pearl millet, and obtain cultivars that are suitable for producing glucose, fructose, sucrose and maltose.

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MATERIALS AND METHODS

Ten pearl millet cultivars. SOSAT C-88, ZANGO, EX-BORNO, LCRI-IC 9701, ICMV-IS 94206, ICMV-IS 94208, GWAGWA, G.I.-14.9, GB 8735, G.I-297-1 and a sorghum cultivar (control) were obtained from Lake Chad Research Institute, Maiduguri. Sorghum was used as control because it has been malted for centuries and the malt is used for the production of baby food and traditional alcoholic and nonalcoholic beverages.[12)] Chemicals and reagents were obtained from recognized distributors and were of analytical grade.

Sample preparation and steeping. The cereal grains were cleaned manually of broken seeds, dust and other extraneous materials. Experimental samples were taken using the quartering procedures of Lees.[13)] The cleaned grains were steeped in thrice quantity of water for 12 h with 1 h air rest after 6 h of steeping. For each air rest, the steep water was changed. After steeping, the grains were sterilized by soaking in a solution of 1% sodium hypochlorite for 20 min before it was drained prior to germination.[14)]

The steeped grains were germinated as described by Obizoba and Atii.[2)] After germination, the seeds were dried in Gallenkamp oven (BS Model OV-160, England) at 50°C for 24 h. Rootlets and shoots of the dried malted grains were separated from the kernels by rubbing the grain in a sieve of coarse mesh size (1.40 mm) which allowed the rootlets and shoots to escape but retained the

kernels.[14]

The ungerminated grains and the polished malt were milled with a hammer mill (Gibbond Electric, Woodrolfe road Tollesbury Essex, UK) to pass through 1 mm mesh size screen into fine flour for determination of various sugars.

Determination of sugars. The flours of defatted malted and unmalted pearl millet were extracted with 80% ethanol for 6 h. The quantity of each sugar was estimated with high performance liquid chromatography (HPLC) as described by Folkes and Crane.[9] The analysis was carried out at the Zonal Laboratory of the National Agency for Food and Drug Administration (NAFDAC), Maiduguri, Nigeria. The standard sugar peaks were obtained by eluting known quantities of each of the standard sugars (sucrose, maltose, glucose and fructose) through the column. A mixture of these sugar solutions was also applied and eluted through the column in order to compare the elution profiles obtained with the individual standard sugars. The sugars in the sample were identified by reference to the elution patterns of standard sugars. For quantitative estimation of individual sugars, each fraction was plotted and the area of the peak was compared with the area of the respective standards.[11] These processes were automatically analyzed and the results were read on the monitor of the computer system attached to the HPLC. The analysis was replicated three times.

Statistical analysis. The mean and standard deviation of triplicate determinations of the individual sugars were calculated for the ten pearl millet cultivars and one sorghum cultivar (control) for the periods of germination. Analysis of variance from a 11×6 factorial experiment in a Randomized Complete Block design was used to determine differences among periods of germination and among cultivars. In each case, means were compared using Duncan Multiple Range Test with statistic computer program, version 4.1, USA.[15,16]

RESULTS AND DISCUSSION

Sucrose.

The sucrose content of malted and unmalted pearl millet cultivars and sorghum cultivar is presented in Table 1. The sucrose content of unmalted grains ranged from 1.32 to 2.02%. Sorghum had the highest ($p<0.05$) sucrose content and among the pearl millet cultivars, SOSAT C-88 had the highest. The sucrose content of most of the grains increased rapidly ($p<0.05$) from 0 to 48 h of germination and reached their peak at 72 h. The sucrose content of the malted grains at 72 h was not different ($p>0.05$) from those at 96 h of germination.

There were wide variations of sucrose content among the grains. The values ranged from 1.35 to 2.05%, 1.44 to 2.09, 1.58 to 2.68, 1.61 to 2.70 and 1.61 to 2.70 at 0, 24, 48, 72 and 96 h of germination, respectively.

The sucrose content of the unmalted grains were within the range reported by Subramanian and co-authors[10,11] that sucrose is the most predominant sugar and form about 60–68% of the total sugars in millet grains. The sucrose content increased in the process of germination. This could be as a result of hydrolytic enzymes, which are synthesized during germination and increase as germination time progresses.[17] Although the sucrose content of unmalted sorghum was highest, SOSAT C-88 had the highest ($p<0.05$) at 72 h of germination. Furthermore, the increase of sucrose content in the course of germination was more significant in pearl millet cultivars than the sorghum used as a control. This could be associated with the level of amylase activity synthesized during germination and those initially present in the unmalted grains. Sorghum malt does not contain β-amylase activity or if it does, is in a very low amount.[18] Since β-amylase activity is the key enzyme in starch hydrolysis to produce sugars, the slow increase of sucrose in sorghum during germination could be attributed to this enzyme activity.

Maltose.

The maltose content of the unmalted and malted pearl millet cultivars and sorghum cultivar is presented in Table 2. Unmalted sorghum cultivar (ICSV 111) had the highest maltose content of 0.06%. The maltose was not detected in 6 unmalted pearl millet cultivars; LCRI-IC 9701, ICMV-Is 94208, GWAGWA, G.I-14.9, GB 8735 and G.I-297-1. It has been previously reported that un-

Table 1. The sucrose content (%) of pearl millet and sorghum as affected by germination time and cultivar.*

Material	Unmalted	Germination time (h)				
		0^f	24	48	72	96
Pearl millet cultivars						
SOSAT C-88	$1.39\pm0.11^{d\,z}$	$1.46\pm0.06^{c\,z}$	$1.55\pm0.08^{d\,z}$	$2.68\pm0.06^{a\,w}$	$2.70\pm0.02^{a\,x}$	$2.70\pm0.04^{a\,x}$
ZANGO	$1.43\pm0.15^{c\,z}$	$1.50\pm0.04^{d\,z}$	$1.59\pm0.05^{c\,z}$	$2.03\pm0.03^{b\,xy}$	$2.23\pm0.04^{a\,y}$	$2.24\pm0.05^{a\,y}$
EX-BORNO	$1.51\pm0.03^{d\,z}$	$1.58\pm0.09^{c\,z}$	$1.66\pm0.07^{d\,z}$	$1.78\pm0.07^{a\,yz}$	$1.80\pm0.07^{a\,z}$	$1.81\pm0.11^{a\,z}$
LCRI-IC 9701	$1.32\pm0.14^{d\,z}$	$1.35\pm0.04^{d\,z}$	$1.44\pm0.05^{c\,z}$	$1.58\pm0.06^{b\,z}$	$1.61\pm0.02^{a\,z}$	$1.61\pm0.03^{a\,z}$
ICMV-IS 94206	$1.80\pm0.06^{d\,y}$	$1.88\pm0.03^{c\,y}$	$1.96\pm0.08^{d\,y}$	$2.08\pm0.06^{a\,x}$	$2.10\pm0.07^{a\,y}$	$2.11\pm0.10^{a\,y}$
ICMV-IS 94208	$1.33\pm0.04^{c\,z}$	$1.38\pm0.08^{d\,z}$	$1.46\pm0.06^{c\,z}$	$1.62\pm0.03^{b\,z}$	$1.67\pm0.04^{a\,z}$	$1.68\pm0.02^{a\,z}$
GWAGWA	$1.48\pm0.28^{c\,z}$	$1.56\pm0.07^{d\,z}$	$1.63\pm0.0^{c\,z}$	$1.73\pm0.02^{b\,z}$	$1.76\pm0.02^{a\,z}$	$1.78\pm0.05^{a\,z}$
G.I.-14.9	$1.81\pm0.14^{c\,y}$	$1.88\pm0.14^{d\,y}$	$1.95\pm0.01^{c\,y}$	$2.07\pm0.06^{b\,x}$	$2.11\pm0.07^{a\,y}$	$2.12\pm0.04^{a\,y}$
GB. 8735	$1.35\pm0.06^{c\,z}$	$1.42\pm0.03^{d\,z}$	$1.51\pm0.01^{c\,z}$	$2.03\pm0.01^{b\,xy}$	$2.08\pm0.04^{a\,y}$	$2.09\pm0.08^{a\,y}$
G.I-297-1	$1.84\pm0.17^{c\,y}$	$1.93\pm0.03^{d\,y}$	$1.99\pm0.10^{c\,y}$	$2.12\pm0.02^{b\,x}$	$2.16\pm0.05^{a\,y}$	$2.18\pm0.08^{a\,y}$
Sorghum cultivar						
ICSV 111	$2.02\pm0.05^{c\,y}$	$2.05\pm0.14^{c\,y}$	$2.09\pm.0.12^{d\,y}$	$2.11\pm0.16^{b\,x}$	$2.19\pm0.14^{a\,y}$	$2.19\pm0.13^{a\,y}$

*Mean $\pm$ SD of triplicate germinations. $^{a-c}$Means within each row not followed by the same superscript are significantly different ($p<0.05$). $^{w-z}$Means within each column not followed by the same superscript are significantly different ($p<0.05$). 0^f h is the time after steeping and before germination.

malted millet do not contain maltose.[11,19] However, SOSAT C-88, ZANGO, EX-BORNO and ICMV-IS 94206 had 0.01% maltose content in this study. This could be as a result of varietal differences and cultural conditions of the land where these millet cultivars were cultivated. The maltose content of unmalted sorghum cultivar (ICSV 111) obtained in this study was within the range (0.06–0.78%) reported by Neucere and Sumrell[20] but lower than the range (0.92 to 3.90%) reported by Subramanian and co-authors.[10] The maltose content of the grains increased ($p<0.05$) in the course of germination. Comparison of the maltose content of grains at different levels of germination time showed that the values ranged from 0.01 to 0.07%, 0.03 to 0.10, 0.04 to 0.18, 0.06 to 0.18 and 0.07 to 0.19 at 0, 24, 48, 72 and 96 h of germination, respectively.

The maltose content of SOSAT C-88, ZANGO, EX-BORNO and ICMV-IS 94206 did not show any significant ($p>0.05$) difference between the unmalted grain and at 0 h of germination. However, the maltose content increased significantly from the 0 h to 48 h of germination, with the peak at 72 h. The other cultivars had no detectable maltose in their unmalted grains but noticeable quantity of maltose emerged at 0 h of germination and increased significantly ($p<0.05$) up to 72 h. Sorghum had comparatively higher ($p<0.05$) maltose in the unmalted grain and the maltose content increased with increase in germination time.

Glucose.

Glucose content of the unmalted and malted grains germinated up to 96 h is shown in Table 3. The glucose content of unmalted and malted at 0 h of germination for SOSAT C-88, ZANGO, LCRI-IC 9701, ICMV-IS 94206 and G.1-297-1 did not differ significantly ($p>0.05$). On the other hand, glucose content of unmalted and malted at 0 h of germination for EX-BORNO, ICMV-IS 94208, GWAGWA, G.1-14.9, GB 8735 and ICSV 111 differed significantly ($p<0.05$). Notwithstanding, the glucose content of all the pearl millet cultivars increased ($p<0.05$) rapidly up to 24 h of germination, then slowly until they reached their peak at 72 h. The glucose content of the pearl millet cultivars did not differ at 72 and 96 h of germination. The sorghum cultivar increased rapidly from unmalted grain to 72 h of germination.

Glucose content of the grains varied at different levels

Table 2. The maltose content (%) of pearl millet and sorghum as affected by germination time and cultivar.*

Material	Unmalted	Germination time (h)				
		0^f	24	48	72	96
Pearl millet cultivars						
SOSAT C-88	$0.01\pm0.01^{d\,z}$	$0.04\pm0.01^{d\,y}$	$0.09\pm0.02^{c\,wx}$	$0.14\pm0.03^{b\,w}$	$0.16\pm0.02^{ab\,uv}$	$0.17\pm0.01^{a\,x}$
ZANGO	$0.01\pm0.01^{c\,z}$	$0.03\pm0.01^{c\,yz}$	$0.08\pm0.03^{b\,wx}$	$0.13\pm0.03^{a\,wx}$	$0.15\pm0.05^{a\,uvw}$	$0.14\pm0.05^{a\,xy}$
EX-BORNO	$0.01\pm0.00^{d\,z}$	$0.02\pm0.01^{d\,yz}$	$0.07\pm0.03^{c\,xy}$	$0.08\pm0.01^{bc\,xy}$	$0.016\pm0.02^{ab\,xyz}$	$0.11\pm0.01^{a\,yz}$
LCRI-IC 9701	ND	$0.01\pm0.01^{c\,z}$	$0.03\pm0.01^{c\,z}$	$0.04\pm0.01^{bc\,z}$	$0.06\pm0.02^{ab\,z}$	$0.07\pm0.01^{a\,z}$
ICMV-IS 94206	$0.01\pm0.01^{c\,z}$	$0.02\pm0.01^{c\,yz}$	$0.08\pm0.03^{b\,wx}$	$0.09\pm0.02^{ab\,xy}$	$0.11\pm0.02^{a\,vwxyz}$	$0.10\pm0.03^{a\,yz}$
ICMV-IS 94208	ND	$0.01\pm0.01^{b\,z}$	$0.03\pm0.01^{e\,z}$	$0.06\pm0.01^{a\,y}$	$0.07\pm0.01^{a\,z}$	$0.08\pm0.01^{a\,z}$
GWAGWA	ND	$0.01\pm0.01^{b\,z}$	$0.03\pm0.01^{b\,z}$	$0.08\pm0.03^{a\,xy}$	$0.09\pm0.02^{a\,yz}$	$0.10\pm0.01^{a\,yz}$
G.I.-14.9	ND	$0.02\pm0.01^{d\,yz}$	$0.05\pm0.02^{c\,yz}$	$0.11\pm0.02^{b\,wx}$	$0.12\pm0.01^{ab\,uvwy}$	$0.14\pm0.04^{a\,xy}$
GB. 8735	ND	$0.01\pm0.01^{c\,z}$	$0.04\pm0.01^{b\,z}$	$0.10\pm0.01^{a\,x}$	$0.01\pm0.03^{a\,xyz}$	$0.09\pm0.03^{a\,z}$
G.I-297-1	ND	$0.03\pm0.01^{c\,yz}$	$0.07\pm0.02^{b\,xy}$	$0.12\pm0.01^{a\,wx}$	$0.14\pm0.02^{a\,uvwx}$	$0.14\pm0.01^{a\,xy}$
Sorghum cultivar						
ICSV 111	$0.06\pm0.01^{b\,y}$	$0.07\pm0.02^{b\,x}$	$0.01\pm0.02^{ab\,w}$	$0.18\pm0.02^{a\,v}$	$0.18\pm0.01^{a\,u}$	$0.19\pm0.02^{a\,x}$

*Mean±SD of triplicate germinations. [a–e]Means within each row not followed by the same superscript are significantly different ($p<0.05$). [u–z]Means within each column not followed by the same superscript are significantly different ($p<0.05$). 0^f h is the time after steeping and before germination. ND=Not detected.

Table 3. The glucose content (%) of pearl millet and sorghum as affected by germination time and cultivar.*

Material	Unmalted	Germination time (h)				
		0^f	24	48	72	96
Pearl millet cultivars						
SOSAT C-88	$0.10\pm0.01^{c\,x}$	$0.13\pm0.03^{c\,y}$	$0.24\pm0.03^{b\,v}$	$0.25\pm0.02^{b\,w}$	$0.34\pm0.03^{a\,w}$	$0.35\pm0.02^{a\,w}$
ZANGO	$0.09\pm0.03^{c\,xy}$	$0.11\pm0.01^{c\,y}$	$0.22\pm0.03^{b\,vwx}$	$0.24\pm0.04^{b\,wx}$	$0.33\pm0.02^{a\,wx}$	$0.32\pm0.03^{a\,wx}$
EX-BORNO	$0.07\pm0.02^{d\,xyz}$	$0.11\pm0.02^{c\,y}$	$0.21\pm0.02^{b\,vwxy}$	$0.22\pm0.01^{b\,wxy}$	$0.28\pm0.01^{a\,xyz}$	$0.28\pm0.01^{a\,xyz}$
LCRI-IC 9701	$0.05\pm0.01^{c\,z}$	$0.08\pm0.01^{c\,z}$	$0.17\pm0.02^{b\,z}$	$0.18\pm0.02^{b\,z}$	$0.25\pm0.2^{a\,z}$	$0.24\pm0.04^{a\,z}$
ICMV-IS 94206	$0.07\pm0.02^{c\,xyz}$	$0.10\pm0.01^{c\,yz}$	$0.23\pm0.02^{b\,vw}$	$0.24\pm0.02^{b\,wx}$	$0.296\pm0.03^{a\,wxyz}$	$0.30\pm0.02^{a\,wxy}$
ICMV-IS 94208	$0.06\pm0.01^{d\,yz}$	$0.10\pm0.02^{c\,yz}$	$0.18\pm0.02^{b\,yz}$	$0.20\pm0.03^{b\,yz}$	$0.26\pm0.03^{a\,yz}$	$0.24\pm0.02^{a\,z}$
GWAGWA	$0.07\pm0.02^{d\,xyz}$	$0.10\pm0.01^{c\,yz}$	$0.19\pm0.02^{b\,xyz}$	$0.21\pm0.01^{b\,xyz}$	$0.27\pm0.03^{a\,yz}$	$0.26\pm0.02^{a\,yz}$
G.I.-14.9	$0.08\pm0.01^{d\,xyz}$	$0.11\pm0.01^{c\,y}$	$0.21\pm0.03^{b\,vwxy}$	$0.23\pm0.01^{b\,wxy}$	$0.30\pm0.02^{a\,wxyz}$	$0.28\pm0.03^{a\,xyz}$
GB. 8735	$0.07\pm0.02^{d\,xyz}$	$0.11\pm0.03^{c\,y}$	$0.20\pm0.02^{b\,wxyz}$	$0.21\pm0.03^{b\,xyz}$	$0.28\pm0.03^{a\,xyz}$	$0.29\pm0.01^{a\,yz}$
G.I-297-1	$0.08\pm0.03^{c\,xyz}$	$0.10\pm0.01^{c\,yz}$	$0.22\pm0.02^{b\,vwx}$	$0.24\pm0.03^{b\,wx}$	$0.31\pm0.02^{a\,wxy}$	$0.29\pm0.02^{a\,xyz}$
Sorghum cultivar						
ICSV 111	$2.05\pm0.02^{e\,w}$	$2.14\pm0.02^{d\,x}$	$2.71\pm0.16^{c\,u}$	$2.82\pm0.20^{b\,v}$	$3.05\pm0.04^{a\,v}$	$3.07\pm0.01^{a\,v}$

*Mean±SD of triplicate germinations. [a–e]Means within each row not followed by the same superscript are significantly different ($p<0.05$). [u–z]Means within each column not followed by the same superscript are significantly different ($p<0.05$). 0^f h is the time after steeping and before germination.

of germination time. It ranged from 0.08 to 2.14%, 0.17 to 2.71, 0.18 to 2.82, 0.25 to 3.05 and 0.24 to 3.07 at 0, 24, 48, 72 and 96 h of germination. Sorghum had the highest glucose content at all levels of germination time, while the glucose content in SOSAT C-88, ZANGO and G.1-297-1 were the highest among the pearl millet cultivars.

Fructose.

Fructose content of the unmalted and malted grains is presented in Table 4. Similar to the data on glucose, fructose content of sorghum was the highest ($p<0.05$), while the fructose content of the unmalted pearl millet cultivars ranged from 0.01 to 0.05%. The fructose content of LCRI-IC 9701 was not detectable. Fructose content of unmalted and malted at 0 h of germination for SOSAT C-88, EX-BORNO, ICMV-IS 94206, GB 8735, G.I-297-1 did not differ significantly ($p>0.05$), while fructose content of unmalted and malted at 0 h of germination for ZANGO and sorghum (ICSV 111) differed significantly. This means that the fructose content of these grains increased significantly ($p<0.05$) during steeping. However, fructose content of the grain increased significantly ($p<0.05$) with increase in germination time up to 96 h.

This study has shown that most of the sugars reached their peak at 72 h of germination. This result confirmed the earlier reports that the optimum germination time for millet grain is 72 h.[3,21] Generally, the contents of sucrose, maltose, glucose and fructose of the grains increased in the course of germination. Among the pearl millet cultivars, SOSAT C-88 had the highest ($p<0.05$) sucrose content, followed by ZANGO, G.I-297-1, G.I-14.9, ICMV-IS 94206 and GB 8735. On the other hand, SOSAT C-88, ZANGO, G.I-297-1, G.I-14.9 had higher maltose content, whereas SOSAT C-88, ZANGO, G.I-297-1, G.I-14.9 and ICMV-IS 94206 had higher ($p<0.05$) glucose content and the fructose content of SOSAT C-88, ZANGO and G. I-297-1 were higher ($p<0.05$) than the rest of the pearl millet cultivars at the 72 h of germination. If the pearl millet cultivars are to be selected based on their sugar levels (especially maltose and glucose) for malting, SOSAT C-88, ZANGO, G.I-14.9 and G.I-297-1 are most suitable. Most of the sucrose, maltose, glucose and fructose contents in malted grain might be produced by activities of starch degrading enzymes. The amylases could produce these products to nourish the embryo-seedling before the photosynthetic systems are developed for enough sugars to support the plant. However, before the young seedlings utilize an appreciable quantity of these products, the development of the seedling is halted by drying but not by temperature which will not completely inactivate the enzymes in the grain.[17]

Demuyakor and Ohta[12] have studied the malt characteristics of *sorghum vulgare* varieties from Ghana and reported that dextrin, maltose and glucose increased during germination. The main sugars encountered were glucose and maltose, with glucose being in the higher quantity. In a similar study, Khetarpaul and Chauhan[22] found out that total soluble sugars, both reducing and non-reducing sugars increased significantly ($p<0.05$) during germination of pearl millet. Choi[23] indicated that starch in the endosperm is degraded slowly during germination and the sugar levels are developed according to degradation of starch. Rise in reducing sugars may be due to mobilization and hydrolysis of seed polysaccharide, leading to more available reducing sugars. Also, rapid amylolysis yields significant amounts of maltose, a reducing sugar. Increased levels of total soluble sugars, reducing sugars and non-reducing sugars during germination have been reported in Chickpea black grain,[24] mung beans[25] and pearl millet.[26]

CONCLUSION

Malting of ten pearl millet cultivars and one sorghum cultivar revealed that germination affects the level of sugars with its optimum at 72 h of germination. The sugar levels vary among the pearl millet cultivars. SOSAT C-88, ZANGO, G.I-14.9 and G.I-297.1 had higher sugar levels and if selection of grains for malting is to be based on sugar levels, these cultivars had good potential for malting.

The authors extend their appreciation to Mr. Obida Musa of Na-

Table 4. The fructose content (%) of pearl millet and sorghum as affected by germination time and cultivar.*

Material	Unmalted	Germination time (h)				
		0^f	24	48	72	96
Pearl millet cultivars						
SOSAT C-88	$0.05\pm0.01^{c\,y}$	$0.08\pm0.02^{c\,w}$	$0.10\pm0.03^{bc\,w}$	$0.13\pm0.01^{abc\,w}$	$0.15\pm0.02^{ab\,x}$	$0.16\pm0.03^{a\,w}$
ZANGO	$0.03\pm0.02^{d\,yz}$	$0.07\pm0.01^{c\,wx}$	$0.09\pm0.04^{bc\,wx}$	$0.11\pm0.02^{ab\,wx}$	$0.14\pm0.02^{a\,x}$	$0.13\pm0.02^{a\,wxy}$
EX-BORNO	$0.02\pm0.02^{b\,z}$	$0.04\pm0.01^{b\,xyz}$	$0.07\pm0.02^{ab\,wxyz}$	$0.096\pm0.01^{a\,wxy}$	$0.10\pm0.04^{a\,yz}$	$0.10\pm0.05^{a\,xyz}$
LCRI-IC 9701	ND	$0.01\pm0.00^{c\,z}$	$0.04\pm0.01^{bc\,z}$	$0.04\pm0.03^{bc\,z}$	$0.07\pm0.01^{ab\,z}$	$0.08\pm0.02^{a\,z}$
ICMV-IS 94206	$0.01\pm0.01^{c\,z}$	$0.03\pm0.02^{c\,yz}$	$0.06\pm0.03^{b\,xyz}$	$0.08\pm0.03^{ab\,xy}$	$0.11\pm0.02^{a\,y}$	$0.11\pm0.04^{a\,xyz}$
ICMV-IS 94208	$0.01\pm0.01^{e\,z}$	$0.02\pm0.01^{de\,yz}$	$0.05\pm0.02^{cd\,yz}$	$0.06\pm0.03^{bc\,yz}$	$0.09\pm0.01^{ab\,z}$	$0.11\pm0.03^{a\,xyz}$
GWAGWA	$0.02\pm0.01^{b\,z}$	$0.05\pm0.03^{b\,wxy}$	$0.08\pm0.02^{ab\,wxy}$	$0.09\pm0.04^{a\,wxy}$	$0.10\pm0.04^{a\,yz}$	$0.11\pm0.05^{a\,xyz}$
G.I.-14.9	$0.02\pm0.01^{b\,z}$	$0.05\pm0.01^{b\,wxy}$	$0.09\pm0.01^{a\,wx}$	$0.09\pm0.02^{a\,wxy}$	$0.11\pm0.01^{a\,y}$	$0.12\pm0.02^{a\,xyz}$
GB. 8735	$0.01\pm0.01^{c\,z}$	$0.02\pm0.01^{c\,yz}$	$0.06\pm0.03^{b\,xyz}$	$0.07\pm0.03^{ab\,yz}$	$0.10\pm0.01^{a\,yz}$	$0.09\pm0.02^{a\,yz}$
G.I-297-1	$0.03\pm0.01^{e\,yz}$	$0.06\pm0.01^{de\,wx}$	$0.09\pm0.03^{cd\,wx}$	$0.10\pm0.03^{bc\,wx}$	$0.13\pm0.01^{ab\,xy}$	$0.14\pm0.02^{a\,wx}$
Sorghum cultivar						
ICSV 111	$2.01\pm0.01^{e\,x}$	$2.16\pm0.17^{d\,v}$	$3.01\pm0.59^{c\,d}$	$3.24\pm0.65^{b\,v}$	$3.27\pm0.68^{ab\,w}$	$3.29\pm0.66^{a\,v}$

*Mean±SD of triplicate germinations. [a-e]Means within each row not followed by the same superscript are significantly different ($p<0.05$). [u-z]Means within each column not followed by the same superscript are significantly different ($p<0.05$). 0^f h is the time after steeping and before germination. ND=Not detected.

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