African Journal of Food Science Vol. 6(11), pp. 308-316, 15 June, 2012
Available online at http://www.academicjournals.org/AJFS
DOI: 10.5897/AJFS12.029
ISSN 1996-0794 ©2012 Academic Journals

Full Length Research Paper

Effect of finger millet varieties on chemical characteristics of their malts

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Accepted 10 May, 2012

Chemical changes during germination and malting characteristics of six Nepalese finger millet varieties (*GPU 0025*, *GE 5016*, *Dalle*, *Okhle*, *Kabre* and *Juwain*) were studied. Millets were steeped in water at room temperature overnight, germinated for 48 h at 28±1°C, kilned at 50±2°C for 24 h and then, chemical characteristics of unmalted and malted millets were analyzed. Germination increased ($p<0.05$) total reducing sugar and glucose contents in all millet varieties. Starch, amylose and amylopectin contents in unmalted millets were between 71.32 to 79.86, 20.39 to 24.13, and 49.11 to 55.72% dry basis (db) respectively; whereas, those of malted millets were 63.74 to 67.12, 16.62 to 19.27 and 44.47 to 50.18% (db) respectively. Similarly, total phenolics (as gallic acid), total flavonoids (as rutin) and tannin (as tannic acid) contents in unmalted millets ranged from 60.9 to 229.2, 35.2 to 141.7 and 169.9 to 566.0 mg% (db) respectively; whereas, the values in malted millets were 123.1 to 247.8, 50.1 to 236.3 and 173.7 to 301.8 mg% (db) respectively. Except in *GE 5016* and *Juwain* millets, malting decreased ($p<0.05$) antioxidant activity in other varieties. Malt extract analysis revealed that all malt extracts possessed aromatic odor and showed negative starch-iodine test. Filtration rate of *Juwain* malt extract was slow but it was normal in other extracts. The color (EBC unit), free amino nitrogen (FAN) (mg% as glycine) and total reducing sugar (% m/v as maltose) contents in extracts were 2.77 to 5.78, 2.6 to 9.0 and 4.50 to 6.93, respectively. Glucose (%, m/v) and extract yield of malt (%, db) ranged from 1.22 to 2.51 and 80.20 to 88.83, respectively. Total soluble solids (TSS) (º Bx), pH, extract (%, m/m), FAN (mg% m/v) and total reducing sugar (% m/m as maltose) in worts derived from *Dalle*, *Kabre* and *Juwain* millet malts were in the range of 12.43 to 13.07, 5.44 to 5.66, 12.0 to 12.7, 19.5 to 20.3 and 7.64 to 10.45, respectively.

Key words: Millet malt, amylose, polyphenols, free amino nitrogen (FAN), antioxidant activity, malt extract, wort.

INTRODUCTION

Millet is the fifth most important cereals in the world after wheat, maize, rice and barley (Shayo et al., 2001). In African countries, among other uses, millet is malted and used to brew various traditional beers (Ekundayo, 1996). Finger millet (*Eleusine coracana*) is widely cultivated in Asia and Africa. It has some very potentially useful characteristics with respect to brewing (Taylor et al., 2006). Major finger millet producing countries (in descending order) are India, China, Uganda and Nepal and its world production was estimated to be 3.76 million metric tonnes (FAOSTAT, 2004). Finger millet malt is superior to other millet malts and it is ranked next to barley (Malleshi and Desikachar, 1986). Millet has been used as a major cereal in the traditional manufacture of malt in Kenya and in India (Ravindran, 1991; Nout, 1981). Millet malt is extensively used in weaning and infant food preparations and in various supplementary food formulations (Malleshi, 2005). The primary objective of malting is to promote the development of hydrolytic enzymes (Briggs et al., 1981), which are present in much lower amounts and activities in non-*Triticeae* species (Daussant et al., 1994). The development of the amylase enzymes during malting is of critical importance as these enzymes are required to hydrolyze the malt and adjuncts starch to fermentable sugars for brewing.

Finger millet has gained importance because of its

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nutritional quality in terms of dietary fiber, functional fiber, starch pattern as well as high calcium and iron contents (Balkrishna Rao et al., 1973; Deosthale et al., 1970). In southern Africa, pearl millet is traditionally processed by malting and fermentation. Malted pearl millet is used to make weaning foods, brew traditional beers and other low-alcoholic beverages (Pelembe et al., 2002). Millets have considerable potential in foods and beverage preparations and being gluten-free, they are suitable for coeliacs (Taylor et al., 2006). Coeliac disease is a syndrome characterized by damage to the mucosa of the small intestine caused by ingestion of certain wheat proteins and related proteins in rye and barley (Fasano and Catassi, 2001). Malting and brewing with sorghum to produce lager and stout, often referred to as clear beer as opposed to traditional African opaque beer, has been conducted on a large commercial scale since the late 1980s, notably in Nigeria (Olori et al., 1996). Nigeria brews in excess of 900 million liters of beer annually; most of this is brewed with at least some sorghum (Institute of Brewing and Distilling, 2005). Brewing with sorghum is also taking place in east Africa, southern Africa and the USA. In contrast, millet malting and brewing to produce clear beer is still at the experimental stage and research has, so far, been less extensive (Taylor et al., 2006).

Finger millet, locally called *kodo,* is the fourth most important food crops of Nepal and it occupies 265,496 ha of land yielding 291,098 MT (NARC, 2010). It is generally consumed by a small segment of the population in the form of dumpling, porridge and *roti*. In Nepal, there are 5 breweries at present and they produce about 500,000 hl of beer annually utilizing about 7,000 MT of barley malt that is imported from overseas. This proves that about NRs. 300 crores (US$ 40 million) is being spent annually to purchase barley malt. Hence, substitution of barley malt with millet malt, partly if not totally, could help to save a considerable amount of foreign currency.

Chemical changes during malting of Indian millet varieties have been studied by Malleshi et al. (1986) and Sripriya et al. (1997). The use of Indian finger millet in brewing has been investigated by Venkatanarayana et al. (1979). Studies related to malting of different millet varieties and their suitability for brewing have also been conducted by Pelembe et al. (2004), Shukla et al. (1986), Makokha et al. (2002) and Shayo et al. (2001). But investigation regarding malting quality of Nepalese finger millet varieties is scanty. Therefore, this paper reports the chemical changes during germination and malting characteristics of some Nepalese finger millet varieties.

MATERIALS AND METHODS

Malting of finger millets

Six finger millet varieties (*GPU 0025*, *GE 5016*, *Dalle*, *Okhle* and *Kabre* varieties from Hill Crops Research Program, Dolakha, and *Juwain* millet from Khotang district of Nepal) were collected. They were cleaned and washed thoroughly to remove immature grains, light materials and dirt and were steeped in surplus water at room temperature (28±2°C), overnight. After soaking, the grain was drained, spread on aluminum tray (7±1 mm bed thickness), covered with moistened muslin cloth and germinated for 48 h at 28±1°C and 93±2% relative humidity (RH). During germination, the millets were gently mixed in order to aerate and prevent from matting; sprayed with water and covered with wetted muslin clothe twice a day. The germinated millet (green malt) was kilned in a mechanical dryer (REICO India) at 50±2°C for 24 h (final moisture content of 9±1%) and the rootlets were removed by rubbing and winnowing.

Chemical analysis of malts

Five hundred milligram of powdered sample was extracted with 10 ml of 80% ethanol, overnight at room temperature, centrifuged and the supernatant were separated. The residue was re-extracted with 5 ml of 80% ethanol for 12 h, centrifuged, the supernatants pooled together and volume made up to 15 ml with 80% alcohol. Antioxidant activity was determined by 1,1-diphenyl-2-picrylhydrazyl (DPPH) (Wako Japan, Lot EpL2139) method as per Sing et al. (2008) with slight modification. Briefly, 0.5 ml of the alcoholic extract and 3 ml of 0.003% methanolic solution of DPPH were mixed in a test tube, incubated at room temperature in the dark for 30 min and absorbance taken in a spectrophotometer at 517 nm. The instrument was adjusted to 100% transmittance (T) with methanol and a control was prepared using distilled water instead of the sample.

A portion of the alcoholic extract (10 ml) was evaporated on a water bath, the residue was dissolved with 20 ml of distilled water and used for the determination of total reducing sugar, glucose, total phenolics and flavonoids contents. Total reducing sugar was determined by Nelson-Somogyi method and glucose by glucose oxidase method using glucose oxidase peroxidase reagent (Span Diagnostics Ltd., India) as per Sadasivam and Manickam (1996). Total phenolics were determined as per Sadasivam and Manickam (1996) with minor modification. Aqueous solution (0.5 ml) was pipetted into a test tube; volume made up to 3 ml with distilled water and 0.5 ml of 1 N Folin-Ciocalteau regent (Loba Chemie Pvt., Ltd., Mumbai, India)) was added and mixed. After 3 min, 3 ml of 20% sodium carbonate solution was added, mixed and incubated at room temperature for 2 h. The absorbance of the resulting blue color was recorded spectrophotometrically at 760 nm and phenolics content was calculated as gallic acid (s.d. fine-chem Ltd, Mumbai, India).

Total flavonoids were determined as per Shen et al. (2009) and the results were expressed as rutin (Loba Chemie Pvt., Ltd, Mumbai, India) equivalent. Tannin content was determined by Folins-Denis method as per Ranganna (1986) and the result was expressed as tanninc acid (Merck Pvt., Ltd., Mumbai, India) equivalent. Starch content was determined by direct acid hydrolysis method as per AOAC Official Method 920.83 (2005). Amylose content was determined according to Sadasivam and Manickam (1996) and the amount of amylose was calculated from amylose (Merck, Germany) standard curve. The amount of amylopectin was obtained by subtracting the amylose content from that of starch.

Extract of malt analysis

Extract of malt analysis was carried out as per AOAC Official Method 935.30 (2005) with minor changes. Malt samples were ground in a coffee grinder and the extracts were analyzed after filtration through Whatman No. 4 filter paper. Specific gravity was determined by pycnometer method (50 ml capacity) as per AOAC Official Method 920.50 (2005) at 20°C. Viscosity was determined by viscometer method using an Ostwald viscometer at 20°C as per

AOAC Official Method 974.07 (2005). Extract yield of malt was determined by reference to specific gravity value and the values were expressed as percent dry basis. Color measurement was done according to EBC Method 4.7.1 (1998) and the result was expressed as EBC units. Total soluble solids (TSS) was determined using hand refractometer (Hanna Instrument, Portugal). Turbidity was determined using turbidity meter (Hanna Instrument, Portugal) at 26°C. pH was determined by digital pH meter (Hanna Instrument, Portugal). Starch-iodine test, filtration rate (Whatman No. 4 filter paper) and aroma were assessed as per AOAC (2005).Total free amino acids and free amino nitrogen contents were determined as per AOAC official Method 945.30 (2005). Total reducing sugar was determined by Lane-Eynon method as per Ranganna (1986) and the results were expressed as maltose.

Mashing and wort analysis

Finger millet malts were ground in a coffee grinder and mashed using malt flour to water ration of 1:5 (m/v) following US mashing process that is commercially used for barley malt for lager beer as per Matz (1991) with minor modifications. The mash temperature was step-wise raised to different temperatures and held at these temperatures for different times (protein rest: 45 min at 45°C; sugar rest: 18 min at 59°C; dextrinizing: 30 min at 70°C; conversion: 15 min at 74°C and mashing off: 8 min at 80°C). After mashing, the mashes were cooled, filtered through Whatman No. 41 filter paper and the worts were analyzed for TSS, pH, total free amino acids, FAN, extract and total reducing sugar contents as described earlier.

Statistical analysis

The experiment was conducted in a completely randomized design (CRD) with three replications. The data were analyzed using Genstat Discovery Program as per Buysse et al. (2007) at 5% level of significance and the means were compared by LSD method.

RESULTS AND DISCUSSION

Chemical changes during malting of finger millets

Chemical constituents of unmalted and malted finger millets were determined and the results are shown in Table 1.

Total reducing sugar

Total reducing sugar content in unmalted millets varied from 70.0 in *Dalle* to 130.0 mg dextrose equivalent (DE)/100 g dry matter (DM) in *GE 5016*, with a mean of 106.1 mg DE/100 g DM. Except in *Dalle*, there was no significant difference ($p>0.05$) on the content of total reducing sugar among the millet varieties. For malted millet, total reducing sugar varied from a minimum of 1410.0 mg DE/100 g DM in *GE 5016* to a maximum of 5953.3 mg DE/100 g DM in *Juwain*. The mean total reducing sugar content in malted millets was 2516.7 mg DE/100 g DM. Malting incurred a significant increase in total reducing content in all millet cultivars. The extent of increment differed with varieties, with *Juwain* having the highest increase of about 53-fold, while *GE 5016* had the lowest increment of about 10-fold. Total reducing sugar contents between *GE 5016* and *Dalle* and between *GPU 0025* and *Okhle* malts did not differ ($p>0.05$) (Table 1). The results showed that the extent of total reducing sugar content in the malts was related to the degree of starch loss during germination. Increase in reducing sugar in malted finger millet was also reported by Nirmala et al. (2000).

Glucose

Glucose content in native millets ranged from 28.7 to 86.7 mg/100 g DM, with a mean of 54.62 mg/100 g DM; however, the values were not statistically different ($p>0.05$). Glucose content in malted millets was highest in *Juwain* (4553.3 mg /100 g DM), followed by *Kabre* (1723.3 mg/100 g DM) while it was lowest in *GE 5016* (883.3 mg/100 g DM), with a mean content of 1788.89 mg/100 g DM for the six millet malts. Malting led to a significant increase in glucose content in all millet varieties. A maximum glucose increment of 96-fold was observed in *Juwain* malt; while a minimum increment of 12-fold was found in *GE 5016* millet malt (Table 1). Glucose contents between *GPU0025* and *Okhle* and between *GE 5016* and *Dalle* malts were not significantly different. From Table 1, it can be envisaged that mean ratios of total reducing sugar to glucose in native and malted millets were 2:1 and 3:2 respectively, indicating that glucose was being utilized at a greater extent during seed germination.

Starch

Starch content in the native millets was in the range of 71.32 to 79.86% (db), with a mean content of 73.58% (db). *Juwain* millet had the highest starch content (79.86% db) of all the millet varieties, while the values among other cultivars did not differ ($p>0.05$). Similarly, starch content in malted millets ranged from 63.74 to 67.12% (db), with a mean value of 65.53% (db); however, the values were not significantly different. Germination significantly reduced starch content in all millet varieties. A maximum starch loss of 20.19% was found in *Juwain* malt, while a minimum of 5.89% was found in *GE 5016* malt, with a mean loss of 10.77% among the six millet varieties.

Sripriya et al. (1997) reported that the starch content of finger millet was 81% db which decreased to 71.3% db on germination at 30°C for 24 h. Decrease in starch content by 33.85% after 4 days of malting was reported in finger millet (Nirmala et al., 2000). Reduction in starch content from 33 to 58.4% in 96 h germinated sorghum cultivars was also reported by Subramanian et al. (1992). Morall and Briggs (1978) reported a 65% decrease in

Table 1. Chemical changes during malting of finger millets.

Attributes*	Samples	Values**					
		GPU 0025	***GE 5016***	***Juwain***	***Okhle***	***Kabre***	***Dalle***
Reducing sugar as glucose (mg %)	Millet	101.7^{a} (2.9)	130.0^{a} (30.0)	110.0^{a} (20.0)	105.0^{a} (5.0)	120.0^{a} (10.0)	70.0^{b} (10.0)
	Malt	2073.3^{c} (160.1)	1410.0^{d} (55.7)	5953.3^{e} (197.3)	1996.7^{c} (193.0)	2116.7^{b} (160.1)	1550.0^{d} (287.9)
Glucose (mg %)	Millet	50.8^{a} (5.9)	67.7^{a} (1.5)	46.8^{a} (3.2)	86.7^{a} (2.9)	47.0^{a} (4.2)	28.7^{a} (0.2)
	Malt	1340.0^{b} (334.2)	883.3^{c} (196.6)	4553.3^{d} (274.3)	1243.3^{b} (285.7)	1723.3^{e} (25.2)	990.0^{c} (165.2)
Starch (%)	Millet	72.93^{a} (3.54)	71.32^{a} (1.85)	79.86^{b} (0.18)	72.88^{a} (2.16)	71.88^{a} (3.07)	72.60^{a} (2.52)
	Malt	64.08^{c} (3.20)	67.12^{c} (1.81)	63.74^{c} (0.88)	66.80^{c} (2.05)	66.22^{c} (2.94)	65.22^{c} (1.95)
Amylose (%)	Millet	21.48^{a} (1.38)	22.22^{e} (0.76)	24.13^{d} (0.08)	21.36^{ae} (0.84)	20.42^{af} (1.17)	20.39^{af} (0.95)
	Malt	18.77^{c} (1.29)	17.87b^{c} (0.67)	19.27^{cf} (0.37)	16.62^{b} (0.73)	18.74^{cg} (1.14)	16.87^{b} (0.71)
Amylopectin (%)	Millet	51.45^{af} (2.16)	49.11^{bf} (1.09)	55.72^{d} (0.11)	51.52^{af} (1.32)	51.46^{af} (2.58)	52.21^{a} (1.57)
	Malt	45.30^{e} (1.91)	49.25^{bf} (1.14)	44.47^{e} (0.52)	50.18^{acf} (1.33)	47.47^{b} (1.80)	48.44^{bc} (1.23)
Total phenolic as gallic acid (mg %)	Millet	103.7^{a} (9.6)	229.2^{b} (15.9)	60.9^{c} (10.2)	165.1^{df} (10.6)	165.9^{d} (5.2)	87.3^{e} (5.5)
	Malt	148.6^{fh} (12.2)	247.8^{g} (8.8)	135.3^{hj} (7.5)	158.7^{df} (8.1)	185.9^{i} (6.8)	123.1^{j} (14.3)
Total flavonoid as rutin (mg %)	Millet	55.3^{a} (6.1)	141.7^{b} (20.3)	35.2^{a} (5.3)	95.8^{c} (3.1)	93.9^{c} (7.0)	52.2^{a} (10.8)
	Malt	98.0^{c} (15.4)	236.3^{d} (33.5)	50.1^{a} (7.0)	120.7^{bc} (8.7)	114.8^{bc} (1.7)	109.1^{c} (41.9)
Tannin as tannic acid (mg %)	Millet	227.1^{ae} (14.4)	566.0^{b} (11.9)	169.9^{c} (20.1)	373.3^{d} (12.1)	374.9^{d} (6.5)	245.7^{e} (16.5)
	Malt	212.2^{a} (12.5)	301.8^{f} (3.2)	173.7^{c} (1.1)	235.1^{e} (10.7)	245.2^{e} (7.5)	178.1^{c} (8.5)
Antioxidant activity (%)	Millet	55.39^{a} (2.82)	77.30^{b} (3.97)	18.23^{c} (3.02)	74.46^{b} (2.14)	71.62^{b} (5.07)	53.18^{ae} (6.59)
	Malt	30.25^{gd} (7.22)	73.05^{b} (15.42)	16.49^{c} (4.81)	42.83^{ef} (7.29)	40.69^{fd} (8.58)	28.86^{gc} (6.01)

*Results are expressed in dry weight basis. **values are the means of three replications. Figures in the parentheses are standard deviations. Means followed by similar superscripts in a row are not significantly different (p>0.05) by LSD.

starch content in germinated barley. The decrease in starch content in the grain was due to hydrolysis by native enzymes (α- and β-amylases) during germination resulting in increase in reducing sugars (Dewar et al., 1995).

The minimum amylose content in native millets was 20.39% (db) in *Dalle* millet, while maximum was 24.13% (db) in *Juwain* millet, with a mean content of 21.68% (db). Germination significantly decreased amylose in all malts compared to their respective unmalted millets. Amylose content in malted millets varied from 16.62% (db) in *Okhle* to 19.27% (db) in *Juwain* with a mean value of 18.02% (db). Amylose reduction ranged from 8.23 to 22.19%, with the minimum reduction being

found in *Kabre* malt and the maximum in *Okhle* malt. This study revealed that amylose accounted for 28.19 to 31.25% of the total starch content in native millet, with a mean of 29.47%. Similarly, in malted millets, amylose accounted for 24.88 to 30.23% of the total starch, with a mean of 27.53%. Amylose content in sorghum and millets were: proso millet, 28%; sorghum, 24%; pearl millet, 21.1%; foxtail millet, 17.5%; kodo millet, 24.0%; and finger millet, 16.0% wet basis (wb) (Zarnkow et al., 2007) and the obtained result appeared a bit higher than that reported for finger millet.

Amylopectin contents in native millets varied within the variety between 49.11% (db) in *GE 5016* and 55.72% (db) in *Juwain*, with a mean content of 51.91% (db). Similarly, malted millets had amylopectin contents ranging from 44.47% (db) in *Juwain* to 50.18% (db) in *Okhle*, with a mean of 47.52% (db). Except in *GE 5016* and *Okhle*, malting significantly decreased amylopectin in all other varieties. Maximum amylopectin reduction was observed in *Juwain* millet malt (20.19%), while a minimum was found in *Dalle* malt (7.22%). It was observed that amylopectin accounted for 68.75 to 71.81% of the total starch in native finger millet, with a mean of 70.53%; while in malted millets, it accounted for 69.68 to 75.12%, with a mean of 72.45%. Moreover, amylose to amylopectin ratios in native and malted millet starch were found to be 29:71 and 28:72 respectively.

Total phenolics

Total phenolics (TPs) contents greatly varied among native millet cultivars ranging from 60.9 mg gallic acid equivalent (GAE)/100 g DM in *Juwain* to 229.2 mg GAE/100 g DM in *GE 5016*, with a mean content of 135.4 mg GAE/100 g DM. TPs contents between *Okhle* and *Kabre* millets were not different ($p>0.05$), while they were significantly different among other native millets. Similarly, TPs content in malted millets ranged from 123.1 mg GAE/100 g DM in *Dalle* to 247.8 mg GAE/100 g DM in *GE 5016* millet malts, with a mean of 166.6 mg GAE/100 g DM. Except in *Okhle* millet, malting significantly increased ($p<0.05$) TPs contents in all other millet varieties. The minimum TPs increment was 8.12% in *GE 5016* malt, while the maximum was 122.17% in *Juwain* millet malt. Analogous result of increase in phenolics during malting of barley was reported by Dvorakova et al. (2008). Nwanguma and Eze (1996) also observed TPs increments between 7- and 14-fold in sorghum cultivars.

Contrary to our findings, Sripriya et al. (1997) reported a decrease in total phenolics content in finger millet malt. Similar decline in phenolics on malting of millet were also reported by Chethan et al. (2008) and Chukwura and Muller (1982). Increase in TPs during germination in this study may be expected as a result of loss of dry matter as well as hydrolysis of condensed tannins due to germination which can be justified from decrease in tannin on malting (Table 1). Furthermore, it can be anticipated that during germination, different enzymes were produced and contributed to the modification of grain composition resulting in the release of bound phenolics and facilitating more extraction of phenolics than that of native grain. According to Maillard and Berset (1995), increase in total phenolics on malting may be due to enzymatic release of bound phenolic compounds during seed germination. Maillard et al. (1996) reported that polyphenols in millet occur both in free and bound forms. Increase in malt TPs may be due to the action of induced esterase activity on bound phenolics, which act on various phenolic acid esters linked either to arabinoxylans or other non-strach polysaccharides.

Total flavonoids

Total flavonids (TFs) contents in unmalted and malted millets ranged from 35.2 mg rutine equivalent (RE)/100 g DM in *Juwain* to 141.7 mg RE/100 g DM in *GE 5016*, and from 50.1 mg RE/100g DM in *Juwain* to 236.3 mg RE/100 g DM in *GE 5016* respectively (Table 1). The mean TFs contents in six native and malted finger millets were 79.0 and 121.5 mg RE/100 g DM respectively. The TFs content was not affected by malting in *Juwain*, *Okhle* and *Kabre* millets, while it was significantly increased ($p<0.05$) in other millet varieties. Results (Table 1) indicated that the TFs increment was highest in *Dalle* malt (109%), followed by *GPU 0025* (77.22%), while it was lowest in *Kabre* millet malt (22.26%). It was further found that both the TPs and TFs contents in malted millets were related with that of their contents in the native millets (that is, the higher the TPs and TFs contents in the native millets, the higher will be their contents in the malts).

Tannin

The tannin contents in native millets ranged from 169.9 mg tannic acid equivalent (TAE)/100 g DM in *Juwain* to 566.0 mg TAE/100 g DM in *GE 5016*, with a mean of 326.2 mg TAE/100 g DM in six finger millet varieties. Similarly, tannin contents in malted millets was in the range of 173.7 (*Juwain*) to 301.8 mg TAE/100 g DM (*GE 5016*), with a mean content of 224.6 mg TAE/100 g DM. Except in *GPU 0025* and *Juwain*, malting significantly decreased tannin contents in other millet varieties. The maximum tannin reduction of 46.7% was observed in *GE 5016* malt, while a minimum of 27.5% was found in *Dalle* malt. The results of tannin contents in native millet varieties were analogous to those reported by Odoemelam and Osu (2009) (0.48 to 0.53%) in Nigerian millet variety, Wadikar et al. (2006) (average value of 0.34%) in three Indian hill region finger millets and Udayasekhara and Deosthale (1988) (0.35 to 2.39%) in

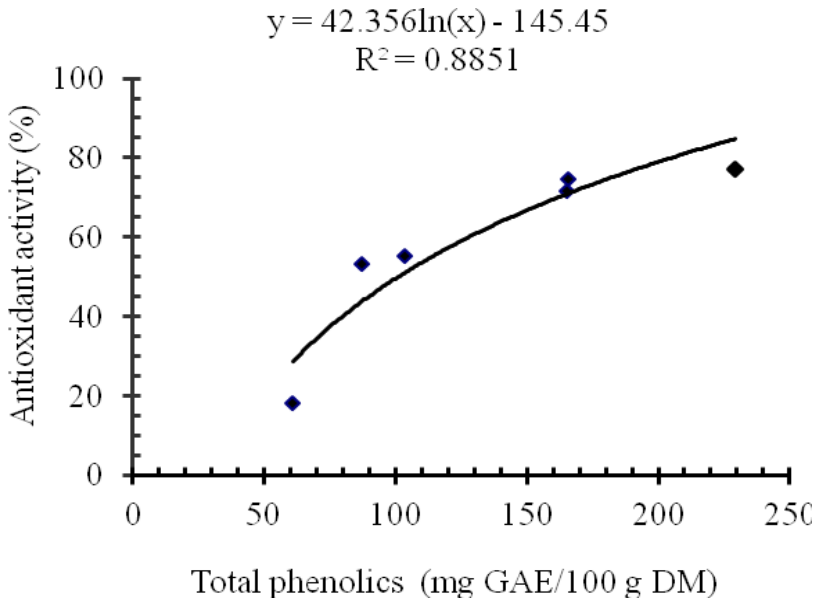

Figure 1. Effect of total phenolics on antioxidant activity of native millet.

brown finger millet varieties. Reichert et al. (1980) also observed a 25% tannin reduction in germinating barley and they noted that the loss could partly be due to polymerization of the tannins in water and/or their possible carbohydrates and proteins. Larger tannin polymers or complexes of tannin with other biopolymers would be insoluble and thus not extractable.

Antioxidant activity

Large variations in antioxidant activity among unmalted (18.23 to 77.30%) and malted (16.49 to 73.05%) finger millets were observed. Except for *GE 5016* and *Juwain* native millets, malting significantly ($p<0.05$) decreased antioxidant activity in other varieties. Malting reduced antioxidant activity by about 25.14, 31.63, 30.93 and 24.32% in *GPU 0025*, *Okhle*, *Kabre* and *Okhle* malts respectively, with a mean reduction of 28.01%. The antioxidant activity of native millet was exponentially related to its TPs content (Figure 1), however, this relationship was not apparent in malted millet. In contrast to our findings, increase in DPPH antiradical power in barley malt was reported by Dvorakova et al. (2008) and could possibly be due to the development of Maillard products during malt kilning.

Of the various chemical characteristics of malts, free amino nitrogen (FAN), tannin and total phenolic contents can be taken as prominent ones, since FAN is essential for the growth of yeast during brewing and excessive presence of tannin and total phenolics will pose problem of beer haze formation. Considering these aspects, malt obtained from *Juwain* finger millet seems appropriate; however, our earlier study showed that *Juwain* millet malt exhibited lower β-amylase activity and total diastatic power (data not shown).

Physico-chemical properties of different millet malt extracts

Millet malts prepared by germinating for 48 h at 28± 1°C were used for extract of malt analysis and the results are shown in Table 2. All extracts were found to be aromatic. Starch-iodine test showed negative results (yellow to brick red coloration) indicating the absence of starch in malt extracts. Except for *Juwain* millet malt, filtration rate was normal in other malt extracts. Extracts TSS ranged from 7.90 to 8.9 °Bx, with a mean of 8.22 °Bx. There was a significant difference ($p<0.05$) in color among malt extracts. Maximum color was recorded in *GE 5016* malt extract (5.78 EBC units) while a minimum of 2.77 EBC unit was found in *Dalle* malt extract. Extract color values were within the range for different British floor malts (2.5 to 7.0 EBC units). Turbidity significantly varied ($p<0.05$), ranging from 9.97 FTU in *Dalle* malt extract to 24.10 FTU in *Juwain* malt extract, with a mean of 16 FTU. Extract pH was in the range of 5.76 to 6.31. The pH of *GPU 0025* and *Kabre*, and that of *GE 5016* and *Okhle* malt extracts were not different ($p>0.05$).

Total free amino acids (TFAAs) varied widely among malt extracts. The lowest TFAAs was 13.9 mg glycine equivalent (GE)/100 ml in *GE 5016*, while the highest was 48.4 mg GE/100 ml in *Juwain* malt extract. TFAAs contents between *GPU 0025* and *Kabre*, and between *Okhle* and *Dalle* malt extracts were not different ($p>0.05$).

Table 2. Physico-chemical characteristics of finger millet malt extracts.

Attributes	Mean values*					
	GPU 0025	***GE 5016***	***Juwain***	***Okhle***	***Kabre***	***Dalle***
TSS (ºBx)	8.12^{ac} (0.10)	7.90^{b} (0.10)	8.90^{d} (0.10)	8.03^{ab} (0.06)	8.10^{a} (0.10)	8.27^{c} (8.27)
Color (EBC unit)	3.92^{a} (0.03)	5.78^{b} (0.02)	4.38^{c} (0.03)	5.67^{d} (0.01)	3.17^{e} (0.02)	2.77^{f} (0.02)
Turbidity (FTU)	13.05^{a} (0.66)	21.49^{b} (0.30)	24.10^{c} (0.14)	15.64^{d} (0.09)	11.73^{e} (0.12)	9.97^{f} (0.16)
pH	6.16^{a} (0.03)	6.31^{bd} (0.01)	5.76^{c} (0.01)	6.29^{d} (0.01)	6.14^{a} (0.01)	6.21^{e} (0.01)
TFAA as glycine (mg/100 ml)	36.7^{a} (3.5)	13.9^{b} (0.9)	48.4^{c} (2.4)	25.8^{d} (0.5)	33.6^{a} (1.8)	24.1^{d} (2)
FAN as glycine (mg/100 ml)	6.8^{a} (0.5)	2.6^{b} (0.1)	9^{c} (0.3)	4.8^{d} (0.1)	6.2^{a} (0.3)	4.5^{d} 90.3)
Glucose (g/100 ml)	1.62^{a} (0.03)	1.22^{b} (0.05)	2.51^{c} (0.01)	1.52^{d} (0.12)	1.78^{e} (0.03)	1.48^{f} (0.01)
Reducing sugar as maltose (g/100 ml)	5.48^{a} (0.13)	4.50^{b} (0.13)	6.93^{c} (0.22)	5.27^{a} (0.25)	6.27^{d} (0.39)	5.13^{a} (0.02)
Extract yield of malt (%, db)	83.67^{a} (0.29)	87.80^{b} (0.26)	88.83^{c} (0.15)	82.17^{d} (0.67)	82.10^{d} (0.46)	80.20^{e} (0.26)
Viscosity (cP)	1.21^{ac} (0.02)	1.22^{a} (0.01)	1.24^{b} (0.01)	1.22^{a} (0.01)	1.20^{c} (0.01)	1.18^{b} (0.01)
Starch-iodine test	−	−	−	−	−	−
Filtration rate	++	++	+	++	++	++
Aroma	√	√	√	√	√	√

*Values are the means of three determinations. Figures in the parentheses are standard deviations. Means followed by similar superscripts in a row are not significantly different (p>0.05) by LSD. −: negative test; ++: normal rate; +: slow rate; √: characteristics aroma.

Table 3. Chemical properties of finger millet malt worts (n = 3).

Attributes	Values for different millet malt worts*		
	Dalle	***Kabre***	***Juwain***
TSS (°Bx)	12.43^{a} ± 0.06	12.43^{a} ± 0.06	13.07^{b} ± 0.12
pH	5.44^{a} ± 0.01	5.66^{b} ± 0.01	5.49^{a} ± 0.01
Extract (g/100 g)	12.00^{a} ± 0.10	12.20^{a} ± 0.10	12.70^{b} ± 0.10
TFAA as glycine (mg %)	104.90^{a} ± 0.90	106.00^{a} ± 0.70	108.00^{b} ± 0.30
FAN as glycine (mg %)	19.50^{a} ± 0.20	19.80^{a} ± 0.10	20.30^{b} ± 0.10
Reducing sugar as maltose (%)	7.64^{a} ± 0.10	10.45^{b} ± 0.04	9.66^{c} ± 0.36

*Values are the means ± S.D. Means followed by similar superscripts in a row are not significantly different (p>0.05) by LSD.

It was found that TFAAs content in the extracts were related with that of its content in the malt [that is, malts containing higher TFAAs also resulted higher TFAAs in the extract (data not shown)]. FAN content (glycine equivalent) in the extracts were between 2.6 and 9.0 mg/100 ml, with minimum content being found in *GE 5016* malt extract and the maximum in *Juwain* millet malt extract. Glucose content differed significantly ($p<0.05$) among malt extracts, ranging from 1.22 g/100 ml in *GE 5016* extract to 2.51 g/100 ml in *Juwain* malt extract.

Similarly, millet variety had a significant effect on the total reducing sugar content of the extract. The reducing sugar contents in the extracts were in the range of 4.5 to 6.93 g maltose/100 ml, where the values among *GPU 0025*, *Okhle* and *Dalle* malt extracts were not different ($p>0.05$). The viscosity of the malt extracts were in the range of 1.18 to 1.24 cP, with a mean of 1.21 cP. The highest viscosity observed in *Juwain* millet malt extract could be attributed to the presence of higher soluble solids in the extract (Table 2). Extract yield ranged from 80.20% db in *Dalle* to 88.83% db in *Juwain* millet malt extract. Except between *Okhle* and *Kabre*, the extract yields were significantly different among other malts. Despite lower β-amylase and diastatic power of *Juwain* millet malt (data not shown), it exhibited the highest extract yield of all the malts studied. Regarding the results of malt extract analysis, all extracts had satisfactory color values. Although clarity of *Dalle* malt extract was significantly superior (that is, the lowest turbidity value), it had lower FAN content and extract yield (Table 2). Hence, in order to obviate the dilemma of choosing the best malt for further study, mashing was carried out using *Dalle*, *Kabre* and *Juwain* millet malts.

Chemical characteristics of different millet malt worts

Chemical characteristics of worts derived from *Dalle*, *Kabre* and *Juwain* millet malts are shown in Table 3. TSS, extract, total free amino acids and FAN contents of

wort derived from *Juwain* malt were significantly higher ($p<0.05$) than those of *Dalle* and *Kabre* malts, while the values between the latter two did not differ significantly. Wort pH was in the range of 5.44 to 5.66, with an average value of 5.53. Total reducing sugar was maximum in *Kabre* malt wort (10.45 g/100 ml as maltose), while a minimum of 7.64 g/100 ml was found in *Dalle* malt wort. Wort composition varies according to the ingredients used in its preparation. Burger and La Berger (1985) reported that the extract, pH and FAN of various worts intended for the production of North American lager beer were 10.8 to 12.5 °P, 5.2 to 5.7 and 140 to 260 mg/L respectively, which are comparable to our results. The results of wort FAN contents are in close agreement with those reported by Eneje et al. (2001), who found FAN contents in the range of 14.8 to 16.8 mg/100 ml in millet (*Pennisetum maiwa*) malt worts.

The pH and FAN contents in a typical wort derived from finger millet and barley malts combination (50:50) were reported to be 6.2 and 62 mg/L respectively, while the values for an all-malt wort were 5.8 and 226 mg/L respectively (Venkatanarayana et al., 1979). Similarly, a FAN content of 10.7 mg/100 ml was also reported in buckwheat malt wort (Phiarais et al., 2005). Analogous results of pH of different sorghum malt worts (5.39 to 6.09) were also reported by Okrah (2008). A total free amino acids content of 1.65 g/L was also reported by Hough (1985) in typical UK wort. Therefore, the obtained results of pH, extract, FAN and reducing sugar contents of millet malt worts were found to be within the reported range for different cereal malt worts. Hence, based on the results of malt, malt extract and wort analyses, *Kabre* finger millet was found to be superior of all millet varieties for malting to produce lager beer.

Conclusion

Total reducing sugar, glucose and total phenolics contents increased while starch and amylose decreased on malting in all millet varieties. Amylopectin was not affected by malting in *GE 5016* and *Okhle* millet, while it decreased in other millet varieties. A wide varietal difference in total flavonoids, tannin and antioxidant activity existed in both native and malted millets. Finger millet variety had a significant effect on chemical characteristics of malt extracts and except for *GE 5016* millet malt, the chemical characteristics of all other malt extracts were satisfactory. Chemical analyses of worts revealed that worts derived from *Dalle*, *Kabre* and *Juwain* malts were all acceptable; however, FAN content in these worts needs to be increased as it has a vital role in beer fermentation.

ACKNOWLEDGEMENT

The authors would like to offer their sincere thanks to Nepal Agriculture Research Council (NARC), Hill Crops Research Program, *Kabre*, for providing different samples of Nepalese finger millet varieties used in this study.

REFERENCES

AOAC (2005) Official Methods of Analysis of AOAC International, 18th Edn. AOAC International Suite Gaithersburg, Maryland, USA.
Balkrishna Rao K, Mithyantha MS, Devi LS, Peru NG (1973). Nutrient content of some new ragi varieties. J. Agric. Sci., 7: 562-565.
Briggs DE, Hough JS, Stevens R, Young TW (1981). Malting and Brewing Science, Vol. I. London, Chapman and Hall.
Burger WC, La Berger DE (1985). Malting and Brewing Quality. In: Barley, Rasumusson D (ed.). Am. Soc. Agron. Madison, WI.
Buysse W, Stern R, Coe R, Matere C (2007). Genstat Discovery Edition 3 for everyday use. ICARF Nairobi, Kenya.
Chethan S, Sreeram YN, Malleshi NG (2008). Mode of inhibition of finger millet malt amylases by the millet phenolics. Food Chem., 111: 187-191.
Chukwura EN, Muller HG (1982). Effect of tannic acid on low tannin African sorghum variety in relation to carbohydrate and amylase. J. Food Sci., 47: 1380-1381.
Daussant J, Sadowski J, Ziegler P (1994). Cereal β-amylases: diversity of the β-amylase isozyme status within cereals. J. Plant Physiol., 143: 585-590.
Deosthale YG, Nagarajan V, Pant KC (1970). Nutrient composition of some varieties of ragi. Indian J. Nutr. Diet., 7: 80.
Dewar J, Taylor JRN, Joustra SM (1995). Accepted Methods of Sorghum Malting and Brewing Analysis. CSIR Food Science and Technology, Prertoria, South Africa.
Dvorakova M, Guido LF, Dostalek P, Skulilova Z, Moreira MM, Barros AA (2008). Antioxidant properties of free, soluble ester and insoluble bound phenolic compounds in different barley varieties and corresponding malts. J. Inst. Brew., 114(1): 27-32.
EBC (1998). European Brewery Convention, Analytica, 5th edn. Verlag Hans Carl, Nurnberg, Germany.
Ekundayo JA (1996). The production of *pito*: a Nigerian fermented beverage. J. Food Technol., 4: 217-225.
Eneje LO, Obeiekezie SO, Aloh CU, Agu RC (2001). Effect of milling and mashing procedures on millet (*Pennisetum maiwa*) malt wort properties. Process Biochem., 36: 723-727.
FAOSTAT (2004). Food and Agriculture Organization Statistical Database. faostat.fao.org.
Fasano A, Catassi C (2001). Current approaches to diagnosis and treatment of celiac disease. An evolving spectrum. Gastroenterology, 120: 636-651.
Hough JS (1985). The Biotechnology of Malting and Brewing. Cambridge Univ. Press, Cambridge, England.
Institute of Brewing and Distilling (2005). African beer production 2003/2004. African Section News Letter, October, p. 7.
Maillard MN, Berset C (1995). Evaluation of antioxidant activity during kilning: Role of insoluble bound phenolic acids of barley and malt. J. Agric. Food Chem., 43: 1789-1793.
Maillard MN, Soum MH, Boivin P, Berset C (1996). Antioxidant activity of barley and malt: relationship with phenolic content. Lebensmittel-Wissenschaft Und-Technoogie, 29: 238-244.
Makokha AO, Oniango RK, Njoroge SM, Kamar OK (2002). Effect of traditional fermentation and malting on phytic acid and mineral availability of sorghum (*Sorghum bicolor*) and finger millet (*Eleusine coracana*) grain varieties grown in Kenya. Food Nutr. Bull., 23: S241-245.
Malleshi NG, Desikachar HSR (1986). Nutritional value of malted millet flours. Qual Plant Foods Hum. Nutr., 36(3): 191-196.
Malleshi NG (2005). Finger millet (ragi). The Wonder Grain. IFIS, http://www. ieis.org/fsc.ixid 13110. In: Mode of inhibition of finger millet malt amylases by the millet phenolics. , Chethan S, Sreeram YN, Malleshi NG (2008). Food Chem., 111: 187-191.
Malleshi NG, Desikachar HSR, Tharanathan RN (1986). Free sugars

and non-starch polysaccharides of finger millet (*Eleusine coracana*); pearl millet (*Pennisetum typhoideum*), Foxtail millet (*Setaria italica*) and their malts. Food Chem., 20: 253-261.
Matz S.A. (1991). The Chemistry and Technology of Cereal as Food and Feed, 2nd. edn. CBS Publishers and Distributors, New Delhi, India, pp. 627, 635.
Morall P, Briggs DE (1978). Changes in cellwall polysaccharides of germinating barley grains. Phytochemistry, 17: 1495-1502.
NARC (2010). Annual Report, (July 16, 2008 – July 15, 2009). Nepal Agriculture Research Council (NARC). Hill Crops Research Program, Kabre, Nepal.
Nirmala M, Subba Rao MVSS, Muralikrishna G (2000). Carbohydrates and their degrading enzymes from native and malted finger millet (Ragi, *Eleusine coracana*, Indaf-15). Food Chem., 69(2): 175-180.
Nout MJR (1981). Aspects of the manufacture and consumption of Kenyan traditional beverages. Wageningen, The Netherlands. In: The brewing potential of *Acha* (*Digitaria exilis*) malt compared with pearl millet (*Pennisetum typhoides*) malt and sorghum (*Sorghum bicolor*) malts, Nzelibe CN, Nwasike CC (1995). J. Inst. Brew., 101: 345-350.
Nwanguma BC, Eze MO (1996). Changes in the concentrations of the polyphenolic constituents of sorghum during malting and mashing. J. Sci. Food Agric., 70: 162-169.
Odoemelam SA, and Osu CI (2009). Evaluation of the phytochemical content of some edible grains marketed in Nigeria. E-J. Chem., 6(4): 1193-1199.
Okrah SG-A (2008). Screening of six local sorghum varieties for their malting and brewing qualities. M.Sc. Dissertation, Department of Biochemistry and Biotechnology, Kwame Nkrumah Univ. of Science and Technology, Ghana.
Olori MO, Makinwa EO, Irefin IA (1996). Indigenous technological capability development in the brewing industry in Nigeria: an engineering economic assessment and policy implications. Food Rev. Int., 12: 511-523.
Pelembe LAM, Dewar J, Taylor JRN (2002). Effect of malting conditions on pearl millet malt quality. J. Inst. Brew., 108: 7-12.
Pelembe LAM, Dewar J Taylor JRN (2004). Effect of germination moisture and time on pearl millet malt quality with respect to its opaque and lager beer brewing potential. J. Inst. Brew., 110(4): 320-325.
Phiarais BP, Wijngaard HH, Arendt EK (2005). The impact of kilning on enzyme activity of buckwheat malt. J. Inst. Brew., 111(3): 290-298.
Ranganna S (1986). Handbook of Analysis and Quality Control for Fruit and Vegetable Products, 2nd. edn, Tata McGraw-Hill Publishing Co., Limited, India.
Ravindran G (1991). Studies on millets: proximate composition, mineral composition and phytate and oxalate contents. Food Chem., 39: 99-107.
Reichert RD, Fleming SE, Schwab DJ (1980). Tannin deactivation and nutritional improvement of sorghum by anaerobic storage H_2O-HCl, or NaOH treated grain. J. Agric. Food Chem., 28: 824-829.
Sadasivam S, Manickam A (1996). Biochemical Methods, 2nd edn. New Age International (P) Limited, Publishers, New Delhi, India.
Shayo NB, Tiisekwa BPM, Laswai HS, Kimaro JR (2001). Malting characteristics of Tanzania finger millet varieties. Food Nutri. J. Tanzania, 10 (1): 1-3.
Shen Y, Jin L, Xiao P, Lu Y, Bao J (2009). Total phenolics, flavonoids and antioxidant capacity in rice grains and their relations to grain color, size and weight. J. Cereal Sci., 42: 106-111.
Shukla SS, Gupta OP, Sawarkar NJ, Tomar AK, Sharma YK (1986). Malting quality of ragi varieties: Nutrient and mineral composition of their malts. J. Food Sci. Technol., 23: 235-237.
Sing G, Kapoor IPS, Sing P, de Heluani CS, de Lampasona MP (2008). Chemistry, antioxidant and antimicrobial investigation on essential oil and oleoresins of *Zingibe officinale*. Food Chem. Toxicol., 46: 3295-3302.
Sripriya G, Antony U, Chandra TS (1997). Changes in carbohydrate, free amino acids, organic acids, phytate and HCl extractability of minerals during germination. Food Chem., 58(4): 345-350.
Subramanian V, Murthy DS, Rao S, Jambunathan R (1992). Chemical changes and diastatic ativity in grains of sorghum (Sorghum bicolor) cultivars during germination. J. Sci. Food Agric., 58: 35-40.
Taylor JRN, Schober TJ, Bean SR (2006). Novel food and non-food uses for sorghum and millets. J. Cereal Sci., 44: 252-271.
Udayasekhara P, Deosthale YG (1988). In vitro availability of iron and zinc in white and color ragi (*Eleusine coracana*): role of tannin and phytate. Plant Food Hum. Nutr., 38: 35-41.
Venkatanarayana S, Sreenivasa Murthy V, Satyanarayana Rao BA (1979). The use of ragi (*Eleusine corana*) in brewing. J. Food Sci. Technol., 16: 204-206.
Wadikar DD, Vasudish CR, Premavalli KS, Bawa AS (2006). Effect of variety and processing on antinutrients in finger millet. J. Food Sci. Technol., 43(4): 370-373.
Zarnkow M, Kebler M, Burberg F (2007). The use of response surface methodology to optimize malting conditions of Proso millet (*Panicum miliaceum* L.) as a raw material for gluten free foods. J. Inst. Brew., 113(3): 280-292.