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Effect of Dehulling Methods and Physical Characteristics of Grains on *Dhal* Yield of Pigeonpea (*Cajanus cajan* L.) Genotypes

U. SINGH, B.A.S. SANTOSA* AND P. V. RAO
International Crops Research Institute for the Semi-Arid Tropics, Patancheru, 502 324, India.

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Two traditional methods of dehulling - manual and home-processing (stone *chakki*); and two laboratory methods - barley pearler and tangential abrasive dehulling device (TADD) - were employed to study the dehulling quality of eight pigeonpea genotypes. *Dhal* yield by TADD was the highest (80.0%) for 'ICPL 87052' and the lowest (54.1%) for 'ICPL 87049' indicating significant (P<0.01) differences among genotypes. These results were further substantiated by *dhal* yield values obtained by the barley pearler. The stone *chakki* gave highly variable and erroneous results on *dhal* yield. The TADD and barley pearler methods were comparable and reliable. The theoretical *dhal* yield (manual method) was not correlated with dhal yields obtained by stone *chakki*, barley pearler and TADD. Grain hardness and grain volume were negatively correlated with the *dhal* yields obtained by the TADD and barley pearler methods, whereas swelling capacity and grain floatation values were not correlated with *dhal* yields obtained by these methods.

Considering the production and consumption, pigeonpea or redgram, is the second largest pulse crop in India and accounts for nearly 85% of the World's supply[1]. In India, it is mostly consumed after dehulling in the form of *dhal* (decorticated split cotyledons) and cooking in water to a desirable softness. Most of the nearly 2 million tonnes of pigeonpea produced annually in India is converted into *dhal*[2]. Not only does dehulling improve palatability and

*Present address: Sukamandi Research Institute for Food Crops (SURIF), Jalan Raya 9, Sukamandi, Subang - Jawa Barat, Indonesia, 41256.
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digestibility of pigeonpea; but it also reduces remarkably its cooking time[3]. Several methods are employed for dehulling pulses in India[4-6].

Variability in dehulling characteristics of pigeonpea may be influenced by variety and agro-climatic factors, but the role of these factors has not been established. In additon, several factors such as pre-treatments like soaking in salt solutions, water and oil application and sun-drying influence the dehulling of pigeonpea[7]. Some laboratory methods have been used to study the dehulling quality of pigeonpea genotypes[8,9]. A machine that removes barley bran was used to study the variability in dehulling characteristics of 19 pigeonpea genotypes[8]. In another study, variability in dehulling quality of 23 pigeonpea genotypes was described using the TADD method[9]. The objectives of this study were to compare different methods of dehulling to evaluate dehulling quality of pigeonpea genotypes, and to examine the relationship between the physical characteristics of the grain and dehulling quality of pigeonpea genotypes.

Materials and Methods

Grain samples of eight genotypes '(C-11', 'BDN 2,' and 'T 15-15' as control, and 'ICPL 87049,' 'ICPL 87052,' 'ICPL 87053,' 'ICPL 87066 and 'ICPL 87075' as newly developed genotypes) of pigeonpea were supplied by the pigeonpea breeding unit of Legumes Program at ICRISAT.

Pre-treatment of whole grain for dehulling: Soaking in water at room temperature followed by drying in the oven was the pre-treatment employed for dehulling. Grains of all genotypes were separately soaked in excess distilled water for 4 h at room temperature (25 ± 1°C). After soaking, excess water was discarded and the samples were dried in an oven at 55°C for 16 h and used for dehulling.

Dehulling methods: Two traditional methods, i.e., manual method and home-processing method (stone *chakki*), and two laboratory methods, barley pearler (Scott Seedburo, USA) and tangential abrasive dehulling device (TADD) as described by Ehiwe and Reichert[9] were used.

Manual method: The *dhal* yield was determined by manually separating the husk from the cotyledons. The seed coat and *dhal* fractions (cotyledons) were dried separately in the oven at 55°C overnight (16 hr) and weighed to calculate *dhal* and husk percentages.

Stone chakki (quem): A stone *chakki* consisting of lower (immovable) and upper (rotating) stone pieces each of 34.5 cm diameter and 5.5. cm thickness were used. A 100-g grain sample of pre-treated pigeonpea was slowly and uniformly added through a central hole in the upper stone which was gently and continuously rotated manually until the material was processed. The upper stone was removed and the processed grain material was collected and separated into *dhal*, brokens, powder and husk fractions. Both unsplit and split decorticated cotyledons were included as *dhal*.

Barley pearler: A 100-g grain material was dehulled for 4 min and the processed material was separated into *dhal*, brokens, powder and husk fractions. As mentioned earlier, both unsplit decorticated and split decorticated cotyledons were included together as *dhal*.

Tangential abrasive dehulling device (TADD): After standardizing the TADD for dehulling of pigeonpea, a 100-g grain sample was dehulled for 1 min by putting an approximately equal mass of grain material in 12 cups/holes of the TADD plate. After dehulling, the processed material was separated into *dhal*, brokens, powder, and husk fractions. As above, both unsplit and split decorticated cotyledons were included as *dhal*.

Physical characteristics: Moisture content was determined by drying the grain at 110°C for 18 h. Grain colour was visually recorded. The 100 grains were weighed in five replicates and the mean 100-grain mass of the sample recorded. For determination of grain volume, 20 ml of water was taken in a measuring cylinder and 50 grains were transferred into it. The increase in volume by the addition of grains was recorded as the volume of the grains. A floatation test was carried out by using sodium nitrate solution of 1.303 g/cc density. Fifty grains were dropped into the solution and shaken well. The number of floating grains was determined and calculated as the floatation percentage. Swelling capacity was determined by soaking 5 g of grains in distilled water at room temperature (25 ± 1°C) for 16 h. Excess water was discarded, traces of water wiped out and the samples weighed. Swelling capacity was expressed as g increase in mass per g of the grain material. An Instron food testing machine (Model 1140, High Wycombe, Buckinghamshire, UK) was used to measure the grain hardness. Fifty grains of each genotype were randomly selected and compressed to a breaking point at a crosshead speed of 80 mm per min with a 2:1 ratio. An average Instron force (Kg) was recorded as the grain hardness of the sample.

Statistical analysis: All the determinations were done in 3 to 15 replicates. Standard errors (SE) were determined by a one-way analysis of variance[10] and are indicated in the Tables as the pooled error of replicates.

Results and Discussion

The theoretical yields of dehulled grain determined by the manual method ranged from 85.2 to 88.4% with mean being 86.7% showing a small variation among the genotypes (Table 1). These *dhal* yield values primarily depend on the content of seed coat (husk) of pigeonpea genotypes as shown in Table 2. Excluding manual method, average *dhal* yield was highest (71.3%) in TADD followed by barley pearler (67.6%) and lowest in stone *chakki* (50.5%), (Table 1). The average *dhal* yield of pigeonpea genotypes analysed by TADD is comparable with that of the commercial *dhal* mills (70.1% *dhal*) in India[5], but is considerably lower than that of the improved commercial dehulling

TABLE 1. *DHAL* YIELD, BROKENS, POWDER AND HUSK FRACTIONS OF PIGEONPEA GENOTYPES OBTAINED BY DIFFERENT METHODS OF DEHULLING

	Dhal yield (%)				Broken (%)			Powder (%)			Husk (%)		
Genotype	MNM	SNC	BRP	TADD	SNC	BRP	TADD	SNC	BRP	TADD	SNC	BRP	TADD
'C-11'	85.8	45.6	71.8	75.7	27.7	4.0	2.5	6.0	5.3	5.9	9.9	13.1	14.6
'BDN2'	85.2	49.9	66.9	76.7	25.9	9.9	4.1	4.0	5.8	5.3	11.9	12.4	13.2
'T 15-15'	88.4	51.4	73.2	78.5	25.0	4.3	1.9	4.7	6.7	6.0	9.7	11.4	12.6
'ICPL 87049'	86.4	46.7	55.6	54.1	25.9	17.7	27.8	4.8	7.7	6.0	11.3	12.8	11.4
'ICPL 87052'	86.6	54.0	73.7	80.0	22.3	5.1	2.2	4.4	3.7	5.6	11.4	13.0	11.6
'ICPL 87053'	85.9	42.6	72.5	75.5	23.6	5.5	2.5	10.4	5.8	6.2	10.9	13.1	14.9
'ICPL 87066'	88.2	54.5	57.6	56.6	25.5	19.8	24.8	3.2	8.5	7.3	10.0	9.5	10.9
'ICPL 87075'	87.0	59.0	69.2	73.5	20.8	9.0	6.6	6.0	4.4	6.8	9.5	10.5	12.6
Mean	86.7	50.5	67.6	71.3	24.6	9.4	9.0	5.5	6.0	6.1	10.6	12.0	12.7
SEM	±0.36	±1.84	±0.51	±0.28	±2.12	±0.42	±0.23	±1.04	±0.32	±0.14	±0.46	±0.25	±0.20

MNM = manual method., SNC = stone *chakki*, BRP = barley pearler, TADD = tangential abrasive dehulling device.
Means of three independent determinations.

TABLE 2. PHYSICAL CHARACTERISTICS OF GRAINS OF PIGEONPEA GENOTYPES

Genotype	Grain colour	Moisture (%)	100-grain mass (g)	Grain volume (ml)	Floatation value (%)	Swelling capacity (g/g)	Grain hardness-force (Kg)	Husk (%)
'C-11'	Brown	9.4	10.0	8.0	8.8	1.08	17.4	14.2
'BDN2'	Cream	11.0	7.7	6.2	6.4	1.08	17.3	14.8
'T 15-15'	Cream	10.1	8.8	6.4	12.0	1.09	18.6	11.6
'ICPL 87049'	Cream	10.1	11.6	9.2	5.2	0.99	19.7	13.4
'ICPL 87052'	Brown	10.1	10.3	8.0	3.2	0.75	19.1	13.4
'ICPL 87053'	Brown	10.4	8.1	7.4	13.6	1.04	18.0	14.1
'ICPL 87066'	Cream	10.3	13.4	10.4	8.0	1.11	19.8	11.9
'ICPL 87075'	Cream	9.6	11.0	8.0	9.2	1.23	19.4	13.0
Mean		10.2	10.1	8.0	8.3	1.06	18.6	13.3
SEM		±1.2	±0.1	±0.1	±0.4	±0.02	±0.5	±0.38

Means of five independent determinatons.

technology developed for dehulling of pigeonpea[11]. The value for *dhal* yield was the highest (80.0%) for 'ICPL 87052' and the lowest (54.1%) for 'ICPL 87049' when dehulled in the TADD. Similar variations in *dhal* yield of these genotypes were observed when dehulled by using the barley pearler (Table 1). This indicated significant ($p < 0.01$) differences in dehulling quality of pigeonpea genotypes. The dehulling losses in terms of brokens were the highest (24.6%) in the stone *chakki* and this might have been due to the attrition action of the stones employed for dehulling in this method. A large variability in dehulling quality of pigeonpea genotypes was observed when they were dehulled by the TADD[9] and the machine that removes barley bran[8]. Eventhough the *dhal* yield primarily depends on the type of machine employed for dehulling, other characteristics such as size, shape and hardness of the grain seem to play an important role in determining dehulling losses and these have been discussed in the following sections. Some newly developed genotypes of pigeonpea '(ICPL 87049' and 'ICPL 87066') produced *dhal* yield lower than the control genotypes, 'BDN 2,' and 'C 11,' which yielded 76.7% and 75.7% *dhal* respectively when dehulled by TADD (Table 1). No large variability in *dhal* yield of these genotypes was obtained when dehulled in the stone *chakki* that also produced the lowest *dhal* yield.

A statistical comparison between dehulling methods indicated that the standard error (SE) and coefficient of variation (CV) of the procedures were the highest for stone *chakki* and the lowest for TADD. Not only did the stone *chakki* produce the highest percentage of brokens as dehulling losses (Table 1), it also produced highly variable and erroneous results on the *dhal* yield. Further, *dhal* yield obtained by a stone *chakki* was neither correlated with the TADD nor with the barley pearler. But there were significant ($P<0.01$) and highly positive correlations ($r=0.97^{**}$) and ($r=0.95^{**}$) between TADD and barley pearler for *dhal* yield and broken fractions, respectively. These results indicated that TADD and barley pearler methods are highly comparable.

Seed coat colour of genotypes varied widely from white to light brown to dark brown. There was no large variation in moisture content of these genotypes (Table 2). The 100-grain mass, grain volume and floatation value of these genotypes showed significant differences ($P \leq 0.01$). Grain hardness ranged between 17.3 and 19.7 kg (Instron force) indicating a small variation. Also, the grain coat content of these genotypes did not reveal a large variation.

The moisture content did not influence the *dhal* yields as there were no significant correlations between these characteristics (Table 3). Although the correlations are not

TABLE 3. CORRELATION COFFECIENT BETWEEN PHYSICAL CHARACTERISTICS AND *DHAL* YIELD OF PIGEONPEA GENOTYPES.

1. Moisture	1.00								
2. 100-seed mass	-0.38	1.00							
3. Grain volume	-0.28	0.94**	1.00						
4. Floatation value	-0.10	-0.36	-0.28	1.00					
5. Swelling capacity	-0.17	0.05	-0.07	0.46	1.00				
6 Grain hardness	-0.20	0.81*	0.72*	-0.29	-0.11	1.00			
7. *Dhal* yield[a]	-0.03	-0.76*	-0.82*	0.24	-0.12	-0.65	1.00		
8. *Dhal* yield[b]	-0.20	-0.67	-0.71*	0.36	-0.16	-0.57	0.97**	1.00	
9. *Dhal* yield[c]	-0.21	0.52	0.34	0.20	0.17	0.65	-0.25	-0.15	1.00

a. *Dhal* yield by TADD
b. *Dhal* yield by barley pearler
c. *Dhal* yield by manual operation

** Significant at 0.01 level, * Significant at 0.05 level.

statistically significant, grain hardness was negatively correlated with the TADD and barley pearler *dhal* yields, whereas it was positively correlated with the *dhal* yield obtained by the manual method (Table 3). It has been shown that greater than 75% of the variability in dehulling efficiency or yield could be accounted for by grain hardness and resistance to splitting of the grain into individual cotyledons[12]. The present results suggest that losses in terms of brokens and powder fraction would be more, if grains of genotypes are hard, requiring more abrasive force during the operation. Grain volume was negatively and significantly ($P \leq 0.05$) correlated to *dhal* yields, obtained by the TADD (r=-0.82) and the barley pearler (r=0.71). There was a positive and significant ($P \leq 0.01$) correlation (r=0.94) between grain volume and 100-grain mass of these genotypes (Table 3). It appeared that *dhal* yield in TADD and barley pearler depended on the size of grains, implying that bolder grains would reduce the *dhal* yield. Swelling capacity and the floatation values of these genotypes were not noticeably correlated with the *dhal* yields obtained by different methods (Table 3). Further, the theoretical *dhal* yield obtained by the manual method was not correlated with the *dhal* yields obtained by the TADD and barley pearler. This indicated that the seed coat content of a genotype obtained by the manual method cannot be used to predict the *dhal* yield of mechanical methods, which are commonly employed for dehulling pigeonpea in India. However, it is emphasized that the observations of this study may be used with caution, as these are based on the analysis of a limited number of genotypes.

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