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RESEARCH ARTICLE

EFFECT OF PRE-MILLING TREATMENTS ON CHARACTERISTICS OF BARNYARD MILLET (E*CHINOCHLOA COLONA)*

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ABSTRACT

Barnyard millet (*Echinochloa colona)*, rich in fiber among minor millets processed by adopting different pre-milling treatments such as cold water soaking for 6-24 hours with 20 minutes steaming (Treatment I); hot water soaking for 1-5 hours with 20 minutes steaming (Treatment II); and steaming for 10-40 minutes (Treatment III). The treated millet was sun/shade dried and milled. Both raw and treated millet were analyzed for its physical, chemical, functional and milling characteristics. Results indicated that the dehusked grain contains significantly higher bulk density, true density, total carbohydrate and protein content than whole grain. The bulk density, grain hardness, water absorption capacity, oil absorption capacity and swelling power of both sun dried and shade dried barnyard millet subjected to various pre-milling treatments were in the range of 0.528 - 0.624 g/ml, 2 – 3.78 kg/mm^2, 0.899 – 1.586 g/g, 1.094 – 1.848 g/g and 4.62 – 5.425 ml/g respectively. The carbohydrate, protein and crude fiber content were increased with increased hours of cold water soaking, hot water soaking and steaming at $p<0.05$. The dehulling yield was directly correlated to grain hardness, water absorption capacity, swelling power and protein content. Thus the study revealed that in all means of analysis A4 treatment was considered to be the best suitable pre-milling treatment for barnyard millet.

INTRODUCTION

The term “millet” is applied to various grass crops whose seeds are harvested for human food or animal feed (Crawford and Lee, 2003). Barnyard, Japanese barnyard or sawa millet [*Echinochloa crusgalli* (L.) P.B. and *Echinochloa colona* (L.) Link] is the fastest growing of all millet and produces a crop in six weeks. It is grown in India, Japan and China as a substitute for rice when the paddy fails. It is also grown as a forage crop in the United States and can produce as many as eight harvests per year. The grain is 2-3 mm long and 1-2 mm wide (Gomez and Gupta, 2003). The utilization of this millet is limited mainly to the poor sections of population and the cattle and poultry. The reason being presence of anti-nutrients, poor digestibility of protein and carbohydrates and low palatability (Chitra et al., 1996). The sensory properties are also poor due to coarse nature of these grains. These are rich in polyphenols, which influence the colour and flavour of millet (Rao and Deosthale, 1988). The non-availability of refined and processed millet in ready-to-use form has further limited their use and acceptability.

Thus, in the present era of food scarcity there exist a need to diversify the use of these millets by developing non-conventional food products, especially for young children among whom protein energy malnutrition is prevalent (Srivastava et al., 2001). The pre-milling treatment would enable the effective utilization of millet in producing dehusked grain and by-products like in the case of rice and wheat. Milling trials on millets and its characterization would enhance the scope for designing new milling equipments and technology by food engineers. Hence in this study an attempt was made to find out the suitable method of pre-milling treatment of barnyard millet which definitely expands the utility of barnyard millet.

MATERIALS AND METHODS

The popular variety of CO1 of barnyard millet was selected and purchased from the local market in Kolli hills at Salem District, Tamil Nadu.

Physical properties

The physical properties such as 100 kernel weight in g (AACC method, 1995), 100 kernel volume in ml (AACC method, 1995), bulk density in g/ml (Wang and Kinsella, 1976) and grain hardness in kg/mm^2 (Gomez et al., 1997), particle size distribution (standard test sieve method), length (mm), breadth (mm), thickness (mm), equivalent

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diameter (mm), sphericity (Mohesenin 1970), true density (g/ml) (ASAE, 2001), bulk density (g/ml) (method of Wang and Kinsella, 1976), porosity (formula of Thompson and Issac, 1967), 100 grain weight and volume (AACC method, 1995) of the selected raw and treated millet were determined.

Functional properties

The flour obtained from raw and treated barnyard millet was sieved through 40 mesh sieve and analysed for its functional properties such as Water Absorption Capacity in g/g (WAC) (method of Janicki and Welczak, 1960), Oil Absorption Capacity in g/g (OAC) (method of Sosulki et al., 1976) and Swelling Power in ml/g (SP) (method of Leach, 1959).

Nutritional properties

The nutritional properties such as carbohydrate (Anthrone method), protein (Lowry's method) and fiber (Acid-Alkali digestion method), moisture (g%), total carbohydrate (g%), protein (N×5.83) (g%), fat (g%), crude fiber (g%) and ash (g%) of whole grains and dehulled grains, prior to processing by the method of Ranganna (2004) and Sadasivam and Manickam (2005). The selected barnyard millet was pre-treated as soaking in cold water for 6 (A1), 12 (A2), 18 (A3) and 24 (A4) hours and then steamed for 20 minutes (Treatment I); soaking in hot water at 70^0C for 1 (A5), 2 (A6), 3 (A7), 4 (A8) and 5 (A9) hours and then steamed for 20 minutes (Treatment II); steaming for 10 (A10), 20 (A11), 30 (A12) and 40 (A13) minutes (Treatment III). The following characteristics were determined for raw and pre-treated barnyard millet and its flour to study the effect of pre-milling treatments.

Milling characteristics of barnyard millet

Milling of treated, dried millet was done in a rice polisher (Satake Emry Polisher) equipped with Emry roller to remove the outer bran layers. The milled flour of millet was obtained by grinding them in a Pullizer miller and subsequently sieving through 40 mesh sieve. The yield of milling fractions of millets such as bran, husk and dehulled grain were measured using an electronic weighing balance of 0.001g accuracy.

Statistical analysis

The one way analysis of variance with critical difference (CD) was used to compare and separate the means. The bivariate correlation matrix (Rank Pearson coefficient of correlation) was used to determine the correlation coefficients of individual grain parameters with dehulling yield.

RESULTS

Characteristics of barnyard millet grain

The particle size distribution of whole millet grain (Fig. 1) indicated that 70.41% had size below 1.4 mm and above (12 mesh in BSS unit). After dehusking, 66% of grain had size in the range of 12 – 14 mesh i.e. 1.18 – 1.4 mm. The result on physical properties of barnyard millet in Table 1 revealed that the length ($p<0.01$), 100 grain mass ($p<0.05$) and 100 grain volume ($p<0.05$) were reduced significantly; the true density and bulk density were increased significantly ($p<0.05$) on dehusking. The total carbohydrate and protein content of dehusked grain was significantly ($p<0.05$) greater than whole grain. The present values of proximate composition of barnyard millet (Table 2).

FIG. 1. Particle size distribution of whole and dehusked grain of Barnyard Millet

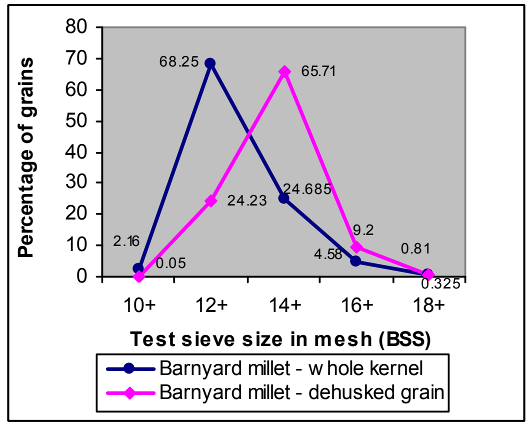

Table 1. Physical properties of whole and Dehusked Grain

Physical properties	Whole grain	Dehusked grain
Length, mm	2.18±0.08	1.94±0.05*
Breadth, mm	1.76±0.16	1.64±0.19 NS
Thickness, mm	1.12±0.13	1.04±0.05NS
Equivalent diameter, mm	1.62±0.11	1.48±0.08NS
Sphericity	0.74±0.03	0.77±0.03NS
True density, g/ml	1.19±0.02	1.56±0.03*
Bulk density g/ml	0.625±0.07	0.777±0.08**
Porosity (%)	47.38±6.51	50.82±4.73NS
100 grain mass, g	0.27±0.01	0.25±0.01**
100 grain volume, ml	0.44±0.05	0.32±0.04**

Values in table (S.No.1-5) are the average of ten determinants and S.No.6-10 are the average of two determinants;
** Significant at p<0.01, NS – Not Significant, **- Significant at p<0.05*

Effect of pre-milling treatments on physical properties of barnyard millet

The changes in physical properties on pre-milling treatments of whole barnyard millet grain were studied and presented in tables 3 and 4. The changes observed in 100 kernel weight and bulk density after treatment and after drying in 100 kernel weight was found to be significant at 1% level since $p<0.01$. The variation in 100 kernel weight and bulk density of the grain subjected to different treatments was also significant at $p<0.05$. The 100 kernel volume of the raw barnyard millet was found to be 0.4±0.02 ml which was increased to 0.5±0.03 ml

Table 2. Nutritional composition of whole and Dehusked Grain of Barnyard Millet

Nutrients (g%)	Whole grain	Dehusked grain
Moisture	9.85±0.04	11.05±0.2^{NS}
Total carbohydrate	53.65±1.5	67.95±0.5**
Protein	4.4±0.14	12.1±1.0*
Fat	4.0±0.6	2.7±0.3^{NS}
Crude fiber	9.3±0.4	4.8±0.14^{NS}
Ash	**5.6±0.14**	**3.5±0.14^{NS}**

**- Significant at p<0.01, **Significant at p<0.05, NS- Not Significant; Values are the average of two determinants.*

after treatment and to the volume of 0.4±0.04 ml after drying (i.e. both sun dried and shade dried). The grain hardness (Table 4) of the treated sample was increased with increase in hours of soaking and steaming. The mean grain hardness of the treated sample of both sun dried and shade dried (1.217± 0.51 and 1.375±0.46 kg/mm^2 respectively) was greater than the grain hardness of raw sample (0.96 kg/mm^2). The grain hardness was increased significantly (p<0.05) after treatments except in A1, A5, A6, A7, A10 and A11 treatments. The maximum grain hardness of barnyard millet was observed in sun dried barnyard millet subjected to A4 treatment (2.1 kg/mm^2).

Effect of pre-milling treatments on functional properties of barnyard millet

The maximum WAC was observed in shade dried barnyard millet (1.791 g/g) subjected to A4 treatment. The WAC of barnyard millet subjected to A4 treatment in group I, A9 treatment in group II and A13 treatment in group III was higher than WAC of raw grain flour (1.504 g/g) in both sun and shade drying. The maximum OAC was observed in shade dried barnyard millet (0.909 g/g) subjected to A9 treatment. The maximum OAC in each treatment group was significantly (p< 0.05) lower or equal to the oil absorption capacity of raw grain flour (0.908 g/g). The swelling power was highest for shade dried barnyard millet subjected to A4 treatment. The maximum swelling power in each treatment group was significantly (p < 0.05) higher than swelling power of raw grain flour (4.885 ml/g). According to Critical Difference values, the WAC, OAC and SP of barnyard millet were increased significantly (p<0.01) with increased hours of soaking and steaming. There was no significant (p > 0.05) difference in swelling power between sun dried and shade dried sample.

Effect of pre-milling treatments on nutritional composition of barnyard millet

The proximate composition of flour fractions of whole raw and treated millet sieved through 40 mesh (BSS) are presented in Table 6. The treated barnyard millet flour contains carbohydrate in the range of 52-64g%. When compared to raw (65.1 g%), the carbohydrate content of treated grain flour was not significantly (p > 0.05) reduced except in A5 treatment. The treated barnyard millet flour contains protein in the range of 9.6-12.8 g%. The protein content of treated grain flour was significantly higher in A4 and A9 treatment at p<0.05 than raw grain flour (10.1 g%). The crude fiber content of treated grain flour was in the range of 2.17-7.12 g%. The decrease in crude fiber

Table 3. 100 kernel weight of raw and treated Barnyard Millet

Method of processing in hours/minutes	Sun drying			Shade drying		
	Raw grain	After treatment	After drying	Raw grain	After treatment	After drying
Treatment I						
A1	0.264	0.28	0.257	0.262	0.271	0.253
A2	0.256	0.268	0.253	0.265	0.275	0.26
A3	0.269	0.279	0.261	0.243	0.265	0.237
A4	0.256	0.269	0.250	0.268	0.279	0.259
Treatment II						
A5	0.252	0.271	0.248	0.226	0.240	0.215
A6	0.259	0.269	0.254	0.266	0.277	0.26
A7	0.251	0.261	0.242	0.288	0.299	0.28
A8	0.279	0.289	0.276	0.300	0.313	0.294
A9	0.280	0.288	0.273	0.232	0.241	0.228
Treatment III						
A10	0.259	0.270	0.254	0.247	0.257	0.238
A11	0.298	0.307	0.296	0.234	0.241	0.227
A12	0.275	0.292	0.27	0.265	0.274	0.259
A13	0.263	0.273	0.257	0.249	0.261	0.24
CD	0.040* 0.029** 0.021***	0.034* 0.025** 0.018***	0.047* 0.033** 0.021***	0.033* 0.024** 0.017***	0.033* 0.024** 0.017***	0.037* 0.027** 0.019***
CD	0.018* 0.014** 0.010***			0.028* 0.022** 0.017***		

*Values in table are the average of two determinants;CD – Critical Difference; * - significant at p<0.001, **- significant at p<0.01, *** - significant at p<0.05.*

Table 4. Bulk density and grain hardness of raw and treated Barnyard Millet

Method of processing in hours/minutes	Bulk density (g/ml)						Grain hardness (kg/mm^2)	
	Sun drying			Shade drying				
	Raw grain	After treatment	After drying	Raw grain	After treatment	After drying	Sun drying	Shade drying
Treatment I								
A1								
A2	0.660	0.56	0.643	0.655	0.541	0.633	0.8^{d}	0.86^{d}
A3	0.640	0.536	0.631	0.663	0.550	0.650	1.42^{c}	1.24^{c}
A4	0.673	0.558	0.653	0.608	0.530	0.593	1.8^{b}	1.59^{c}
Treatment II	0.640	0.537	0.625	0.670	0.558	0.648	2.09^{c}	2.04^{c}
A5	0.630	0.542	0.620	0.565	0.479	0.538	0.65^{b}	0.56^{c}
A6	0.648	0.538	0.635	0.665	0.553	0.650	0.72^{c}	1.3^{d}
A7	0.628	0.521	0.605	0.720	0.598	0.700	0.8^{c}	1.36^{d}
A8	0.698	0.578	0.689	0.750	0.626	0.735	1.03^{d}	1.44^{b}
A9	0.700	0.576	0.683	0.580	0.482	0.570	1.48^{c}	1.92^{b}
Treatment III	0.648	0.539	0.635	0.618	0.514	0.595	0.79^{c}	0.8^{c}
A10	0.745	0.614	0.740	0.585	0.482	0.566	0.92^{d}	1.24^{c}
A11	0.688	0.583	0.675	0.663	0.548	0.648	1.28^{c}	1.6^{c}
A12	0.658	0.545	0.643	0.623	0.522	0.600	2.04^{c}	1.72^{b}
A13								
CD	0.100* 0.071** 0.051***	0.069* 0.049** 0.035***	0.112* 0.083** 0.060***	0.084* 0.060** 0.043***	0.067* 0.047** 0.034***	0.094* 0.067** 0.048***	0.219* 0.156** 0.112***	0.158* 0.112** 0.081***
CD	0.042* 0.033** 0.025***			0.066* 0.052** 0.039***			0.715* 0.534** 0.394***	

Values in table are the average of two determinants; CD – Critical Difference;
** - significant at p<0.001, ** - significant at p<0.01, *** - significant at p<0.05; a, b, c and d indicates the significance in comparison with raw grain hardness at p<0.001, p<0.01, p<0.05 and not significant respectively; Bolded value indicates the maximum value.*

content was significant in all variations of treatment group II and III. According to critical difference analysis, the carbohydrate, protein and crude fiber content were increased with increased hours of cold water soaking, hot water soaking and steaming at $p<0.05$. There was no significant difference in nutritional composition between sun dried and shade dried samples.

Effect of pre-milling treatments on milling characteristics of barnyard millet

Data regarding the milling yield in Table 7 revealed that the dehulling yield of treated grain ranged from 63.55% to 69.52% for sun dried and from 60.99% to 71.18% for shade dried sample. The dehulling yield of untreated grain was 65.4% and there was no significant difference in dehulling yield of raw and treated grain sample. Results also confirmed that the dehulling yield increased significantly with increase in hours of soaking and steaming at $p<0.05$ as per critical difference analysis. The data regarding the flour yield from dehulled grain revealed that it was in the range of 99.8-100 %.

Correlation between characteristics of treated barnyard millet

The 100 kernel weight was directly correlated with bulk density at $p<0.01$. Grain hardness was directly correlated with water absorption capacity, oil absorption capacity, swelling power, protein content, fat content and dehusked grain yield. A significant ($p < 0.01$) inverse correlation was obtained between grain hardness and bran yield; swelling power and bran yield; protein content and bran yield; husk yield and bran yield as well between bran yield and dehusked grain yield.

DISCUSSION

The particle size distribution of whole millet grain similar findings was observed by Singh et al (2005) that in general whole barnyard millet flour was characterized by low values of bulk density than the endosperm. This fact was also supported by Premavalli et al (2005). The findings reported by Gopalan et al (2007). Kebakile et al (2007) reported that the meal protein content obtained with all the milling processes was higher than the whole grain protein content, because the grain pericarp, which is relatively poor in protein, was removed. The changes in physical properties on pre-milling treatments of whole barnyard millet grain were studied and presented in tables 3 and 4. Mepba et al (2007) reported that the low bulk

Table 5. Functional properties of raw and treated whole Barnyard Millet flour

Method of processing in hours/minutes	Water absorption capacity (g/g)		Oil absorption capacity (g/g)		Swelling power (ml/g)	
	Sun drying	Shade drying	Sun drying	Shade drying	Sun drying	Shade drying
Treatment I						
A1	1.327^{c}	1.465^{d}	0.725^{c}	0.769^{b}	5.086^{c}	5.127^{b}
A2	1.582^{c}	1.632^{c}	0.769^{b}	0.785^{c}	5.115^{b}	5.145^{b}
A3	1.642^{b}	1.723^{b}	0.792^{b}	0.788^{c}	5.125^{b}	5.295^{b}
A4	1.733	1.791^{b}	0.835^{c}	0.817^{c}	5.32^{c}	5.425^{b}
Treatment II						
A5	1.408^{b}	1.437^{c}	0.767^{b}	0.815^{c}	4.922^{c}	5.015^{c}
A6	1.441^{d}	1.456^{c}	0.792^{b}	0.853^{c}	5.075^{c}	5.024^{c}
A7	1.482^{d}	1.479^{d}	0.815^{c}	0.876^{d}	5.124^{b}	5.031^{b}
A8	1.502^{d}	1.501^{d}	0.837^{c}	0.899^{d}	5.14^{c}	5.076^{c}
A9	1.588^{d}	1.573^{c}	0.853^{c}	0.909^{d}	5.177^{b}	5.13^{c}
Treatment III						
A10	1.575^{c}	1.443^{c}	0.804^{c}	0.733^{b}	4.701^{b}	4.62^{c}
A11	1.62^{d}	1.483^{d}	0.824^{c}	0.750^{c}	4.728^{b}	4.725^{c}
A12	1.652^{c}	1.533^{c}	0.851^{c}	0.798^{b}	4.95^{d}	4.83^{d}
A13	1.691^{c}	1.666^{c}	0.863^{d}	0.823^{c}	5.239^{b}	5.008^{b}
Raw	1.504		0.908		4.885	
CD	0.088* 0.063** 0.045***	0.022* 0.016** 0.011***	0.023* 0.016** 0.012***	0.024* 0.017** 0.012***	0.062* 0.044** 0.032***	0.065* 0.047** 0.033***

*Values in table are the average of two determinants; CD – Critical Difference; * - significant at p<0.001, ** - significant at p<0.01, *** - significant at p<0.05; a, b, c and d indicates the significance in comparison with raw grain hardness at p<0.001, p<0.01, p<0.05 and not significant respectively; Bolded value indicates the maximum value.*

Table 6. Nutritional composition of raw and treated whole Barnyard Millet flour

Method of processing in hours/minutes	Sun drying			Shade drying		
	Carbohydrate	Protein	Fiber	Carbohydrate	Protein	Fiber
Treatment I						
A1	60^{d}	11^{d}	5.61^{d}	59.4^{d}	11..3^{d}	6.51^{d}
A2	59.6^{d}	11.7^{d}	5.99^{d}	59^{d}	11.7^{d}	6.93^{d}
A3	62^{d}	12^{d}	6.10^{d}	61^{d}	12.1^{d}	7.03^{d}
A4	64^{d}	12.6^{d}	6.32^{d}	62^{d}	12.8^{d}	7.12^{d}
Treatment II						
A5	56^{d}	10.6^{d}	2.76^{c}	52^{c}	10.5^{d}	2.86^{c}
A6	57.4^{d}	10.9^{d}	2.95^{c}	55^{d}	10.8^{d}	2.97^{c}
A7	57^{d}	11.3^{d}	3.02^{b}	55.5^{d}	11^{d}	3.03^{b}
A8	58^{d}	11.9^{d}	3.10^{c}	57^{d}	12.1^{d}	3.09^{b}
A9	60^{d}	12.1^{d}	3.17^{c}	61^{d}	12.7^{d}	3.15^{c}
Treatment III						
A10	64^{d}	9.6^{d}	2.53^{b}	63^{d}	10^{d}	2.17^{b}
A11	62^{d}	10.3^{d}	2.70^{c}	61^{d}	10.6^{d}	2.34^{b}
A12	60^{d}	10.8^{d}	3.50^{c}	59^{d}	10.9^{d}	3.42^{c}
A13	63^{d}	11.2^{d}	4.43^{c}	60^{d}	11.1^{d}	4.13^{b}
Raw	65.1	10.1	6.2	65.1	10.1	6.2
CD	6.29* 4.49** 3.22***	1.56* 1.11** 0.80***	0.79* 0.56** 0.41***	5.54* 3.95** 2.84***	1.4* 1.05** 0.8***	0.92* 0.65** 0.47***

*Values in table are the average of two determinants; CD – Critical Difference; * - significant at p<0.001, ** - significant at p<0.01, *** - significant at p<0.05; a, b, c and d indicates the significance in comparison with raw grain hardness at p<0.001, p<0.01, p<0.05 and not significant respectively; Bolded value indicates the maximum value.*

density could be an advantage in the formulation of baby foods where high nutrient density to low bulk is desired. This is confirmed by the findings of Shobana and Malleshi (2007) who reported that equilibrating the millet to 33±2% moisture content and steaming the same for about 20 minutes at atmospheric pressure followed by drying to 12±2% moisture content enhanced the hardness of the millet kernel from 1.1±0.2 to 7.1±0.5 kg/cm^2 and enabled its decortication.

Kebakile et al (2007) reported that grains with harder endosperms give higher flour yields than those with softer endosperms; the softer the grain, the more the meal was

millet kernel from 1.1±0.2 to 7.1±0.5 kg/cm^2 and enabled its decortication.

Kebakile et al (2007) reported that grains with harder endosperms give higher flour yields than those with softer endosperms; the softer the grain, the more the meal was contaminated with bran; the harder the grain, the less germ was removed; grain hardness significantly correlated with the meal protein content and hard endosperm sorghum grains produce relatively coarser meals. Premavalli et al (2005) reported that the increased water absorption capacity and swelling power in ragi subjected to pre-treatments was due to the starch granules of pre-

Table 7. Milling yield of raw and treated Barnyard Millet

Method of processing in hours/minutes	Sun drying			Shade drying		
	Husk	Bran	Grain	Husk	Bran	Grain
Treatment I						
A1	13.49 ^{d}	22.7 ^{d}	63.74 ^{d}	16.73 ^{d}	22.28 ^{d}	60.99 ^{d}
A2	13.84 ^{d}	21.8 ^{d}	64.36 ^{d}	17.04 ^{d}	19.37 ^{d}	63.59 ^{d}
A3	9.6 ^{c}	24.6 ^{c}	65.8 ^{d}	13 ^{c}	17.01 ^{d}	69.99 ^{d}
A4	13.10 ^{c}	17.38 ^{d}	69.52 ^{d}	12.08 ^{c}	16.14 ^{d}	**71.18** ^{d}
Treatment II						
A5	16.02 ^{d}	19.14 ^{d}	64.84 ^{d}	15.04 ^{d}	20.39 ^{d}	64.57 ^{d}
A6	15.44 ^{d}	19.34 ^{d}	65.22 ^{d}	16.05 ^{d}	17.43 ^{d}	66.52 ^{d}
A7	15.9 ^{d}	18.78 ^{d}	65.32 ^{d}	14.8 ^{d}	18.54 ^{d}	66.66 ^{d}
A8	15.72 ^{d}	18.02 ^{d}	66.26 ^{d}	14.43 ^{d}	18.05 ^{d}	67.52 ^{d}
A9	16.37 ^{d}	15.97 ^{d}	67.66 ^{d}	16.51 ^{d}	13.57 ^{d}	69.92 ^{d}
Treatment III						
A10	11.20 ^{c}	25.25 ^{d}	63.55 ^{d}	14.16 ^{d}	24.76 ^{c}	61.08 ^{d}
A11	10.52 ^{c}	24.16 ^{d}	65.32 ^{d}	15.52 ^{d}	22.91 ^{d}	61.57 ^{d}
A12	9.7 ^{c}	24.3 ^{d}	66 ^{d}	18.67 ^{d}	16.98 ^{d}	64.35 ^{d}
A13	11.67 ^{c}	20.1 ^{d}	68.23 ^{d}	13.42 ^{d}	21.63 ^{d}	64.95 ^{d}
Raw	17.48	17.12	65.4	17.48	17.12	65.4
CD	4.70* 3.35** 2.41***	6.65* 4.75** 3.40***	9.98* 7.12** 5.11***	6.09* 4.35** 3.12***	6.34* 4.53** 3.25***	9.80* 6.99** 5.01***

*Values in table are the average of two determinants; CD – Critical Difference; * - significant at p<0.001, ** - significant at p<0.01, *** - significant at p<0.05; a, b, c and d indicates the significance in comparison with raw grain hardness at p<0.001, p<0.01, p<0.05 and not significant respectively; Bolded value indicates the maximum value.*

gelatinised flour which was more susceptible to hydration. Puyed and Prakash (2006) reported that heat treatments such as microwave heating and pressure cooking increased the fat absorption capacity of defatted soy flour and peanut flour. This increase could be due to dissociation and denaturation of proteins occurring on heating. The observed values of protein were close to the values reported by Singh et al (2005) viz., 10.13 g% in whole barnyard millet flour and 11.63 g% in milled barnyard millet flour. Fang and Cambell (2002) reported that the yield and quality of the flours from any mill set up are influenced by the endosperm texture of the kernels, diameter, gap setting and rpm of the mill rolls, besides the stress-strain experienced by the kernels during milling.

Similarly, under the optimized conditions of milling, the yield of refined flours from sorghum, pearl millet and finger millet were 72.4, 78.4 and 71.3% respectively reported by Malleshi et al (2004). The maximum dehulling yield was noted in grains subjected to A4 treatment and shade drying. This concluding result on milling yield was in concordance with the findings of Rajkumar et al (2004) who reported that among the treatments, milling yield was significantly higher for paddy varieties dried in shade drying. The results on correlation between grain hardness and protein content was found to be the case as observed by the Khetarpaul et al (2005) that grain hardness was not significantly correlate with the meal protein content which was found to be negative for what expected. Nkama et al (2005) revealed that the grain density was significantly correlated with 100 kernel weight ($r = +0.85$, $p<0.05$). There was a significant correlation between grain density and dehulling yield ($r = +0.42$, $p<0.05$).

CONCLUSION

The equivalent diameter, 100 grain mass, 100 grain volumes were decreased on dehusking. Whereas the sphericity, true density, bulk density and porosity of barnyard millet were increased on dehusking. The moisture, total carbohydrate and protein content were found to be less and crude fiber, ash and fat content were high in whole grain compared to dehusked grain. The pre-milling treatments significantly increases the grain hardness, water absorption capacity, oil absorption capacity, swelling power, protein content and dehulling yield. The barnyard millet grain soaked in cold water for 24 hours and steamed for 20 minutes (A4 treatment) resulted in better dehulling yield.

REFERENCES

AACC. 1995. Cereal laboratory methods. American Association of Cereal Chemists. St Paul USA: 89-96.

ASAE. 2001. Cubes, Pellets and Crumbles – Definitions and methods for determining density, durability and moisture content. American Society of Agricultural Engineers. 48th edition, Michigan.

Chitra, U., Singh, U., Rao, P.V. 1996. Phytic acid, *in vitro* protein digestibility, dietary fiber and minerals of pulses as influenced by processing methods. Plant Foods in Human Nutrition, 49: 307-316.

Crawford, G.W. and Lee Gyoung-Ahi. 2003. Agricultural origins in the Korean peninsula. Antiquity, 77 (295): 87-95.

Fang, C. and Cambell, G.M. 2002. Stress-strain analysis and visual observation of wheat kernel breakage during roller milling using fluted rolls. Cereal Chemistry, 79:511-517.

Gomez, M. and Gupta, S.C. 2003. Millets, Encyclopedia of Food Sciences and Nutrition. Second edition. Academic Press: 3978-3979.

Gomez, M.I., Obilana, A.B., Martin, D.F., Madz Vamuse, M. and Monyo, E.S. 1997. Manual of laboratory procedures for quality evaluation of sorghum and pearl millet. Technical Manual No.2. International Crops Research Institute for the Semi Arid Tropics Patancheru: 116.

Gopalan, C., Ramasastri, B.V. and Balasubramanian, S.C. 2007. Food Composition tables. Nutritive value of Indian Foods. National Institute of Nutrition/Indian Council of Medical Research Hyderabad: 43.

Janicki, N.A. and Walczak, J. 1960. Wateriness in meat and methods for its determination. Prexemysl Rolny I Spozywexy 1954. 8: 197-201 as cited in Advanced Food Research, 10: 355-394.

Kebakile, M.M., Rooney, L.W. and Taylor, J.R.N. 2007. Effects of hand pounding, abrasive decortication - hammer milling, roller milling and sorghum type on sorghum meal extraction and quality. Cereal Foods World, 52 (3): 129 – 137.

Khetarpaul, N., Grewal, R.B., Jood, S. 2005. Quality evaluation and functional properties used in baking. Bakery Science and Cereal Technology. Daya Publishing House, New Delhi: 101-125.

Leach, H.W., McCowen, M.C. and Schoch, L.D. 1959. Structure of the starch granule, swelling and solubility patterns of various starches. Cereal Chemistry, 36: 534-544.

Malleshi, N.G., Reddy, P.V. and Klopfenstein, C.F. 2004. Milling trials of sorghum, pearl millet and finger millet in Quadrumat Junior mill and experimental roll stands and the nutrient composition of milling fractions. Journal of Food Science and Technology, 41(6): 618-622.

Mepba, H.D., Eboh, L. Nwaojigwa, S.U. 2007. Chemical composition, functional and baking properties of wheat-plantain composite flours. African Journal of Food, Agriculture, Nutrition and Development, 7(1); Bioline code: NDO 7003.

Mohesenin, N.N. 1970. Physical properties of plant and animal materials. Gordan and Breach science publication, New York.

Nkama, I., Drame, D., Uga, C.O., Ndoye, A., Kaka, S. and Manful, J. 2005. Physical, Chemical and dehulling characteristics of pearl millet cultivars grown in the West African sub-region. Journal of Food Science and Technology, 42(2):188-191.

Premavalli, K.S., Satyanarayanaswamy, Y.S., Madhura, C.V., Majumdar, T.K. and Bawa, A.S. 2005. Effect of pretreatments on the physico-chemical properties of puffed ragi (finger millet) flour. Journal of Food Science and Technology, 42 (5): 443-445.

Puyed, S.S. and Prakash, J. 2006. Functional properties of thermally treated defatted soy and peanut flours. Journal of Food Science and Technology, 43 (3): 286-290.

Rajkumar, P., Varadharaju, N. and Devadas, C.T. 2004. Effect of drying methods on increasing milling yield of parboiled paddy varieties using rubber roll sheller. Journal of Food Science and Technology, 41(3): 303-305.

Ranganna, S. 2004. Handbook of analysis and quality control for fruit and vegetable products Tata McGraw Hill Publishing Co. Ltd. New Delhi.

Rao, U.P. and Deosthale, Y.G. 1998. *In vitro* availability of iron and zinc in white and colored ragi (*Eleusine coracana*): Role of tannin and phytate. Plant Foods in Human Nutrition, 38: 35-41.

Sadasivam, S. and Manickam, A. 2005. Biochemical methods. New Age International Private Ltd. New Delhi, Second Edition: 8-9, 20-21 and 56-57.

Shobana, S. and Malleshi, N.G. 2007. Preparation and functional properties of decorticated finger millet *(Eleusine coracana).* Journal of Food Engineering, 79 (2): 529-538.

Singh, P., Singh, G., Srivastava, S. and Agarwal, P. 2005. Physico-chemical characteristics of wheat flour and millet flour blends. Journal of Food Science and Technology, 42 (4): 340-343.

Sosulski, F., Humbert, E.S., Bui, K. and Jones, J.D. 1976. Functional properties of rapeseed flour, concentrates and isolates. Journal of Food Science, 41: 1349-1379.

Srivastava, S., Thathola, A. and Batra, A. 2001. Development and nutritional evaluation of proso millet-based convenience mix for infants and children. Journal of Food Science and Technology, 38 (5): 480-483.

Thompson, R.A. and Issac, G.W. 1967. Porosity determination of grains and seeds with air comparison pycometer. Trans ASAE, 10: 693-696.

Wang, J.C. and Kinsella, J.E. 1976. Functional properties of novel proteins: alfalfa leaf protein. Journal of Food Science, 41: 286-292.

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