NUTRITIONAL EVALUATION OF MUTANTS AND SOMACLONAL VARIANTS OF SORGHUM (*SORGHUM BICOLOR* (L) MOENCH) IN KENYA

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Abstract
Several improved sorghum varieties are adapted to semi-arid and tropic environments. Selection of varieties meeting specific local food and industrial requirements from this great biodiversity is important for food security in Kenya and other developing countries. More than 7000 sorghum varieties have been identified hence, need for further characterization with respect to nutritional traits. *Sorghum bicolor* (L) Moench mutants and somaclone lines (Seredo, Serena, Mtama 1 and El-gardam) were developed towards improvement for drought tolerance at the Jomo Kenyatta University of Agriculture and Technology. Using mutation techniques. X-ray with the dose of 15000R was used to induce genetic variation. Somaclones were produced through somatic embryogenesis on Linsmaier and Skoog's (LS) media with 0.5 M concentration of Mannitol as an osmoticum to simulate drought conditions. The study was conducted to evaluate the chemical composition, B-vitamins, mineral profile, anti-nutrient content and levels of protein digestibility of somaclones, mutants and parents of the *Sorghum bicolor* (L) Moench local cultivar in Kenya (namely Mtama 1, Seredo, El Gardam and Serena). The proximate composition, B-vitamins, anti-nutrient contents and levels of protein digestibility of the flour from the cultivars were determined. The chemical components did not vary among and within varieties ($P \geq 0.05$). Serena and Seredo showed high levels of Anti-nutreint (phytates and Tannins) than Mtama 1 and El-dargam (tannin: 0.03-2.22%, Phytates: 124.3-374 mg/100 g) ($P \geq 0.05$). The somaclones and mutants of the sorghum cultivars except Mtama 1 were noted to have reduced quantities of tannin. Protein digestibility range, between 39.1%-88.4% and were low in Seredo and Serena than in Mtama 1 and El-gardam. No differences ($P \geq 0.05$) were observed among and within the treatments of the same varieties of the sorghum for proximate composition, B-vitamins and mineral compositions ($p < 0.05$). It was concluded that major variations among the varieties arose due to anti-nutrients. High anti-nutrient factors would affect the utilization of the Serena and Seredo varieties since these anti-nutrients reduced the availability other nutrients.

Key words: Varieties, mutants, somaclones, drought-tolerance, nutritional traits, anti-nutrients

1.0 Introduction

Sorghum (Sorghum bicolor L. Moench) is the fifth most important cereal crop in the world after wheat, rice, corn and barley (FAO, 2005). About 90% of the world's sorghum areas lie in the developing countries, mainly in Africa and Asia. This crop is primarily grown in poor areas subject to low rainfall and drought where other grains are unable to survive unless irrigation is available. The future of the sorghum economy is linked with its contribution to food security in Africa, income growth and poverty alleviation in Asia, and efficient use of water in drought-prone regions in much of the developed world.

The sorghum grain quality is affected by factors such as genotype, climate, soil type, and fertilization, among others, which can affect the chemical composition and the nutritive value (Ebadi *et al*., 2005). Starch is the main component of sorghum grain, followed by proteins, non-starch polysaccharides (NSP) and fat (BSTID-NRC, 1996). Its protein content is higher than that of corn although its nutritional protein quality is lower (Dowling et al., 2002). Moreover, high tannins content in sorghum bind to protein, carbohydrates, and minerals making these nutrients unavailable for digestion by the body. Reduction of the tannins levels is possible through decortication, fermentation, germination and chemical treatment according to Beta *et al*., 1999, Dicko *et al*., 2005 and Drina *et al.,* 1990. Sorghum also contains phenolic acids (McDonough *et al*., 1986). The objective of this study was to evaluate the chemical composition, mineral composition, B-vitamins and anti-nutrients (tannin and phytates) content of the parent *Sorghum bicolor* (L) Moench local cultivar in Kenya (namely Mtama 1, Seredo, El Gardam and Serena) compared to their somaclones and the mutants.

2.0 Methodology

Four cultivars of *Sorghum bicolor* (L) Moench seeds form two growing seasons (about 5 kg for each cultivar) were selected from Kenya Agricultural Research Institute (K.A.R.I.) Katumani, a semi arid region in Eastern province of Kenya. They were: Serena, Seredo, Mtama 1 and El-dargam. *Sorghum bicolor* (L) Moench mutants and somaclone lines (Seredo, Serena, Mtama 1 and El-gardam) were developed towards improvement for drought tolerance at the Jomo Kenyatta University of Agriculture and Technology. Mutants were produced by using mutation techniques. X-ray with the dose of 15000R was used to induce genetic variation. Somaclones were obtained through somatic embryogenesis on Linsmaier and Skoog's (LS) media with 0.5 M concentration of Mannitol as an osmoticum to simulate drought conditions (Makobe *et al*., 2006). Ground samples from the seeds from the two growing seasons were use for the food analysis experiment. Each experiment was carried out in duplicates per sample.

2.1 Proximate Analysis

Moisture, protein, carbohydrates, fat, ash and crude fibre were determined according to AOAC methods specification 950.46 (AOAC, 1995).

Tannins: This was done according to vanillin-hydrochloric acid method (Burns, 1963; Price *et al*., 1978).

2.2 Phytates

For phytate determination, HPLC analysis according to Camire and Clydesdale, (1982) was used. 50 mg of each sample being utilized. Extraction was carried out with 25 ml of 3% H_2SO_4 for 30 minutes on a shaker bath (German model KS 259 basic) at medium speed for 30 min at room temperature. The slurry was filtered through fast filter and rinsed using a fine jet stream from a squeeze bottle, with a small volume of extracting solvent. The filtrate was transferred to 50ml centrifuge tubes and placed in boiling water bath for 5 minutes before addition of 3 ml of a $FeCl_3$. The tubes were heated in boiling water bath to allow for the complete precipitation of the ferric phytate complex. Centrifugation was done at 2,500 rpm (Japan model H-2000C) for 10 min. and the supernatant discarded. The precipitates were washed once with 30m distilled water, centrifuged and the supernatant discarded again. Three (3) ml of 1.5N NaOH and a few ml of distilled water were added to the contents of the tubes. The volume will then be brought to approximately 30 ml with distilled water and heated in boiling water bath for 30 minutes to precipitate the ferric hydroxide. The cooled samples were centrifuged and the supernatant transferred to 50ml volumetric flasks. The precipitate was then rinsed with 10 ml distilled water, centrifuged and the supernatant added to the contents of the volumetric flask.

Samples of 2 µl of the supernatant were injected into a HPLC (Shimazu model C-R7A plus) fitted with a 50377 RP-18 (5 µl) column Cat. at an oven temperature of 30°C and RID-6A detector model. A stock solution of the standard containing 10mg/ml of sodium phytate (inositol hexaphosphoric acid C_6H_6 $OPO_3Na_2)_6$ + H_2O) in

distilled water was prepared. Serial dilutions were made for the preparation of the standard curve. Results of the phytate content were obtained as per the calculations of Vohra *et al.,* (1965).

2.4 Minerals

Five grams of sample were weighed in crucibles and transferred to hot plates in the fume hood chamber where they were charred to clear all the smoke from the carbonatious material before transferring them to the muffle furnace. The charred materials were then incinerated at 550ºC until they were reduced to white ashes. The ashes were cooled, 15 ml of 6N HCL was added to each of them in the crucibles before transferring them to 100 ml volumetric flasks. Distilled water was used to top them up to the mark before mineral analysis (AOAC, 1995). Atomic Absorption Flame Emission Spectrophotometer was used for the sodium metal residue analysis of the alkali treated samples (Model A A-6200, Shimadzu, Corp., Kyoto, Japan).

2.5 Protein Digestibility

Protein digestibility was done according to the method described by Mertz *et al*., (1984). This method involved determination of the protein content of sample before and after pepsin enzyme digestion.

The pepsin digestion involved weighing 0.2 g of ground sample that was passed through a 0.4mm screen and adding 35ml of 0.1 M phosphate buffer: pH 2 containing 1.5mg pepsin /ml. Incubation of the pepsin-sample mixture was done at 37ºC for 2hrs with continuous gentle shaking. The suspension was then centrifuged at 4800rpm, at temperatures of 4ºC for 20 min (Centrifuge Model H–2000C, Shimadzu Corp., Kyoto, Japan). The supernatant was discarded and the residue washed with 15ml of 0.1 M phosphate buffer: pH 7 followed by centrifugation as previously done. The supernatant was again discarded and the residue washed on Whatman's No. 3 filter paper in a Buchner funnel. The filter paper containing the undigested protein residue was folded, placed in a digestion tube and dried for 2 hrs at 80ºC.

A blank was prepared and treated in the same way but without the sample. Protein content was determined using AOAC, 1995 Method 928.08.
Calculation: Percentage protein digestibility = (A–B)/A
Where: A = % protein in the sample; and B = % protein factor after pepsin digest.

2.6 Group B-vitamins

A reversed-phase HPLC method by Ekinci and Kadakal (2005), modified from Cho *et al.,* (2000) was used. The sample treatment consisted of SPE with Sep-Pak C_{18} (500 mg) cartridges that enabled separation of water-soluble vitamins and removed most of the interfering components. 20 g of water were added to 5 g of the sample. The mixture was homogenized using a homogenizer at medium speed for 1min. The homogenized samples were centrifuged for 10min at 14×10^3g (Centrifuge Model H–2000C Shimadzu Corp., Kyoto, Japan). The stationary phase preparation involved flushing with 10ml methanol and 10ml water (pH 4.2) to activate it. The homogenized and centrifuged samples were then loaded. The sample was eluted with 5 ml acidified water (pH 4.2) then 10ml methanol at a flow rate of 1ml min^{-1}. The eluent was collected in a bottle and evaporated to dryness. The residue was dissolved in mobile phase and then filtered through 0.45 μm pore size filters. Approximately 20 μl of samples was injected into the HPLC column. The column elute was monitored with a photodiode-array detector at 234nm for thiamine, 324 nm for pyridoxine, 282nm for folic acid, and 261nm for niacin.

The vitamins were analyzed in a HPLC (Model SCL-10A, Shimadzu Corp., Kyoto, Japan) using a column of inertsil ODS 5 μm 4.6 × 250 mm 5LI0101Z with 0.1 mol /L KH_2PO_4 (pH 7.0)–methanol, 90:10 mobile phase (filtered through 0.45μm membrane and degassed by sonication), flow rate of 0.5 ml/min, a photodiode-array detector (Model Waters 2996, Waters Corp., Mailford, USA), oven temp. of 25ºC, and a sample volume of 20 μl. Identification of compounds was achieved by comparing their retention times and UV spectra with those of standards stored in a data bank. Five different concentrations of each standard were used to prepare calibration plots for each vitamin. This was done by plotting concentration (μg/ml) against peak area (mAU). Their correlation coefficients were greater than 0.997 (Appendix III). Concentrations of the water-soluble vitamins were calculated from integrated areas of the sample and the corresponding standards.

Vitamin content (mg/g) = (y/b) × (dilution factor / weight of sample (g) × 1000)

Where y=is the y intercept of obtained from the standard curve of the vitamin in question, and b is the peak area of the injected sample.

2.7 Statistical Analysis

Each determination was carried out in duplicates on the basis of growth season and the figures averaged. Data was assessed by the analysis of variance (ANOVA) (Snedecor and Cochran, 1987). Duncan Multiple Range Test (DMRT) was used to separate the means. Significance was determined at $P < 0.05$.

3.0 Results and Discussion

3.1 Chemical Composition

The proximate composition of sorghum flour from the parents, somaclones and mutants are shown in Table 1.

Table 1: Proximate composition of the sample raw materials (mg/100g) of the sorghum varieties

	Nutrients					
Cultivars	Moisture%	Protein	Fat	Carbohydrates	Crude fibre	Ash
El-gar. M	6.3^{bcde}±0.8	15.7^{a}±0.6	3.1^{ce}±0.2	70.2^{a}±0.14	3.1^{a}±0.11	2.7^{a}±0.1
El-gar. P	8.3^{ace}±0.1	13.8^{a}±0.4	3.8^{ace}±0.3	68.0^{a}±0.6	3.8^{a}±0.12	2.3^{a}±0.2
El-gar. S	6.4^{bcde}±0.4	16.8^{a}±0.4	2.6^{e}±0.2	69.4^{a}±0.1	2.8^{a}±0.48	2.1^{a}±0.5
Mta. 1 P	7.2^{abce}±0.1	12.9^{a}±0.2	1.4^{b}±0.5	73.4^{a}±0.44	3^{a}±0.42	3.6^{a}±0.6
Mta. 1 S	6.9^{abcde}±0.1	15.3^{a}±0.8	1.7^{b}±0.2	71.3^{a}±0.17	3.1^{a}±0.14	1.8^{a}±0.1
Mta. 1 M	6^{bcde}±0.1	12.8^{a}±0.6	3.2^{ce}±0	73.4^{a}±0.44	2.1^{a}±0.5	2.6^{a}±0.14
Seredo M	5.1^{bd}±0.5	15.1^{a}±0.6	3.0^{e}±0.4	72.9^{a}±0.19	2.4^{a}±0.33	1.9^{a}±0.04
Seredo P	$6.4b^{cde}$±0.2	13.3^{a}±0.6	4.6^{a}±0.4	71.8^{a}±0.72	2.6^{a}±0.21	1.5^{a}±0.3
Seredo S	7.7^{abce}±0.4	12.7^{a}±0.3	5.5^{ad}±0.2	72.5^{a}±0.41	2.2^{a}±0.36	2.1^{a}±0.12
Serena M	5.1^{bd}±0.3	15.8^{a}±0.2	5.9^{d}±0.1	68.4^{a}±0.34	5.9^{a}±0.23	2.6^{a}±0.03
Serena P	5.1^{bd}±0.3	14.4^{a}±0.5	4.7^{a}±0.07	70.7^{a}±0.76	3.1^{a}±0.5	2.0^{a}±0.33
LSD	0.03	0.07	0.03	0.08	0.01	0.05
C.V%	7.3	7.4	14.3	1.7	1.2	32.3

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates.

The ash content was found to range between 1.5% and 3.6% Mtama 1 parent being the highest and Seredo parent showing the lowest. The data obtained showed that the ash content of the cultivars do not vary significantly. The protein content was found to be in the range of 12.7% to 16.8% and do not vary among the cultivars with the different treatments. Protein content and composition varies due to genotype, and water availability, temperature, soil fertility and environmental conditions during grain development. The protein content of sorghum is usually 11-13% but sometimes higher values are reported. The fat content of the flour range between 1.4% and 5.9%. Fat content do not range widely between the cultivars but is noted to be significantly different between treatments of the same cultivar. Moisture content range 5.1% to 8.3% and do not vary significantly within cultivar treatments except in Seredo where the somaclone shows a higher moisture content than the parent and mutant. Carbohydrates content ranged from 68% to 73.4% and do not vary significantly within same cultivars and within treatments of the same cultivar. Crude fibre content ranged from 2.9% to 5.9% and do not significantly differ within and among cultivars.

3.2 Mineral Composition

Mineral composition of the sorghum cultivars are shown in Table 2. The ranges obtained are confirmed in previous similar work (Noha *et al*., 2001). The mineral compositions among all the cultivars do not seem to vary significantly except for iron and calcium. Magnesium was found to range between 0.61-2.29 mg/100 g, Mtama 1 somaclone having the lowest with Mtama 1 parent being the highest. The lower amount of magnesium averagely in Seredo and Serena may be due to the fact that divalent cations such as Mg may be present as mineral phytate chelates which may explain the lower availability of these minerals (Mamiro et al., 2001). Copper ranged between 1.08-2.17 mg/100 g, zinc 0.12-0.44 mg/100 g, sodium 0.09-0.3 mg/100 g, calcium 2.45-3.52 mg/100 g, potassium 1.07-4.71 mg/100 g and iron 1.03-9.1mg/100g.

Table 2: Minerals composition (mg/100g) of the sorghum varieties

Cultivars	Mg	Mn	Cu	Zn	Na	Fe	Ca	K
El-Gar M	2.27^{a}±1.1	1.33^{a}±0.3	1.28^{a}±1.1	0.32^{a}±0.2	0.21^{a}±0.1	4.18^{b}±17.1	2.45^{e}±5.3	1.35^{a}±1.9
El-Gar P	2.02^{a}±0.6	0.58^{abc}±0.2	1.35^{a}±0.2	0.12^{b}±0	0.15^{a}±0.1	1.61^{f}±9.1	2.75^{cd}±6.3	4.70^{a}±1.8
El-Gar S	1.22^{a}±0.6	0.85^{abc}±0.1	2.09^{a}±0.8	0.16^{ab}±0	0.11^{a}±0	4.08^{b}±4.2	3.52^{a}±5.9	3.22^{a}±1.4
Mta. 1 M	0.70^{a}±0.1	0.67^{abc}±0.1	1.59^{a}±0.9	0.36^{ab}±0.1	0.30^{a}±0.2	0.91^{g}±4.2	2.52^{de}±12.5	5.01^{a}±2.8
Mta. 1 P	2.29^{a}±2.7	0.80^{abc}±0.6	1.24^{a}±1	0.30^{ab}±0.1	0.27^{a}±0.2	5.93^{a}±4.2	2.89^{c}±7.9	2.43^{a}±2.8
Mta. 1 S	0.61^{a}±0.3	0.61^{abc}±0.3	2.07^{a}±0	0.16^{ab}±0.1	0.29^{a}±0.1	3.39^{c}±6.1	2.49^{e}±11.8	1.99^{a}±0.4
Seredo M	1.19^{a}±0.2	1.19^{ab}±0.2	2.17^{a}±0.5	0.26^{ab}±0.2	0.13^{a}±0	1.07^{g}±0.35	2.94^{bc}±5.9	1.07^{a}±1.5
Seredo P	1.24^{a}±1	0.28^{c}±0.4	1.08^{a}±0.9	0.21^{a}±0.2	0.16^{a}±0	2.80^{c}±0.0	2.91^{c}±21.2	1.68^{a}±0.7
Seredo S	1.66^{a}±2	0.12^{c}±0.2	1.31^{a}±0.5	0.29^{ab}±0.2	0.16^{a}±0	1.03^{g}±0.98	2.83^{c}±11.9	2.22^{a}±1.1
Serena M	1.04^{a}±0	0.83^{abc}±0.3	1.76^{a}±0.5	0.21^{ab}±0.1	0.14^{a}±0.1	2.71^{d}±9.7	2.55^{de}±11.8	2.68^{a}±0
Serena P	1.47^{a}±0.9	0.42b^{c}±0.6	1.91^{a}±1.1	0.44^{a}±0	0.09^{a}±0.1	1.98^{e}±7.1	3.16^{b}±2.61	4.71^{a}±0
LSD	0.076	0.014	0.048	0.007	0.0069	0.048	0.067	0.093
CV%	82.5	32.2	46.4	43.5	59.7	28.1	37.2	49

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates. S=somaclone, P=parent, M=mutant

3.3 Group B-Vitamins

The vitamins results are shown in (Table 3) and are in the ranges obtained by Mamoudou *et al*, 2006. Niacin ranged between 0.2-6.65mg/100g. Seredo mutant showed the lowest while Mtama 1 had the highest quantities. There were no significant differences in niacin quantities among all the cultivars and within each cultivar. Thiamine quantities ranged between 0.1-1.49 mg/100g with El-dargam parent showing the highest and Seredo mutant having the lowest. There are no significant differences among all cultivars and within each cultivar. Vitamins are reported to be unstable and can be lost during processing and storage (Ekinci and Kadakal, 2005)

Table 3: B-vitamins in of the sorghum varieties

Cultivars	Niacin	Thiamin	Riboflavin	Pyridoxine
El-gar M	0.91^{de}±0.0	0.16^{c}±0.0	1.37^{de}±0.24	0.22^{b}±0.0
El-gar P	1.19^{cd}±0.3	1.49^{a}±0.6	0.29^{f}±0.06	0.48^{b}±0.1
El-gar S	1.05^{d}±0.2	0.43^{bc}±0.0	6.0^{a}±0.2	0.15^{b}±0.0
Mta. 1 M	0.64^{de}±0.1	0.24^{bc}±0.1	5.93^{a}±0.26	0.16^{b}±0.0
Mta. 1 P	6.65^{a}±0.1	0.14^{c}±0.0	3.33^{b}±0.07	0.16^{b}±0.0
Mta. 1 S	0.75^{de}±0.1	0.22^{bc}±0.0	1.39^{de}±0.27	0.03^{b}±0.02
Seredo M	0.2^{e}±0.0	0.1^{c}±0.1	1.33^{de}±0.0	0.73^{b}±0.06
Seredo S	0.85^{de}±0.8	0.35^{bc}±0.1	2.26^{cd}±0.5	0.65^{b}±0.14
Seredo P	0.66^{de}±0.4	0.19^{bc}±0.1	2.99^{bc}±0.01	0.25^{b}±0.02
Serena M	2.30^{b}±0.0	0.56^{bc}±0.1	6.44^{a}±1.2	0.14^{b}±0.03
Serena P	1.82^{bc}±0.2	0.65^{b}±0.0	0.61^{ef}±0.02	0.07^{b}±0.01
LSD	19.3	47.1	14.4	53
C.V%	0.02	0.01	0.03	0.03

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates. S = somaclone, P = parent, M = mutant

3.4 Anti-nutrients

The anti-nutrients results for the sorghum varieties are shown on (Table 4). The tannin values were similar to those reported from similar studies (Gomez *et al*., 1997; Beta *et al*., 1999).

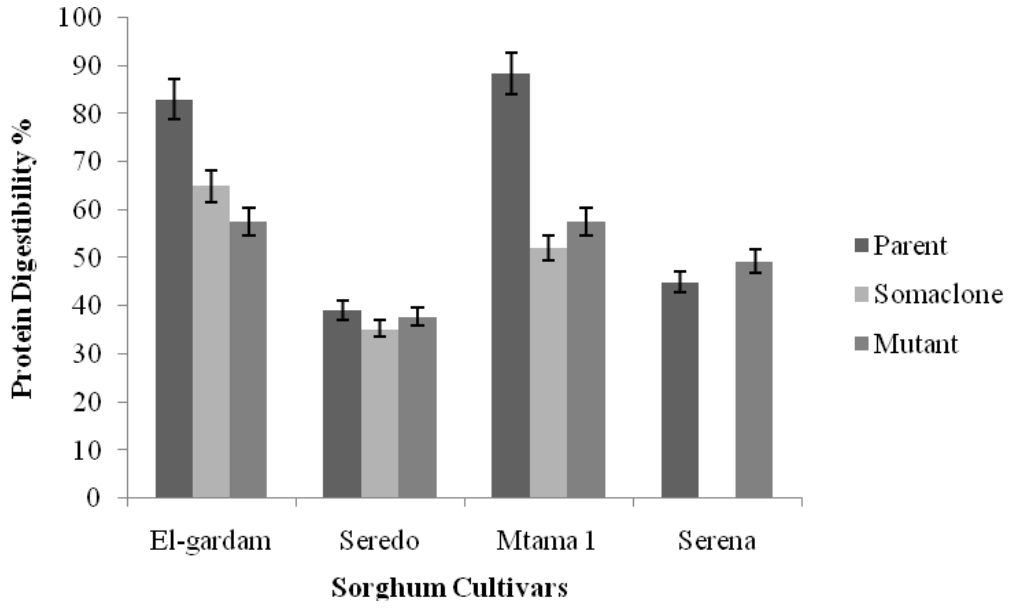
Table 3: Anti-nutrient factors (Tannins and phytates) in the sorghum varieties

Cultivars	Tannins (%C.E)	Phytates (mg/100g)
El-gar M	0.12^{b}±0.03	250.3^{e}±11.7
El-gar P	0.81^{ab}±0.06	288.9^{d}±9
El-gar S	0.70^{ab}±0.04	254.9^{e}±3.8
Mta. 1 M	0.06^{b}±0.04	255.6^{e}±5.9
Mta. 1 P	0.03^{b}±0.01	170.0^{f}±0.99
Mta. 1 S	0.04^{b}±0.01	124.3^{g}±5.2
Seredo M	0.49^{b}±0.08	295.1^{d}±1
Seredo S	0.88^{ab}±0.2	320.5^{c}±13.3
Seredo P	2.22^{a}±0.06	351.4^{b}±2.6
Serena M	0.7^{ab}±0.03	374.5^{a}±5.9
Serena P	1.2^{ab}±0.16	155.0^{f}±2.8
LSD	0.04	0.44
C.V%	15.9	2.7

Values are means (± SD). Means sharing a common superscript letter in a column are not significantly different at ($p \leq 0.05$) as assessed by Duncan's multiple range tests. S.D=Standard deviation. LSD= Least significant difference of the mean replicates. S=somaclone, P=parent, M=mutant

Tannin content is generally realized highest in the red sorghum cultivars (Serena and Seredo) and lowest in the white sorghum (Mtama 1 and El-gardam). The range obtained (120-370%C.E) lies similar to ranges obtained in similar studies (Noha *et al*., 2001). The somaclones and mutants of the sorghum cultivars except Mtama 1 are noted to have reduced quantities of tannin. Red sorghum genetically has higher condensed tannin compared to white sorghum and pearl millet. Tannins impart a bitter taste to the grains making them unpalatable and also interfere with protein digestibility. Before ripening the tannin content of grain is always higher than after ripening. The tannin content of dark grains is always higher than that of pale grains. The phytate amounts are also noted to be elevated in the red sorghum generally compared to the white sorghum and ranges from 124.3% to 374.5%. Significant differences in the phytate quantities were observed within and among the cultivars.

Protein digestibility findings showed a range of 5.2% to 11.4% (Figure 1). The lower ranges for protein digestibility were noted in the red sorghum cultivars (Serena and Seredo) and higher for the white sorghum Mtama 1 and El-gardam). This can be attributed to the high anti-nutrient content in the red sorghum that reduces digestibility of proteins and utilization of other mineral contents in sorghum. In vitro studies and in vivo studies with livestock and laboratory animals indicate that sorghum proteins are generally less digestible than those of other cereals (Muindu and Thomke, 1981). Phytates and polyphenols such as tannins bind to both exogenous and endogenous proteins including enzymes of the digestive tract, affecting the utilization of proteins (Asquith and Butler, 1986; Griffiths, 1985; Eggum and Christensen, 1975).



Graph 1: Protein digestibility (%) of the sorghum cultivars

4.0 Conclusion

The insignificant mean square values obtained from the analysis of variance for the proximate composition, B-vitamins and minerals (Table 1) suggests that differences do not exist between the sorghum cultivars and between treatments of the same cultivars, indicating that they are not highly variable. Variability of the cultivars, however, is shown in the anti-nutrient content of the cultivars with Seredo, Serena and El-gardam showing elevated amounts. The white Mtama 1 especially, somaclone with lower anti-nutrient is therefore the best with respect to nutrient availability since anti-nutrients in sorghum are shown to reduce the utilization of nutrient by the body. However, methods such as fermentation, germination and fortification can be used to reduce anti-nutrients in those cultivars with high amounts.

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