Amylase Activities and Values in Hot and Cold Water Extracts of Pearl Millet

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Abstract: Amylase activities from various cultivars of pearl millet and a sorghum cultivar and their values in cold water and hot water extracts were studied. The α -amylase and β -amylase activities and values in hot water and cold water extracts were determined at intervals of 24 h for a period of 96 h. The correlation between amylase activities and values in hot water and cold water extracts was also determined. Activities of α -amylase and β -amylase increased progressively during germination with a concomitant increase in values in hot water and cold water extracts. The amylase activities and values in hot water and cold water extracts of the pearl millet cultivars were found to be comparable to those of sorghum. There was positive correlation ($p < 0.05$) between amylase activity and values in hot water and cold water extracts. This study has shown that pearl millet could be used for producing various malt beverages and malt-based products.

Key words: amylase, pearl millet, malting, water extracts

Pearl millet is grown extensively in a semi-arid region of Nigeria but there appears to be not much recognition in the international market as compared with other grain.^{1–4)} Nevertheless, the wide range of pearl millet cultivars available suggests that the genetic potential for the production of cultivars suitable for food and industrial use is still extensive. However, before meaningful selection is possible, quality requirements should be specified. One important feature of malt quality for brewing is the levels of amylase activities in hot water and cold water extracts which develop during germination of cereal grains.¹⁾

Recent reports by other researchers around the world^{5–11)} and in Nigeria,^{12,13)} showed that the researchers only concentrated on anti-nutrient contents and nutritional quality, but there is only a little information on its amylase activity.⁹⁾ Furthermore, these studies on pearl millet were carried out mostly in India using the cultivars grown there. Pearl millet cultivars may also vary in their potential to develop amylase activities depending on the cultural conditions and probably the climate of the area where they are grown. In view of these problems, it was decided to assess the α -amylase and β -amylase activities in hot water and cold water extracts which result in malt quality of various pearl millet cultivars grown in semi-arid regions of northern Nigeria. This assessment will be important in selecting suitable cultivars for malting and subsequent brewing, if necessary.

MATERIALS AND METHODS

Materials. Ten millet cultivars and one sorghum cultivar (as a control) were obtained from International Crops Research Institute for Semi-Arid Tropics, Kano and Lake Chad Research Institute, Maiduguri, Nigeria. Chemicals and Reagents used 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.¹⁴⁾ The cleaned grains were steeped in water for 12 h at 30°C^{5–11)}; with a grain to water ratio of 1:10 (w/v)¹¹⁾ and 1 h air rest was applied after 6 h of steeping. For each air rest, the steeping water was changed. At the end of the 12 h steeping, the steeped grains were sterilized by immersion in a solution of 1% sodium hypochlorite for 20 min¹⁵⁾ before they were drained and germinated at 32 ± 20°C for 0, 24, 48, 72 and 96 h as described by Obizoba and Atii.¹³⁾

After germination, the green malt was harvested, dried in a fan-fitted Gallenkamp oven (BS model ov-160, England) at 500°C for 24 h. After drying, the rootlets and shoots were separated from the kernels by rubbing the grain in a sieve of coarse mesh size (1.40 mm).¹⁵⁾ The polished malt was milled with hammer mill (Gibbons Electric, Tollesbury, Essex, U.K.).

Determination of amylase activity.

The α -amylase activity was determined as described by Shekib and co-authors.¹⁶⁾

Reagents. The reagents used for the determination of α -amylase activity were as follows:

Lugol's iodine. Iodine crystals weighing about 2.2 g were added to 4.4 g of potassium iodide and dissolved in distilled water to make up 100 mL. The solution of the substances was stored in a dark bottle and labeled stock solution. Five-tenths of a milliliter of the stock solution was diluted to 500 mL with distilled water to make the working solution (Lugol's Iodine).

Phosphate buffer. Phosphate buffer was prepared by dissolving 2.9 g disodium hydrogen phosphate and 3.1 g of sodium dihydrogen phosphate in 100 mL distilled water to make solution A and B, respectively. The solution A (37.5 mL) was mixed with 62.5 mL solution B to make up 100 mL solution of buffer (pH 6.6).

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Sodium chloride solution. Sodium chloride solution was prepared by dissolving 1.2 g of sodium chloride crystals in 100 mL of distilled water.

Soluble starch solution. Soluble starch solution (which was the substrate for the enzymes) was prepared by dissolving 1 g soluble starch powder (BDH England) in 100 mL of distilled water and allowing it to boil for 5–10 min. It was allowed to cool at room temperature. This was prepared freshly before use.

Enzyme extracts. Two grams of dry and malted grain of pearl millet cultivars and sorghum cultivar flours were mixed with 10 mL of ice-water in a centrifuge tube and centrifuged for 10 min at 80 rpm with a Hettich Universal 11 Centrifuge. The supernatant was used as enzyme extract.

Procedure. Four milliliter of phosphate buffer (pH 6.6), 1 mL of sodium chloride and 1 mL of enzyme extract were added to 5 mL of soluble starch solution in a test tube at room temperature ($32 \pm 3^\circ\text{C}$). It was mixed thoroughly to make a reaction mixture. Aliquots (0.2 mL) of the reaction were taken at 0 min and 5 min intervals up to 30 min, after the addition of the enzyme extract and dispensed into 10 mL Lugol's iodine solution (1 to 100 dilutions). The absorbance of the starch iodine complex was measured with a Corning colorimeter 253 at 620 nm.

The method reported by Bernfield¹⁷⁾ was used to determine β -amylase activity.

Reagents. The following reagents were prepared and used to determine the β -amylase activity.

Phosphomolybdic acid. Thirty-five grams of molybdic acid and 5 g of sodium tungstate were dissolved in 200 mL of 10% sodium hydroxide and 200 mL distilled water. This was gently boiled for 30 min to remove ammonia. The solution was diluted to 350 mL after cooling. One hundred twenty-five milliliter of phosphoric acid (S.G. 1.75) was added and diluted to 500 mL with water.

Procedure. Exactly 0.5 mL of the enzyme extract was incubated for 3 min at room temperature ($32 \pm 3^\circ\text{C}$) with 1 mL of starch solution. The enzyme reaction was stopped by addition of 1 mL alkaline copper tartarate and the mixture heated over boiling water for 2 min and cooled to room temperature. Exactly, 1 mL of phosphomolybdic reagent was added after which 20 mL of distilled water was added. The absorbance was read at 680 nm. Blank experiments were run side by side in which the enzyme extract was omitted. A unit of amylase activity was estimated as:

$$\frac{A_0 - A_t}{A_0} \times 100$$

Where A_0 , absorbance of the iodine complex of starch digestion at time, zero; A_t , absorbance of the iodine complex of starch digestion at time of complete hydrolysis.

Specific activity of amylase is expressed in U/mg protein/min.^{16,17)}

Determination of cold and hot water extracts. Cold water extract (C.W.E.) was determined by the method of Gothard and co-authors.¹⁸⁾ About 3 g of sample was extracted with 30 mL solution (27.5 mL distilled water + 2.5 mL 0.1 M NH_4OH solution) at 25°C . The extract was filtered through Whatman No. 1 (England) filter paper and

the percentage of dissolved sugar read at 20°C with an Abbe Refractometer. The percentage of C.W.E. was calculated using the following equation¹⁹⁾: $\% \text{C.W.E.} = P (M + 1000) / (100 - P)$ and the value corrected to moisture dry basis using the equation: $\% \text{C.W.E. (dry basis)} = 100 \times (100 - m) / X$; where P is the percentage sugar by refractometer reading, m is malt moisture content, and X is percentage extract.

The method described by Gothard and co-authors¹⁸⁾ and modified by Palmer¹⁾ was used to determine the hot water extract. It was calculated by the method of Demuyakor and Ohta.¹⁹⁾ Three grams of malt grist was transferred into a 100 mL Erlenmeyer flask and extracted with 25 mL distilled water in a water bath at 45°C for 30 min. The wort was then decanted from the mash and kept separately while the mash was brought to 100°C in a boiling water bath. It was maintained at 100°C for 2 min and then cooled to 65°C . The mash and the wort were recombined and then further extraction was carried out at 65°C for 1 h. At the end of the extraction, the solution was cooled and the volume made up to 35 mL with distilled water. It was mixed and allowed to settle for 20 min after which it was shaken again and decanted into a fluted filter (Whatman No. 1). The percentage sugar content of the clarified wort was read with an abbe refractometer (Bellingham and Stanley Ltd., UK) and the percentage hot water extract was calculated as for cold water extract.²⁰⁾

Statistical analysis. The mean and standard deviation of triplicate determinations of the α and β -amylase in hot and cold water extracts were calculated for the ten millet cultivars and one sorghum cultivar. Analysis of variance from an 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's multiple range test with Statistic computer program, version 4.1, U.S.A.²¹⁾ The correlation coefficients among the amylase activity in hot water and cold water extracts were also determined with the same computer program.

RESULTS AND DISCUSSION

Amylase activity.

The α -amylase activity of various pearl millet and sorghum cultivars are shown in Table 1. In general, the α -amylase activity increased significantly ($p < 0.05$) up to 72 h of germination. The 0 h of germination showed the lowest α -amylase activity and it gradually increased in the course of germination up to 96 h. The highest α -amylase activity was attained at 72 and 96 h of germination.

The α -amylase activity varies widely among cultivars. However, the variations were not noticeable until 48 h of germination. The α -amylase activity of the pearl millet cultivars varied significantly ($p < 0.05$) from 22.53 to 46.10 U/mg protein/min, 36.23 to 86.35 and 35.86 to 87.23 at 48, 72 and 96 h of germination, respectively. Most of the pearl millet cultivars significantly ($p > 0.05$) had the similar α -amylase activities as the sorghum cultivar at 72 h of germination. The pearl millet cultivars that had lower ($p < 0.05$) α -amylase activity at 72 h of germination

Table 1. The α -amylase activity (U/mg protein/min) of pearl millet and sorghum as affected by germination time and cultivar.¹

Material	Germination time (h)				
	0 ^c	24	48	72	96
Pearl millet cultivars					
SOSAT C-88	6.32 ^d	18.92 ^c	42.02 ^{b y}	85.03 ^{a xy}	85.13 ^{a xy}
ZANGO	6.01 ^d	18.43 ^c	46.10 ^{b y}	80.22 ^{a xy}	80.30 ^{a y}
EX-BORNO	6.03 ^d	18.04 ^c	44.36 ^{b y}	82.01 ^{a xy}	81.73 ^{a xy}
LCRI-IC 9701	5.54 ^d	16.00 ^c	24.25 ^{b z}	39.45 ^{a z}	39.55 ^{a z}
ICMV-IS 94206	5.47 ^d	15.12 ^c	22.70 ^{b z}	36.46 ^{a z}	36.34 ^{a z}
ICMV-IS 94208	5.38 ^d	15.01 ^c	22.94 ^{b z}	36.23 ^{a z}	36.39 ^{a z}
GWAGWA	6.00 ^d	18.55 ^c	43.10 ^{b y}	80.92 ^{a xy}	82.18 ^{a xy}
G.I.-14.9	6.19 ^d	18.26 ^c	45.52 ^{b y}	82.06 ^{a xy}	82.17 ^{a xy}
GB. 8735	5.78 ^d	15.60 ^c	22.53 ^{b z}	36.05 ^{a z}	35.86 ^{a z}
G.I-297-1	6.04 ^d	18.08 ^c	45.05 ^{b y}	81.03 ^{a xy}	80.54 ^{a y}
Sorghum cultivar					
ICSV 111	6.45 ^d	19.01 ^c	45.74 ^{b y}	86.35 ^{a x}	87.23 ^{a x}

¹Mean of triplicate determinations. ^{a-d}Means within each row not followed by the same superscript are significantly different ($p < 0.05$). ^{x-z}Means within each column not followed by the same superscript are significantly different ($p < 0.05$). 0 h is the time after steeping and before germination.

Table 2. The β -amylase activity (U/mg protein/min) of pearl millet and sorghum as affected by germination time and cultivar.¹

Material	Germination time (h)				
	0 ^c	24	48	72	96
Pearl millet cultivars					
SOSAT C-88	54.96 ^{d x}	60.98 ^{c x}	71.23 ^{b w}	80.45 ^{a v}	80.32 ^{a v}
ZANGO	53.01 ^{d x}	59.83 ^{c x}	67.91 ^{b wxy}	78.36 ^{a vw}	79.46 ^{a vw}
EX-BORNO	49.35 ^{d x}	52.81 ^{c xy}	58.36 ^{b wxy}	66.01 ^{a vwxy}	65.24 ^{a vwxy}
LCRI-IC 9701	40.26 ^{c y}	48.31 ^{b y}	50.18 ^{b y}	57.83 ^{a y}	56.95 ^{a y}
ICMV-IS 94206	48.31 ^{d xy}	58.93 ^{c x}	68.35 ^{b wx}	71.65 ^{a vwxy}	70.63 ^{a vwxy}
ICMV-IS 94208	46.45 ^{d xy}	49.26 ^{c y}	51.83 ^{b y}	57.99 ^{a xy}	58.93 ^{a xy}
GWAGWA	42.83 ^{d y}	48.16 ^{c y}	56.45 ^{b xy}	61.32 ^{a vwxy}	60.27 ^{a wxy}
G.I.-14.9	47.93 ^{d xy}	56.36 ^{c xy}	68.18 ^{b wx}	76.02 ^{a vwxy}	75.33 ^{a vwxy}
GB. 8735	46.55 ^{d xy}	52.84 ^{c xy}	59.64 ^{b wxy}	70.95 ^{a vwxy}	71.35 ^{a vwxy}
G.I-297-1	48.35 ^{d xy}	53.56 ^{c xy}	61.32 ^{b wxy}	77.23 ^{a vw}	77.02 ^{a vwxy}
Sorghum Cultivar					
ICSV 111	32.55 ^{b z}	36.25 ^{b z}	44.15 ^{ab z}	45.10 ^{ab z}	45.95 ^{a z}

¹Mean of triplicate determinations. ^{a-d}Means within each row not followed by the same superscript are significantly different ($p < 0.05$). ^{v-z}Means within each column not followed by the same superscript are significantly different ($p < 0.05$). 0 h is the time after steeping and before germination.

nation were GB 8735, ICMV-IS 94208, ICMV-IS 94206 and LCRI-IC 9701. Therefore, most of the pearl millet cultivars could be classified into two groups and the group having higher α -amylase activity could be selectable for malting, since the cultivars in this group showed values similar to that in sorghum.

These findings were similar to reports of other scientists. Swanston and co-authors²²⁾ indicated that a clear distinction between sorghum cultivars for diastatic activity could not be made before 48 h of germination. It was reasonable to make this comparison because the diastatic power of sorghum malts is mainly due to α -amylase activity.^{23,24)} It was not surprising that the sorghum cultivar used as the control had higher α -amylase activity than most of the grains. Other studies have also indicated that diastatic activity increases during germination.²²⁾ They also found that appreciable variation among the cultivars was only noticeable from 48 h of germination. EtokAkpan²⁴⁾ and Okafor²⁵⁾ stated categorically that the diastatic power

of sorghum malt is due to α -amylase activity. Therefore, it was not unexpected that sorghum showed higher level of α -amylase activity.

Variation of β -amylase activity among the cultivars showed that the values ranged from 32.55 to 54.96 U/mg protein/min, 36.25 to 60.98, 44.15 to 71.23, 45.10 to 80.45 and 45.95 to 80.32 for 0 h, 24, 48, 72 and 96 h, respectively (Table 2). The β -amylase activity of sorghum was the lowest among the grains during the germination process. This has been confirmed by early reports that there is a low concentration of β -amylase in sorghum due to lower amounts of salt-soluble proteins.²⁶⁻³¹⁾ Long before now, Kneen³²⁾ stated that β -amylase is either absent from sorghum malts or present in a very low amount. Therefore, pearl millet cultivars used in this study had higher amounts of β -amylase and may be considered as better substitutes for sorghum malt. The β -amylase is usually bound to proteins and is released by proteolytic enzymes during germination.²⁵⁾

Table 3. Hot water extract (%) of pearl millet and sorghum as affected by germination time and cultivar.¹

Material	Germination time (h)				
	0 ^c	24	48	72	96
Pearl millet cultivars					
SOSAT C-88	26.37 ^{d x}	31.17 ^{c yz}	42.99 ^{b y}	58.91 ^{a y}	59.77 ^{a x}
ZANGO	26.55 ^{d x}	33.41 ^{c y}	42.35 ^{d yz}	57.89 ^{a y}	58.39 ^{a xy}
EX-BORNO	25.01 ^{d xy}	32.23 ^{c y}	42.70 ^{b yz}	54.68 ^{a yz}	56.33 ^{a xyz}
LCRI-IC 9701	20.05 ^{d z}	27.08 ^{c z}	39.02 ^{b yz}	51.07 ^{a z}	52.87 ^{a yz}
ICMV-IS 94206	26.01 ^{d x}	30.43 ^{c yz}	40.49 ^{b yz}	55.01 ^{a yz}	56.75 ^{a xyz}
ICMV-IS 94208	21.13 ^{d yz}	27.97 ^{c yz}	40.14 ^{b yz}	52.89 ^{a yz}	53.22 ^{a yz}
GWAGWA	20.49 ^{d yz}	27.69 ^{c yz}	39.33 ^{b yz}	53.17 ^{a yz}	54.06 ^{a xyz}
G.I.-14.9	23.55 ^{d xyz}	31.04 ^{c yz}	42.59 ^{b yz}	56.15 ^{a yz}	56.81 ^{a xyz}
GB. 8735	22.83 ^{d xyz}	30.43 ^{c yz}	41.94 ^{b yz}	54.94 ^{a yz}	55.49 ^{a xyz}
G.I-297-1	23.49 ^{d xyz}	30.35 ^{c yz}	41.00 ^{b yz}	56.78 ^{a yz}	57.47 ^{a xyz}
Sorghum cultivar					
ICSV 111	19.83 ^{d z}	26.76 ^{c z}	39.67 ^{b z}	50.87 ^{a z}	51.69 ^{a z}

¹Mean of triplicate determinations. ^{a-d}Means within each row not followed by the same superscript are significantly different ($p < 0.05$). ^{x-z}Means within each column not followed by the same superscript are significantly different ($p < 0.05$). 0 h is the time after steeping and before germination.

Table 4. Cold water extract (%) of pearl millet and sorghum as affected by germination time and cultivar.¹

Material	Germination time (h)				
	0 ^c	24	48	72	96
Pearl millet cultivars					
SOSAT C-88	7.996 ^{d yz}	10.31 ^{c yz}	13.94 ^{b y}	18.25 ^{a w}	18.80 ^{a v}
ZANGO	7.39 ^{d yz}	9.91 ^{c yz}	14.39 ^{b y}	17.67 ^{a w}	18.23 ^{a vw}
EX-BORNO	8.68 ^{cd y}	10.87 ^{bc y}	12.71 ^{ab yz}	13.39 ^{a xyz}	14.38 ^{a xyz}
LCRI-IC 9701	7.03 ^{b yz}	9.63 ^{a yz}	10.58 ^{a yz}	11.00 ^{a yz}	11.70 ^{a yz}
ICMV-IS 94206	8.31 ^{cd yz}	10.22 ^{bc yz}	11.75 ^{b yz}	14.78 ^{a wxy}	15.17 ^{a vwxyz}
ICMV-IS 94208	7.19 ^{cd yz}	9.33 ^{bc yz}	10.56 ^{ab yz}	11.65 ^{a xyz}	12.18 ^{b yz}
GWAGWA	7.56 ^{cd yz}	9.56 ^{bc yz}	11.45 ^{ab yz}	12.23 ^{a xyz}	12.94 ^{a xyz}
G.I.-14.9	7.63 ^{c yz}	9.59 ^{c yz}	13.99 ^{b y}	15.25 ^{ab wx}	16.36 ^{a vwx}
GB. 8735	8.68 ^{c y}	10.12 ^{bc yz}	12.01 ^{b yz}	14.61 ^{a wxy}	15.59 ^{a vwxy}
G.I-297-1	7.63 ^{cd yz}	9.65 ^{c yz}	12.70 ^{b yz}	15.44 ^{a wx}	16.51 ^{a vwxy}
Sorghum Cultivar					
ICSV 111	6.52 ^{cd z}	8.28 ^{bc z}	9.15 ^{b z}	10.54 ^{a z}	10.90 ^{c z}

¹Mean of triplicate determinations. ^{a-d}Means within each row not followed by the same superscript are significantly different ($p < 0.05$). ^{v-z}Means within each column not followed by the same superscript are significantly different ($p < 0.05$). 0 h is the time after steeping and before germination.

Aniche³³⁾ reported that α -amylase activity increases as germination time increases and reaches its highest value on the 6th day of germination. Similarly, Taylor and Robbins²⁾ reported that β -amylase activity in sorghum malt increases with germination time. They reported that ungerminated sorghum grain does not exhibit β -amylase activity and there is a significant effect ($p < 0.05$) of germination time on β -amylase activity.

Hot water and cold water extracts.

Hot water extract (HWE) of the various pearl millet cultivars and sorghum are presented in Table 3. Hot water extract increased with the increase in germination time for all the grains. Hot water extract varied widely among the cultivars. It ranged from 19.83 to 26.55%, 26.76 to 31.17, 39.67 to 42.99, 50.87 to 58.91 and 51.69 to 59.77 at 0, 24, 48, 72 and 96 h of germination, respectively.

Cold water extracts of the pearl millet cultivars and sorghum cultivar also increased with the progress of germi-

nation time and varied among cultivars (Table 4). The values varied from 6.52 to 8.68%, 8.28 to 10.87, 9.15 to 14.39, 10.54 to 18.25 and 10.90 to 18.80 at 0, 24, 48, 72, and 96 h of germination, respectively. In all pearl millet cultivars cold water extracts were higher than that of sorghum. SOSAT C-88, ZANGO, G.I-297-1, and G.I-14.9 showed higher cold water extracts than the rest of the grains.

The hot water extract generally reflects the pattern of enzyme activity development in the malts. The hot water extracts increased with increase in germination time with a concomitant increase in amylase activity.¹⁹⁾ Hot water and cold water extracts are used as criteria for evaluating grain malt quality, indicating that SOSAT C-88 and ZANGO, having very high values in hot water extract, may be candidates for good malt varieties. Cold water extract measures only water extract by preventing the enzyme action with ammonia.³⁴⁾ As with the α -amylase activity, cold water extract values were highest at 72 h of

Table 5. Correlation analysis between α -amylase, β -amylase, cold water and hot water extracts of pearl millet cultivars.

	α -Amylase	β -Amylase	Hot water extract
β -Amylase	0.40		
Hot water extract	0.65	0.98 ^a	
Cold water extract	0.70	0.90 ^a	0.98 ^a

^aSignificant at 5% level ($p < 0.05$).

germination. Therefore, cultivar and germination time may affect values in cold water and hot water extracts significantly ($p < 0.05$). Ezeogu and Okolo³⁵ have reported a similar result.

Increase in germination time affected the values of the hot and cold water extracts of the various pearl millet cultivars. A rapid increase occurred up to 48 h of germination, reaching the peak at 72 h. Hot water and cold water extracts did not show significant ($p > 0.05$) difference at 72 and 96 h of germination. Many researchers have reported similar findings for other grains. Aniche³³ malted two maize varieties and the result showed that cold water extracts increase with an increase in germination time. This has also agreed with the other report by Jayatisa and co-authors.³⁶

High value in hot water extracts of pearl millet cultivars compared to sorghum may be due to the temperature of starch gelatinization of the grains. The gelatinization temperature of sorghum starch is 70 to 75°C,²⁴ while that of millet is 61.1 to 68.7°C³⁷ which is slightly lower than that of sorghum. The gelatinization temperature of sorghum starch is higher than the optimum temperature (50 to 65°C) for amylase activities, while pearl millet starch gelatinization temperature is within the optimum temperature for amylase activity.

There was good correlation between amylase activities and values in hot water and cold water extracts (Table 5). Values in hot water and cold water extracts were highly positively correlated ($p < 0.01$) with β -amylase activity and also positively correlated ($p < 0.05$) with α -amylase activity. Values in cold water extracts were highly positively correlated ($p < 0.01$) with hot water extracts but there was no correlation ($p < 0.05$) between values in cold water and hot water extracts.

CONCLUSION

Ten pearl millet cultivars were malted along with a sorghum cultivar. The results of the study indicated that α -amylase and β -amylase activities of the grains increased significantly ($p < 0.05$) during germination. The optimum germination time for the pearl millet cultivar was 72 h. SOSAT C-88, ZANGO, EX-BORNO, GWAGWA, G.1-14.9 and G.1-297-1 showed potential for having higher amylase activities and could be selectable for malting. Values in hot water and cold water extracts also increased in the course of germination with a concomitant increase in amylase activities. There was good correlation between amylase activity and values in hot water and cold water extracts.

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