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RESEARCH ARTICLE

Studies on physical and chemical properties of velvet bean, an underutilized wild food legume

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ABSTRACT : The present investigation was carried out to ascertain physical and chemical properties in the fractions of two different germplasm of velvet bean, an underutilized wild food legume (Valanadu – black and Kailasanadu – white). VB registered for higher values both for complex and basic geometric traits in the studied fractions than KW. Solid density, porosity and surface area of VB ranged from 0.17 to 0.25 (g/cm^3); 136.38 to 259.67 (%) and 375.89 to 651.26 (mm^2), respectively and significantly differed in fractions (p< 0.05). But it was less significant for chemical traits in fractions and germplasm. Crude protein, crude fat and moisture contents were higher in VB germplasm *i.e.*, 22.65 to 29.67% (DM); 6.01 to 8.05%; 6.72 to 9.56% (w.b) whereas, the lowest coefficient static fraction was noticed against stainless steel surface than on other studied materials in both the germplasm. Whereas, angle of repose ranged between 26.43 and 30.23^0 for VB; 30.82 and 35.98^0 for KW. To sum up, germplasm VB exhibited significance physical and chemical properties for further processing for industrialization and commercialization.

Key words : Germplasm, Physical and chemical properties, Velvet bean, Western ghats, Wild food legume

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INTRODUCTION

Legumes comprised as important food stuff and are chief economic sources of protein in the diets of economically weaker sections of population. Now-a-days, research is being geared up for the exploitation of underutilized legume seeds as a cheap source of vegetable protein. Underutilized species are those which potential not yet fully exploited to contribute to food security and poverty alleviation (Bhat and Karim, 2009). Velvet bean, *Mucuna pruriens* (L.) DC.*var. utilis* (wall ex Wight Br.), is an underutilized tropical legume comprising of protein (20%), carbohydrates (65%), fat (15%) together with several minerals and vitamins. It is also found that these plants species rich in bioactive compounds like *mucunine, mucunadenine* and other quinone compounds (Gurumoorthi *et al.*, 2008). Recently, for the last two decades enormous research effort has been carried out and documented with reference to nutritional / anti-nutritional factors and different processing aids to minimize/ eliminate ANF's to a greater extent. Furthermore, major research projects were undertaken to reduce / completely to eliminate or deactivate certain anti- nutritional factors by traditional and technological methods (Eilitta *et al.*, 2003). At the outset, research findings are paved the way for commercial exploitation of these pulses both for nutrition and therapeutic purposes. However, only limited information is available with regard to physical properties of velvet bean (Rich and Teixeira, 2005; Ezeagu *et al.,* 2003). In order to design and develop of machine(s) / equipment(s) for handling, conveying, grading, drying and packaging, it is necessary to determine their physical properties as a function of moisture content. Bulk density, true density and porosity can be useful in sizing grain hoppers and storage facilities. In turn, they can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Grain bed with low porosity will have greater resistance in preventing escape of water vapour during drying process,

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which may lead to higher power to drive the aeration fans. Whereas the static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Such information is useful in designing equipments for grain transportation and handling (Seifi and Alimadani, 2010). Keeping these aforesaid views in mind, the envisaged study was conducted to investigate moisture dependent physical and chemical properties of velvet bean with respect to size, shape, volume, sphericity, seed mass, true density, bulk density, porosity, coefficient of friction, angle of repose, crude protein, crude lipid, crude fibre, carbohydrates, ash content and moisture content.

EXPERIMENTAL PROCEDURE

Both white and black- seed coloured germplasm of velvet bean, *Mucuna pruriens* (L.) DC. Var *utilis* (Wall ex Wight) (Baker ex Burck), were collected from Kailasanadu and Valanadu agro-climatic regions of Tamil Nadu and Kerela bordering to Western Ghats. After drying and thrashing the mature pods, the seeds were stored in plastic containers at room temperature (25°C) until further use. The stored germplasm of KW (Kailasandu – white coloured) and VB (Valanadu-black coloured) were divided into four fractions based on their size (Fig. A).

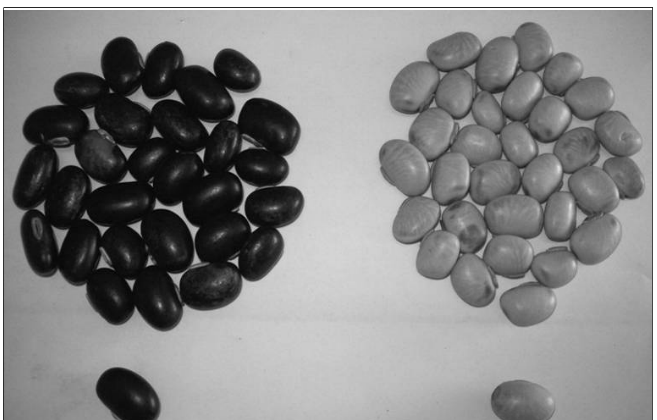


Fig. A : White and black seeded germplasm of velvet bean

Each sample carrying 100 seeds of both KW and VB on four fractions was taken in five replicates. The unit mass, m (g) was recorded by using an experimental balance (Sartorius Basic, India) with an accuracy of ±0.001 g. Geometrical dimensions length (x), width (y) and breadth (z) (Fig.1) were measured with a digital vernier caliper (Mitutoyo, Japan) with an accuracy of ±0.01mm. The arithmetic mean diameter (Da) and geometric mean diameter (Dg) of seeds were calculated from the geometrical dimensions according to the methods of Mohsenin (1980) and Bahnasawy (2007).

$$Da = \frac{(x + y + z)}{3} \qquad 1$$

$$Dg=(x \cdot y \cdot z)^{1/3} \qquad 2$$

Sphericity was calculated based on the isoperimetric property of a sphere.

$$\phi=(x.y.z)^{1/3} \quad \frac{Dg}{X} \qquad 3$$

N Unit mass, Vu (cm_3) of seeds was determined based on the assumption that the germplasm KW and VB are similar to a scalene ellipsoid where x > y > z. The formula was derived from the scalene ellipsoid volume as follows (Mohsenin, 1980).

$$Vu= \frac{4/3 \cdot (x \cdot y \cdot z)}{1000} \qquad 4$$

The bulk density is the ratio of the mass of the sample to its container volume. It was measured by weighing a filled measuring cylinder with known volume and calculated as follows

$$P_b=m/V \qquad 5$$

where,

P_b bulk density (g/cm^3), m is mass (g) and V is the volume of the sample.

The solid density or true density is defined as the ratio of mass of the sample to its true volume (Joshi *et al*., 1993).

$$p_s=m/n \cdot Vu \qquad 6$$

where, p_s solid density (g/cm^3), n is number of seeds in the sample.

Porosity, ε (%) indicates the amount of pores in the bulk material and was calculated as followed by Mohsenin (1980).

$$\varepsilon =(1-pb/ps) \cdot 100 \qquad 7$$

Approximate surface area, S (mm^2) of the seeds was determined by approximating their shape by prolate ellipsoids (Rich and Teixeira, 2005)

Coefficient of static friction is the ratio of force required to start sliding the sample over a surface divided by the normal force, *i.e.* the weight of the object. The static coefficient of friction of velvet bean seeds against different materials, *viz.,* plywood, aluminum, stainless steel and GI was determined. A wooden frame (10cm×10cm×6cm) was filled with seeds and placed over different plain surfaces. The filled frame was pulled along the surface and the peak force required to start motion was recorded by a fixed spring scale (Model Kern HDB 5k5, India). It was calculated as follows:

$$\mu=FT-FE/W \qquad 8$$

where μ coefficient of static friction, FT force required to start motion of filled frame in (N), FE force required for starting motion of empty wooden frame in (N), W weight of the object (N). The angle of repose indicates the cohesion among the individual units of a material. The higher the cohesion, higher is the angle of repose. The angle of repose of germplasm KW and VB were measured in two ways: (i) the filling method, to determine the static angle of repose and (ii) the emptying method, to determine the dynamic angle of repose or the filling method, (Schlumberger, 2008). The cylinder was placed over a plain surface and the germplasm were filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope. The dynamic angle of repose was calculated from the height and diameter of the piles:

$$\phi' = \tan\text{-}12h/D \qquad 8$$

where ϕ' angle of repose (°), h height of the pile (cm) and D diameter of the pile (cm).

The moisture content of the seed sample was determined gravimetrically on oven drying (105 ± 1°C) until constant weight was attained. Total nitrogen and crude protein were determined by the micro-Kjeldahl method (Humphries, 1956). By multiplying total nitrogen (N) with factor 6.25. The crude lipid was estimated by Soxhlet extraction using diethyl ether, crude fibre by acid and alkaline digestion and ash were determined gravimetrically on incineration in a muffle furnace at 550°C. The crude carbohydrates were calculated by difference (Muller and Tobin, 1980).

Crude carbohydrate (%) =100 - crude protein (%) +crude lipid (%) +crude fibre (%) + ash (%)

Statistical analysis:

All the values were estimated in five replicate determinations. The data were analyzed statistically using the AGRES statistics programme version 7.01,1994. Significant difference between mean values were calculated by analysis of variance(ANOVA) using Duncan's multiple range test at p<0.05.

EXPERIMENTAL FINDINGS AND ANALYSIS

Basic geometric traits of the four analyzed fractions of both the germplasm of velvet bean in terms of length, width, breadth, arithmetic mean diameter, geometric diameter, volume and unit mass are presented in Table 1. It is observed that all the studied characteristics within the fraction and between the germplasm were significantly different at P<0.05. The seeds of VB germplasm showed higher mean values for all the investigated traits compared with those of KW germplasm. Fraction I registered for highest magnitude for all the studied traits in both the germplasm. But lowest values were found in fractions of IV and III as the case of VB and KW germplasm. Nonetheless, there was no significant difference with regard to unit mass (which ranged between 0.199 to 0.20(g)). But drastic difference was noticed in length (ranged from 14.33 to 20.31mm (VB) and 13.97 to 17.26mm (KW), width (from 7.41 to 10.14mm (VB) and 7.44 to 8.47 mm (KW), breadth (10.54 to 13.57mm (VB) and 11.15 to 13.1 mm (KW)) and volume (4.72 to 11.71 cm^3 (VB) and 4.72 to 8.10 cm^3 (KW)).

Complex geometric characteristic such as porosity, sphericity, surface area and solid density are given in Table 2. The sphericity of seeds did not show any significant difference either between fractions or between germplasm. This implies that seeds are closer to shape of sphere. It was noticed that the parameters like surface area, porosity differed significantly among the fractions ($p < 0.05$). Highest values were obtained for the seeds of fraction I for all the parameters in both the germplasm except for solid density. Higher values for solid density were obtained from the seeds of fractions IV (0.25 g/cm^3) and III (0.24 g/cm^3) in VB and KW germplasm, respectively. The values for porosity ranged between 136.38 per cent and 259.67 per cent for the seeds of VB germplasm and for KW germplasm it range between 131.39 per cent and 215.10 per cent. While surface area ranged from 375.89 to651.26 mm^2 and 408.39 to 572.45 mm^2 for the fractions of black and white seed germplasm, respectively.

Coefficient static friction of seeds of both germplasm on various surfaces is given Fig. 1 and 2.

It shows that static friction on plywood surface was higher

Table 1 : Basic geometric traits of velvet bean germplasm (black and white -coloured seeds)[a]

Fractions	Length x (mm)	Width y (mm)	Breadth z (mm)	Arithmetic diameter Da (mm)	Geometric diameter Dg (mm)	Volume Vu (cm^3)	Unit mass m(g)
VB							
I	20.31±0.78[a]	10.14±0.57[a]	13.57±0.54[a]	14.67±5.17[a]	14.07±0.54[a]	11.71±1.36[a]	0.200±0.01581[a]
II	18.41±0.59[b]	9.37±0.37[b]	12.78±0.40[b]	13.52±4.56[b]	13.01±0.39[b]	9.23±0.85[b]	0.1996±0.005[bc]
III	17.20±1.00[c]	9.54±0.24[c]	11.96±0.23[c]	12.90±3.91[c]	12.51±0.32[c]	8.20±0.63[c]	0.1992±0.019[cd]
IV	14.33±0.51[d]	7.41±1.53[d]	10.54±0.51[d]	10.82±3.56[d]	10.34±0.93[d]	4.72±1.23[d]	0.1994±0.008[ab]
KW							
I	17.26±0.65[a]	8.47±0.61[a]	13.1±0.22[a]	12.94±4.39[a]	12.40±0.42[a]	8.01±0.85[a]	0.1998±0.00447[ab]
II	15.44±1.03[b]	7.83±0.31[c]	12.13±0.55[b]	11.80±3.82[c]	11.34±0.38[b]	6.13±0.62[b]	0.1994±0.00894[abc]
III	13.97±1.05[c]	7.44±0.42[d]	11.15±0.41[d]	10.86±3.26[b]	10.57±0.35[d]	4.72±0.46[d]	0.1996±0.00894[abc]
IV	15.06±0.77[d]	8.08±0.18[b]	11.83±0.40[c]	11.79±3.69[d]	11.28±0.32[c]	6.03±0.54[c]	0.2008±0.02168[a]

VB: Valanadu Black-coloured germplasm; KW: Kailasanadu White-coloured germplasm
a- All the values given in the table are mean of five replicates ± Standard deviation
Fractions were based on sizes(s) Fraction I) size s >13.52 and = 14.67; II) 13.52 ≥ s≥12.90; III) 12.90≥10.82; IV) ≥10.82 (Black seeds)
For white seeds Fraction I was s > 11.80 = 12.94; II) >10.86 ≥ 11.80; III) > 11.79 ≥ 10.86; IV) ≥ 11.79.
Values in the same column with different superscripts are significantly different statistically (p < 0.05).

Table 2 : Complex geometric characteristics of velvet bean germplasm (black and white-coloured seeds)[a]

Fractions	Sphericity φ (%)	Bulk density (ρ_b)(g/cm^3)	Solid density(ρ_s) (g/cm^3)	Porosity ε (%)	Surface area S (mm^2)
VB					
I	0.69 ± 0.01^{c}	0.60 ± 0.01^{a}	0.17 ± 0.01^{d}	259.67 ± 41.96^{a}	651.26 ± 53.12^{a}
II	0.72 ± 0.02^{a}	0.58 ± 0.01^{d}	0.18 ± 0.01^{c}	214.30 ± 28.97^{b}	566.22 ± 33.57^{b}
III	0.72 ± 0.06^{a}	0.57 ± 0.02^{c}	0.19 ± 0.01^{b}	191.25 ± 19.79^{c}	458.15 ± 76.51^{c}
IV	0.70 ± 0.009^{ab}	0.56 ± 0.02^{b}	0.25 ± 0.07^{a}	136.38 ± 61.73^{d}	375.89 ± 32.31^{d}
KW					
I	0.71 ± 0.01^{d}	0.49 ± 0.03^{d}	0.15 ± 0.01^{cd}	215.10 ± 33.61^{b}	572.45 ± 16.23^{a}
II	0.73 ± 0.30^{c}	0.60 ± 0.08^{a}	0.15 ± 0.02^{cd}	284.54 ± 39.97^{a}	493.68 ± 41.98^{b}
III	0.75 ± 0.04^{a}	0.55 ± 0.05^{b}	0.24 ± 0.02^{a}	131.39 ± 23.89^{d}	408.39 ± 27.13^{d}
IV	0.74 ± 0.02^{b}	0.54 ± 0.02^{c}	0.19 ± 0.01^{b}	157.78 ± 53.86^{c}	462.06 ± 27.13^{c}

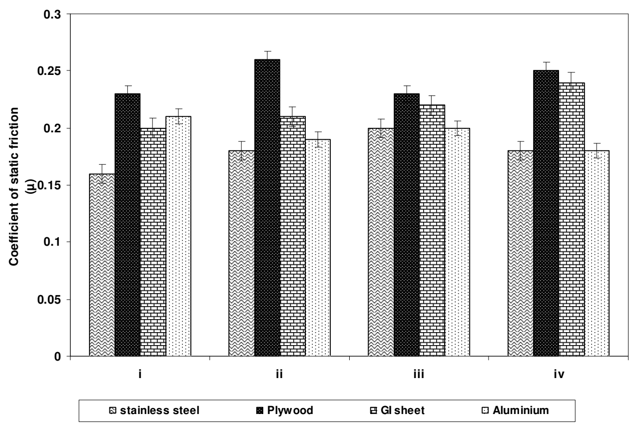
VB: Valanadu Black-coloured germplasm; KW: Kailasanadu White-coloured germplasm

a- All the values given in the table are mean of five replicates ± Standard deviation

Fractions were based on sizes(s) Fraction I) size s >13.52 and = 14.67; II) 13.52 ≥ s≥12.90; III) 12.90≥10.82; IV) ≥10.82 (Black seeds)

For white seeds Fraction I was s > 11.80 = 12.94; II) >10.86 ≥ 11.80; III) > 11.79 ≥ 10.86; IV) ≥ 11.79.

Values in the same column with different superscripts are significantly different statistically ($p < 0.05$).



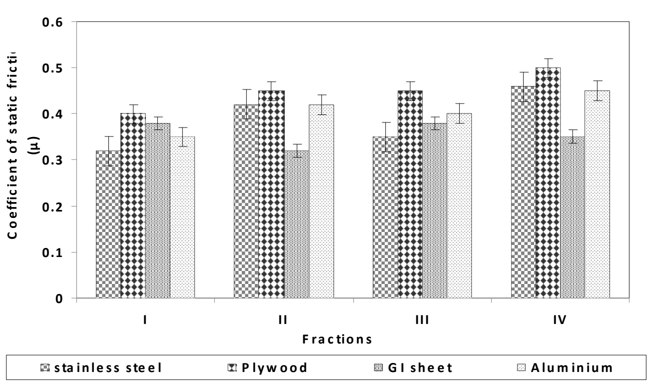
White seeds Fraction I was s > 11.80 = 12.94; II) >10.86 = 11.80; III) > 11.79 = 10.86; IV) = 11.79. Error bars indicate ± standard deviation

Fig. 1 : Coefficient of static friction in velvet bean germplasm (Kailasanadu white –coloured seeds)

(0.26ì) than the other surfaces. Static friction of stainless steel was found to be lowest *i.e.*, 0.16 m for the seeds of fraction I of KW and VB germplasm. Between two germplasm, the germplasm VB registered for higher coefficient of static friction when compared to KW germplasm on all the studied surfaces. The order of coefficient static friction was observed in following manner. Stainless steel > aluminum > galvanized iron sheet > plywood. The difference could be due to the differences in surface roughness of seeds and increased moisture content together which causes increased cohesion between grain and surface. The similar trend was observed for chickpea, pigeonpea, soybean and barbunia seeds (Konak *et al.*, 2002; Baryeh and Mangope, 2002; Tavakoli *et al..,* 2009; Cetin 2007).

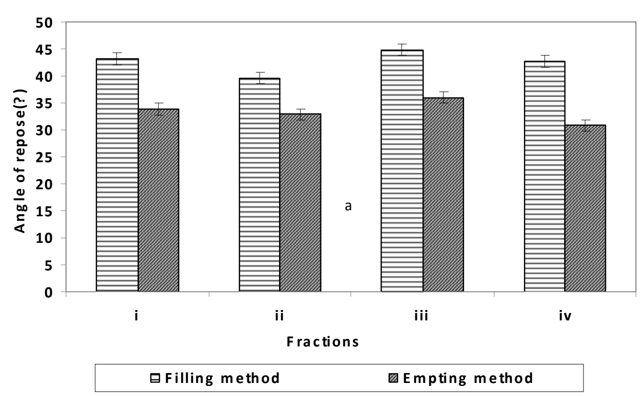
The data on angle of repose for the seeds of both the germplasm was displayed in Fig. 3 and 4.

The values were higher when applying filling method and emptying method. Angle of repose of seeds is decreasing with



Fractions were based on sizes(s) Fraction I) size s >13.52 and = 14.67; II) 13.52 = s=12.90; III) 12.90=10.82; IV) =10.82 (Black seeds). Error bars indicate ± standard deviation

Fig. 2 : Coefficient of static friction in velvet bean germplasm (Valanadu black coloured seeds)



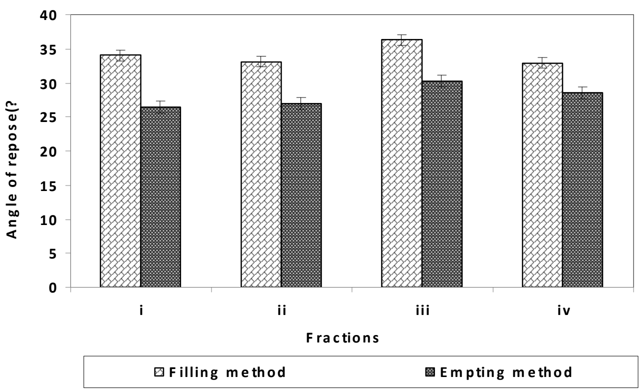
Fractions were based on sizes(s) Fraction I) size s >13.52 and = 14.67; II) 13.52 = s=12.90; III) 12.90=10.82; IV) =10.82 (Black seeds). Error bars indicate ± standard deviation

Fig. 3 : Angle of repose of velvet bean germplasm (Valanadu black coloured seed)

Table 3 : Chemical properties of velvet bean germplasm of black and white coloured seeds

Fractions	Moisture content (% w.b)	Ash content (%)	Crude protein (% DM)	Crude lipid (%)	Crude fiber (%)	Crude carbohydrate (%)
VB						
I	9.56±0.13[a]	8.93±0.56[a]	29.67±3.67[a]	8.05±3.75[a]	7.75 ±2.74[a]	50.02± 6.50[a]
II	8.99±0.64[b]	7.38±1.29[b]	26.11 ±5.28[b]	7.45± 2.91[b]	7.37 ±2.54[b]	47.72±3.77[b]
III	7.86±0.48[c]	6.54± 0.53[c]	24.91± 3.80[c]	6.61± 2.14[d]	6.96 ±2.10[c]	45.81 ±3.38[c]
IV	6.72±0.42[d]	5.56 ±0.75[d]	22.65± 2.86[d]	6.01 ±1.46[c]	5.82 ±1.51[d]	43.63±1.97[d]
KW						
I	9.58±0.27[a]	8.17±0.98[a]	28.67±2.28[a]	7.25±2.89[a]	7.83±4.25[a]	51.42±5.24[a]
II	8.63±0.49[b]	6.58±0.34[b]	27.11±7.07[b]	6.65±2.12[b]	5.65±1.43[bc]	44.74±4.73[b]
III	7.61±0.56[c]	5.92±0.85[bc]	23.45±3.01[c]	6.01±1.46[bc]	6.10±1.16[b]	43.2±3.27[c]
IV	6.31±0.60[d]	3.96±0.77[d]	21.45±2.04[d]	5.81±1.40[cd]	4.82±0.71[d]	41.55±3.67[d]

VB: Valanadu Black-coloured germplasm; KW: Kailasanadu White-coloured germplasm
a- All the values given in the table are mean of five replicates ± Standard deviation
Fractions were based on sizes(s) Fraction I) size s >13.52 and = 14.67; II) 13.52 ? s?12.90; III) 12.90?10.82; IV) ?10.82 (Black seeds)
For white seeds Fraction I was s > 11.80 = 12.94; II) >10.86 ? 11.80; III) > 11.79 ? 10.86; IV) ? 11.79.
Values in the same column with different superscripts are significantly different statistically ($p < 0.05$).



White seeds Fraction I was s > 11.80 = 12.94; II) >10.86 = 11.80; III) > 11.79 = 10.86; IV) = 11.79. Error bars indicate ± standard deviation

Fig. 4 : Angle of repose of velvet bean germplasm (Kailasanadu white coloured seed)

increasing unit mass. This is because smaller seeds showed higher cohesion than larger ones.

Chemical properties of analyzed fraction of both the germplasm of velvet bean are given Table 3.

In both the germplasm fraction 1 registered for the higher values of moisture content, ash content, crude protein, crude fibre, crude lipid and crude carbohydrates whereas fraction IV registered for lowest values. Significant difference existed between fractions and germplasm. Between two germplasm, seeds of fraction I of black seeded germplasm registered for higher contents of moisture (6.72 to 9.56% w.b); ash (5.56 to 8.93%); crude protein (22.65 to 29.67%); and crude lipid (6.01 to 8.05%). Nonetheless, fraction I of white seeded germplasm exhibited higher contents of crude fiber (4.82 to 7.83%) and crude carbohydrates (41.55 and 51.42%). In general, black seeded germplasm was found to contain higher amount of all the studied parameters except crude fibre, crude carbohydrate.

Conculsion:

The germplasm VB registered for higher values both for complex and basic geometric traits in the studied fractions than KW and showed significant difference between fractions ($p< 0.05$). However, it is less pronounced for chemical traits among fractions and between germplasm. Crude protein, crude fat and moisture contents were found to be higher in VB germplasm. Nonetheless, in both the germplasm, the lowest coefficient static fraction was found against stainless steel surface than on aluminum, GI sheet and wooden surfaces. While angle of repose, by emptying method, ranged between 26.43 and 30.23° for VB; 30.82 and 35.98° for KW germplasm. Between two germplasm VB exhibited significant physical and chemical properties for future processing compared to KW germplasm. The sum up, the findings based on this study clearly reveals that the black beans can be promoted further for dhal making and other industrial protein extraction procedures for industrialization followed by commercialization.

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