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PHYSICO-CHEMICAL PROPERTIES OF RAW, DEHUSKED AND SPLIT PIGEON PEA

HEMASANKARI PALANI,[1] R.K. VISWAKARMA[2], INDORE NAVNATH SAKHARAM[3], MANJU BALA[4] AND MRIDULA DEVI[5]

[1,2,3]FG & OP Division, ICAR-CIPHET, Ludhiana, Punjab
[4]Biochemistry, ICAR-CIPHET, Ludhiana, Punjab, India
[5]FG&OP Division, ICAR-CIPHET, Ludhiana, Punjab

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Abstract–Laboratory trials were done with CIPHET dhal mill using pigeonpea of 1kg lot and the milling efficiency without pre-treatment was determined. The random sampling was done for determination of whole dhal (pulses), split dhal, small brokens and chaff. Moisture content was deter -mined for the selected pigeonpea using hot air oven method. The physical properties of pigeon pea of length, width, thickness, volume, bulk density, true density, porosity, surface area, spheri -city, geometric mean diameter, arithmetic mean diameter,1000 kernel weight, length/ weight ratio, aspect ratio and type of grain were determined using laboratory standard procedure. Moisture content of the raw pigeon pea taken for analysis is 11.67%wb±0.13 and the dehusked dhal of pigeon pea is 8%±0.33.Length of whole pigeon pea dhal was greater than dehusked pigeon pea by 6.05%, dehusked pigeon pea is 19.54% greater than dehusked split dhal. Bulk density is more in whole pigeon pea that that of the dehusked dhal by 3% and true density of whole pigeon pea is less than dehusked dhal by 23.18%. Porosity of dehusked dhal is 48.91% more in dehusked dhal than whole dhal. 1000 kernel weight is 12.17% higher in de-husked pigeon dhal than whole dhal. Chemical properties of carbohydrate using formula method, protein using kjeldhal apparatus, fibre using fibrastatand fat using soxhlet apparatus for pigeon pea dhal, both husked and dehusked were determined using standard AOAC method of analysis. The mean protein content of pigeon pea in dehusked dhal is 20.30g±1.15 and that of whole pigeon pea is 20.02± 1.82.The mean protein content of de-husked pigeon pea is 1.37% greater than that of whole pigeon pea. The mean ash content of dehusked was less than whole by 6.29%.The mean carbohydrate value of dehusked and whole pigeon pea was estimated to be 60.52±1.25 and 53.97±1.25 respectively using AOAC method. Skewness is a measure of the asymmetry and kurtosis is a measure of peakedness of a distribution. In dehusked pigeon pea, positively skewed variables include fat (0.71), ash (1.22) and carbohydrate (0.26), negatively skewed variables include protein(-0.15) and fibre (-1.53). In split whole pigeon pea positive variables include fat (0.71), ash(1.22) and carbohydrate (0.26), negatively skewed variables include protein(-0.15) and fibre(-1.53). In chemical properties in whole pigeon pea, negative kurtosis variable include protein (-4.09) and carbohydrates(-3.31), positive kurtosis variables include, fat(2.63), fibre(3.66) and ash(3.79) in dehusked pigeon pea the negative kurtosis include protein(-3.33) and carbohy -drate (1.78), fibre(2.88) and ash(1.76).

INTRODUCTION

Pulses play an important role in managing the malnutrition among children and adults. Pulses include black gram, green gram, chickpea and pigeon pea. Pigeon pea is considered difficult to mill pulse, but has potential to eradicate malnutrition due to nutritional value. The processing of pigeon pea includes cleaning, grading, milling and packaging. Pigeon pea physiochemical characterisation is much needed to reduce the losses in post harvest level especially in milling. The physical properties include moisture content (%wb), length, width, thickness, volume, length/width ratio, arithmetic mean diameter, geometric mean diameter, sphericity, bulk density, true density, porosity, surface area, aspect ratio, 1000 kernel weight, static coefficient of friction, dynamic

([1]Scientist (ss)(AS&PE), [2]Principal Scientist (AS&PE), [3]Scientist (AS&PE), [4]Principal Scientist, [5]Head, FG&OP Division)

coefficient of friction, angle of repose, static angle of internal friction and dynamic angle of internal friction. The chemical properties include, carbohydrate, protein, fat, crude fibre and ash. These physical parameters determine the characteristics of the crop selected and design of processing machinery to reduce the post harvest loss. Pulses especially pigeon pea produced during 2013-14 (FAO, 2013) is 19.7mi.t. Milling of pulses is primarily done to remove the outer hull and to get the dhal recovery more.

MATERIALS AND METHODS

Raw pigeon pea (*Cajanus cajan*) freshly harvested were procured from the Agri-Market of Ludhiana, Punjab and subjected to cleaning and grading to remove the impurities and then random sampling was done to avoid ambiguity and then subjected to physiochemical analysis. Selected physical properties of moisture content determined by hot air oven method, length, weight, thickness were determined using vernier calipers. Bulk density was measured using determination of weight and volume, true density using toluene method, porosity was determined using bulk density and true density, 1000 kernel weight was measured using grain counting apparatus. This whole pigeon pea sample is subjected to milling and dehusked dhal is obtained and then subjected to splitting and the physical parameters were found out. Chemical properties of whole pigeon pea dhal, dehusked dhal and split dhal were found out using formula method of determination of carbohydrate, protein, fat, crude fibre and ash. Carbohydrate content was determined using AOAC method, protein content was determined using kjeldahl method, fat using soxhlet apparatus, crude fibre using fibrastat apparatus and ash was determined using Association of Analytical Chemists method. The values of these physical properties were determined in the cleaning and grading laboratory of FG&OP division of ICAR-CIPHET. The data and their interpretation are as follows.

Physical properties

Moisture content: The known weight of the pigeon pea samples husked, dehusked and split dhal in 3 replicates were taken in 3 replicates in hot air oven method of drying.100g of the sample was oven dried at 130 °C till it reaches the constant weight and the difference in weight is taken as the measure of moisture content in %wb.

mc(%wb)=((w1-w2)/w1);

w1-Initial weight before drying;g

w2-final weight after drying, g

Length, width and thickness: Length, Width and Thickness are measured using vernier calipers. 3 replications were taken and average were taken for unhusked, dehusked and split dhal samples.

Arithmetic mean diameter: The pigeon pea both whole, dehusked and split dhal in 3 replicates for arithmetic mean diameter is obtained by adding length, width and thickness divided by 3.

Arithmetic mean diameter, mm = ((l+w+t)/3),

l- length, mm; w- width, mm; t- thickness, mm

Length/width ratio: Length by Weight ratio was taken for 3 whole, dehusked and split dhal pigeon pea samples. This length/weight ratio decides the type of grain, if it is ≥ 2.50cm then it is said to be bold variety and if it is ≥ 2.50cm then it is said to be long slender variety.

Geometric mean diameter: This is obtained by adding length, width and thickness to the power of 0.33. This is useful in measuring the sphericity of the selected dhal samples of unhusked, dehusked and split dhal samples.

geometric mean diameter, mm= $(l+w+t)^{0.33}$

l-length, mm; w-width, mm, t-thickness, mm

Sphericity

This is a measure of the roundness of the sample. This sphericity is the ratio of geometric mean diameter by length of the individual whole, dehusked and split dhal samples.

$Ø=(l+w+t)^{0.33}/l$

l- length, w-width and t-thickness;

Ø - sphericity

Bulk Density: This is the ratio between weight and volume of the given dhal sample. A known weight of the sample is tilted in the container and the volume of the container was found out. The random samples of unhusked, dehusked and split dhal were taken for experiments.

bulk density=(weight/volume)kg/m^3

Surface Area: The surface area of the dhal was measured using formula method for whole, dehusked grain and split dhal samples.

surface area, $mm^2=((Đ/4)*d^2)$; d- diameter, mm

Aspect Ratio: It is the ratio between width and length of the unhusked, dehusked and split dhal sample. aspect ratio=(width/length)

True density: The true density is determined by toluene displacement method. 10g known weight of the sample is taken and 20 ml of toluene is taken in a measuring cylinder and the grains are put in the cylinder and the displacement of volume is noted. True density is calculated by knowing the weight and volume of the unhusked, dehusked and split dhal sample.

true density, kg/mm^3=(weight/volume)

Porosity: By knowing the bulk density and true density, porosity can be calculated by the following formula for unhusked, dehusked and split dhal samples.

Porosity,%=(1-(bulk density/true density))

1000 kernel weight: This is obtained by counting 1000 kernels in 1000 kernel weight apparatus for unhusked, dehusked and split dhal samples.

Angle of Repose: The angle of repose is obtained by pouring the grains in angle of repose apparatus hop per and the height of the heap that is formed is measured using a graduated scale in three standard diameter discs of 100mm diameter, 150mm diameter and 200mm diameter. The formula used to find out the angle of repose is,

$Ø=\tan^{(-1)}(h/d)$;

h-height of the grain, mm;

d-diameter of the disc,mm for unhusked, dehusked and split dhal samples.

Coefficient of friction: The coefficient of friction can be calculated by applying measured load/weight at one end to the measured weight of the grain. The weight required to initiate the pulling of the measured amount of pigeon pea grain is said to be static coefficient of friction and the weight required to travel 1m length of different plates made from wooden, galvanized iron and mild steel is said to be dynamic coefficient of friction for unhusked, dehusked and split dhal samples.

cof(μ)=(f/w);

f- measured load/weight at one end, g; w-measured weight of the grain,g

Angle of internal friction: This coefficient of friction is equal to the tangent of the angle of internal friction for the material. The angle of internal friction obtained from static coefficient of friction is called as static angle of internal friction and with dynamic coefficient of friction is said to be dynamic angle of internal friction for selected unhusked, dehusked and split dhal samples.

$aoif=\tan^{(-1)}(\mu)$;

μ-coefficient of friction

Chemical properties

Protein Analysis: Powdered pigeon pea samples were tested for its chemical constituents namely, carbohydrate, protein, fat, crude fibre and ash content. Nitrogen estimation is done using Micro-Kjeldahl method with KHL PLUS nitrogen estimation system (PELICAN) for unhusked,de-husked and split dhal samples.

crude protein (%)=(nitrogen (%)*6.25)

Fat Analysis: Fat analysis was estimated using soxhlet apparatus for unhusked, dehusked and split dhal samples.(AOAC,1995).

%Fat=((w1-w2)/w),

w1-wt of flask with fat,g, w2-wt of empty flask, g,

w-wt of sample before drying, g

Crude Fibre Analysis: This is estimated using fibre extraction system for unhusked, dehusked and split dhal samples (Fibraplus)(Pelican)(AOAC,1995)

% crude fibre=((w1-w2)/w))*100, w1-wt of crucible+ash, g, w2-wt of ash, g, w-wt of sample,g

Ash Analysis: This is estimated using muffle furnace for unhusked, dehusked and split dhal samples. (AOAC, 1995)

Ash(%)=((wt of the ash/wt of the sample)*100)

Carbohydrates Analysis: Carbohydrate content was calculated by difference method AOAC(1995) on dry basis using following formula.

total carbohydrates,%=(100-(crudefat+crude protein + crude ash+crude fibre)) for unhusked, dehusked and split dhal samples.

RESULTS AND DISCUSSION

Physical Properties: Laboratory trials were done with CIPHET dhal mill using pigeon pea of 1kg lot in whole pigeon pea, dehusked pigeon pea and split dehusked pigeon pea (Fig.1,2&3) in the pulse milling machine and the milling efficiency without pretreatment was determined. The random

Fig. 1. dehusked pigeon pea

Fig. 2 whole pigeon pea

Fig. 3 split dhal of pigeon pea

sampling was done for determination of whole dhal, split dhal, small brokens and chaff content. Moisture content was determined for the selected pigeon pea using hot air oven method. The physical properties of pigeon pea of length, width, thickness, volume, bulk density, true density, porosity, surface area, sphericity, geometric mean diameter, arithmetic mean diameter, 1000 kernel weight, length/weight ratio, aspect ratio, angle of repose and type of grain were determined using laboratory standard procedure (Fig. 4). The length, width, thickness and geometric diameter of pigeon seeds in India according to Khan *et al.* (2017), ranged from 4.9 to 6.9mm, from 4.52 to 5.40mm, from 4.10 to 4.70mm and from 4.95 to 5.45mm, respectively. The length, width and thickness in pigeon pea is used in designing of hopper chutes, crushing drum of the milling chamber. The arithmetic mean diameter was found to be more as compared to dehusked pigeon pea dhal and split dhal. Length/width ratio of whole dhal was lesser than dehusked dhal and split dhal. This length/width ratio data was needed for designing crushing/milling chamber. Geometric mean diameter was also more in whole pigeon pea compared to dehusked dhal and split dhal since whole dhal is larger in size as compared to dehusked dhal and split dhal is still smaller in size. The sphericity was more in dehusked pigeon pea dhal as compared to whole pigeon pea since outer

Table 1. Selected physical properties of milled whole pigeonpea, dehusked and split pigeon pea dhal

Sl.	Parameters	Whole pigeon pea	Dehusked pigeon pea	Split pigeon pea	p-vals/ns
1	Moisture content (%wb)	8.00(0.00)	11.67(0.30)	10.00(0.09)	0.01(s)
1a	Moisture content (%db)	8.70(0.00)	13.21(0.30)	11.11(0.09)	0.01(s)
2	Length (mm)	4.67(0.15)	4.09(0.59)	3.97(0.10)	0.00(s)
3	Width (mm)	3.31(0.32)	3.10(0.16)	3.02(0.16)	0.00(s)
4	Thickness (mm)	2.56(0.05)	2.42(0.24)	0.60(0.10)	0.10(s)
5	Arithmetic mean ˜,(mm)	3.52(0.13)	3.20(0.33)	1.41(0.10)	0.05(s)
6	Length/width	1.42(0.12)	1.36(0.05)	4.68(0.50)	0.15(s)
7	Geometric mean ˜,(mm)	2.18(0.03)	2.11(0.00)	1.61(0.00)	0.01(s)
8	Sphericity	0.47(0.01)	0.52(0.00)	0.46(0.00)	0.00(s)
9	Bulk density (kg/m^3)	932.00(28.84)	900.00(40.00)	1378.60(107.4)	0.02(s)
10	Surface area (m^2)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.14(s)
11	Aspect ratio	0.71(0.05)	0.76(0.17)	0.22(0.02)	0.08(s)
12	True density, (kg/m^3)	1074.00(64.15)	1263.23(159.1)	3284.30(413.7)	0.12
13	Porosity (%)	13.12(2.80)	27.73(12.20)	57.64(5.48)	0.13
14	Angle of repose (º)	12.19(0.29)	11.95(0.42)	13.10(1.50)	0.00(s)
15	1000 kernel weight (g)	44.73(0.01)	50.93(0.01)	40.60(2.88)	0.00(s)
16	Coefficient of friction, static (º)	0.43(0.08)	0.65(0.23)	0.72(0.23)	0.02(s)
17	Angle of internal friction, static (º)	23.36(3.72)	32.39(8.96)	35.03(8.48)	0.01(s)
18	Coefficient of friction, dynamic (º)	0.43(0.13)	0.70(0.23)	0.77(0.23)	0.03(s)
19	Specific gravity (g/cc)	1.07(0.06)	1.26(0.20)	3.28(0.40)	0.12
20	Angle of internal friction, dynamic (º)	22.44(6.08)	34.37(0.20)	36.91(8.07)	0.02(s)

layer, husk is present in whole pigeon pea dhal and in split dhal the sphericity is much less since it is divided into two halves. Bulk density was more in whole pigeon pea than in dehusked pigeon pea and in split dhal it is more. The bulk density is less in whole pigeon pea dhal due to husk that is present in the outer layer of the grain that increases the volume but not the weight as compared to dehusked pigeon pea dhal. Aspect ratio was less in whole pigeon pea dhal than in dehusked dhal and it is still less in split dhal. True density was more in split dhal than in dehusked pigeon pea and whole pigeon pea dhal. The porosity increases from whole dhal to dehusked pigeon dhal and split dhal. This may be due to the density difference and due to the unequal shape distribution among the grains. This parameter is needed to design the hopper in any grain processing machinery. 1000 kernel weight is less in split dhal as compared to whole pigeon pea dhal and dehusked pigeon pea dhal. Static coefficient of friction was more in split dhal as compared to dehusked pigeon pea dhal and in whole pigeon pea dhal. The dynamic coefficient of friction was slightly more than static coefficient of friction in whole pigeon pea dhal, dehusked pigeon pea dhal and then in split dehusked dhal. The static angle of internal friction gradually increases from whole pigeon pea to dehusked pigeon pea dhal and then split dhal. The specific gravity of split dhal was highest as compared to dehusked and whole pigeon pea dhal. The dynamic angle of internal friction was slightly more than the static angle of internal friction. The higher value may be due to the frictional force developed by the split dhal to achieve maximum

Table 1a. Coefficient of friction and angle of internal friction of whole, dehusked and split dehusked pigeon pea after milling in 3 different surfaces of wooden, galvanized iron sheet and mild steel

Sn.	Parameters	Coefficient offriction	Angle of internal friction(º)
1	Unhusked wooden, static	0.50	26.57
2	Unhusked galvanized iron, static	0.35	19.29
3	Unhusked mild steel, static	0.45	24.23
	Mean(sd)	0.43(0.08)	23.36(3.72)
	p(≥0.05)	0.01(s)	0.01(s)
4	Unhusked wooden, dynamic	0.55	28.81
5	Unhusked galvanized iron, dynamic	0.30	16.70
6	Unhusked mild steel, dynamic	0.40	21.80
	Mean(sd)	0.42(0.13)	22.44(6.08)
	p(≤0.05)	0.01(s)	0.01(s)
7	Dehusked wooden, static	0.45	24.23
8	Dehusked galvanized iron, static	0.60	30.96
9	Dehusked mild steel, static	0.90	41.98
	Mean(sd)	0.65(0.23)	32.39(8.96)
	p(≤0.05)	0.04(s)	0.02(s)
10	Dehusked wooden, dynamic	0.50	26.57
11	Dehusked galvanized iron, dynamic	0.65	33.02
12	Dehusked mild steel, dynamic	0.95	43.53
	Mean(sd)	0.70(0.23)	34.37(8.56)
	p(≤0.05)	0.03(s)	0.02(s)
13	Split wooden, static	0.50	26.57
14	Split galvanized iron, static	0.70	34.99
15	Split mild steel, static	0.95	43.53
	Mean(sd)	0.72(0.23)	35.03(8.48)
	p(≤0.05)	0.03(s)	0.02(s)
16	Split wooden, dynamic	0.55	28.81
17	Split galvanized iron, dynamic	0.75	36.87
18	Split mild steel, dynamic	1.00	45.00
	Mean(sd)	0.77(0.26)	36.89(8.10)
	p(≤0.05)	0.03(s)	0.02(s)

( ) Figures in parenthesis represents standard deviation values,
Each value in the table is the replication of three experimental values

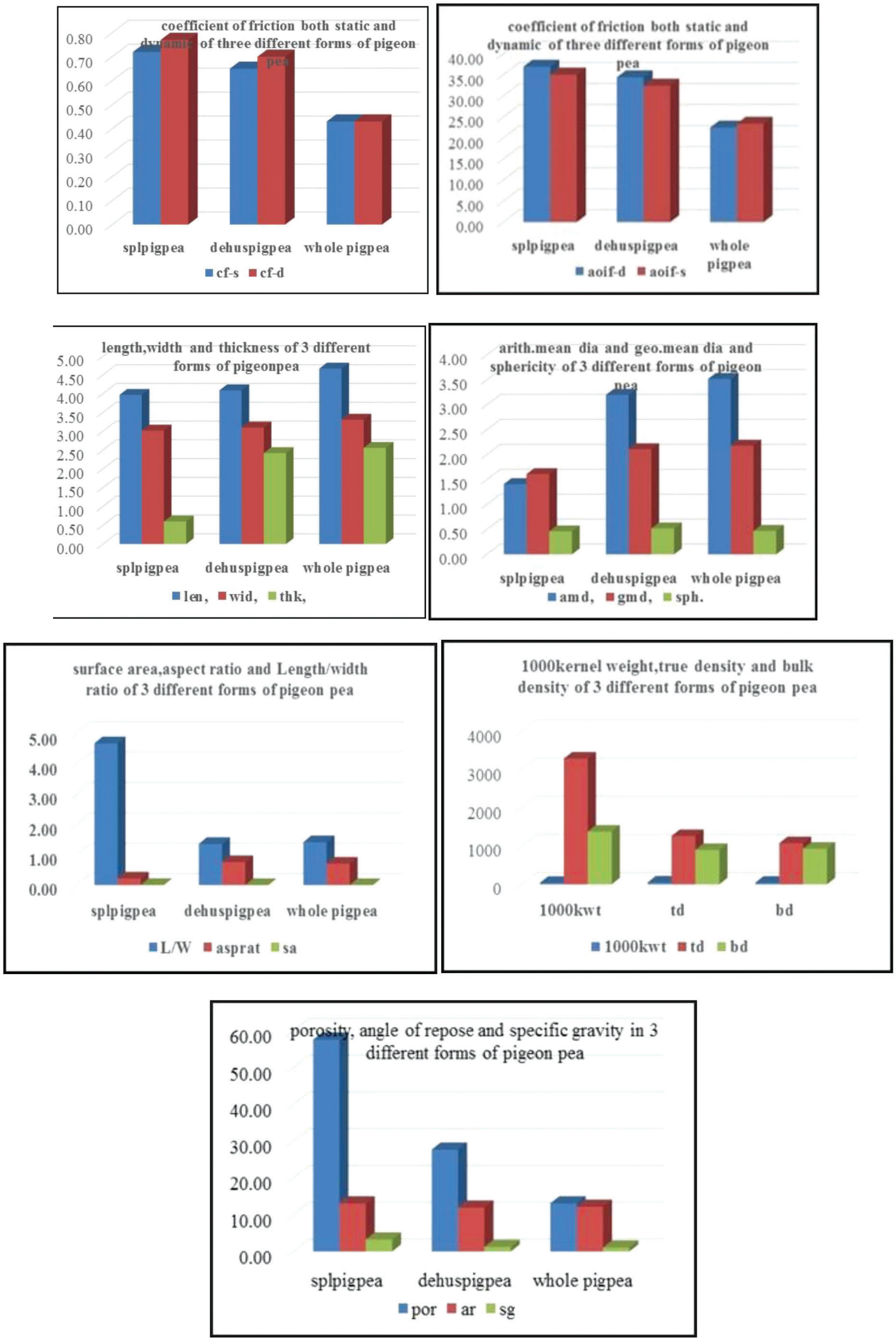

Fig. 4. Physical properties of raw whole pigeon pea, dehusked pigeon pea and dehusked split pigeon pea

height and in dehusked and whole pigeon pea due to round shaped in nature, the grains fall and do not form a big cone and hence the value of angle of repose is less. Length of whole pigeon pea dhal was greater than dehusked pigeon pea by 6.05%, dehusked pigeon pea is 19.54% greater than dehusked split dhal. Sphericity of whole pigeon pea dhal was 9.62% less than dehusked dhal, in split dhal it is much lesser. 1000 kernel weight of dehusked whole pigeon pea dhal is 20.28% greater than dehusked split dhal. 1000 kernel weight of whole pigeon pea dhal was 12.17% less than dehusked pigeon pea dhal. Porosity was 50.16% greater in dehusked pigeon pea than that of whole pigeon pea, dehusked split pigeon pea was 51.89% greater than dehusked pigeon pea. Angle of repose

Table 2. Observed and predicted values of different physical properties of raw pigeon pea

SN.	Parameters	obs. val	pred.val
1	Moisture content (%wb)	8.00	20.52
2	Length (mm)	4.67	18.31
3	Width (mm)	3.31	18.02
4	Thickness (mm)	2.56	17.12
5	Arithmetic mean, (mm)	3.52	17.41
6	Length/width	1.42	18.66
7	Geometric mean diameter (mm)	2.50	17.48
8	Sphericity	0.31	17.06
9	Bulk density (kg/m^3)	932	521.64
10	Surface area (m^2)	0.00	16.90
11	Aspect ratio	0.71	16.97
12	True density (kg/m^3)	1074.07	1228.20
13	Porosity (%)	13.12	38.11
14	Angle of repose(•)	12.19	21.63
15	1000 kernel weight(g)	44.73	31.68
16	Coefficient of friction, static	0.43	17.17
17	Angle of internal friction, static(•)	23.36	30.02
18	Coefficient of friction, dynamic	0.42	17.18
19	Specific gravity (g/cc)	22.44	18.11
20	Angle of internal friction, dynamic (•)	1.07	30.80

Table 3. Observed and predicted values of different physical properties of dehusked pigeon pea

Nn.	Parameters	Obs.val	Pred.val
1	Moisture content (%wb)	10.00	9.61
2	Length (mm)	3.49	6.00
3	Width (mm)	3.49	4.53
4	Thickness (mm)	0.75	3.72
5	Arithmetic mean ˜,(mm)	1.41	4.75
6	Length/width	4.68	2.47
7	Geometric mean ˜,(mm)	2.36	3.64
8	Sphericity	0.24	1.27
9	Bulk density (kg/m^3)	1378.67	1012.21
10	Surface area (m^2)	0.00	0.94
11	Aspect ratio	0.22	1.70
12	True density, (kg/m^3)	3284.39	1166.36
13	Porosity(%)	57.64	15.17
14	Angle of repose (º)	13.18	14.16
15	1000 kernel weight (g)	40.60	49.47
16	Coefficient of friction, static(º)	0.72	1.40
17	Angle of internal friction, static(º)	35.03	26.28
18	Coefficient of friction, dynamic(º)	0.77	1.39
19	Specific gravity (g/cc)	36.91	25.28
20	Angle of internal friction, dynamic (º)	3.28	2.10

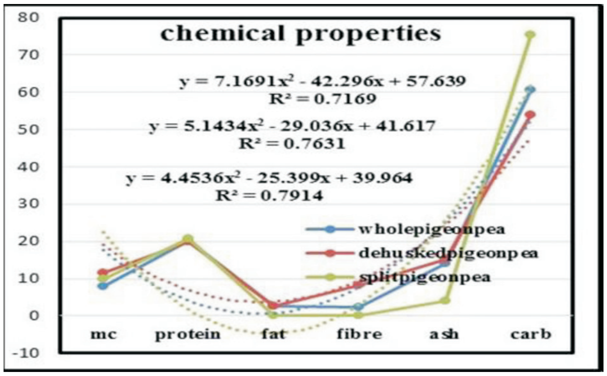

Fig. 5. Chemical properties of whole pigeon pea, dehusked pigeon pea and split pigeon pea

of whole pigeon pea dhal was 1.97% greater than dehusked pigeon pea dhal, dehusked pigeon pea dhal is 8.78% less than dehusked split dhal. The higher value may be due to the frictional force developed by the split dhal to achieve maximum height and in dehusked and whole pigeon pea due to the round shaped in nature, the grains fall and do not form a big cone and hence the value of angle of repose is less. The static coefficient of friction for mild steel in dehusked, unhusked and split dhal was greater than galvanized iron sheet and wooden platform. The frictional force exerted by the wooden platform was found to be more compared to galvanized iron sheet and then mild steel. The static coefficient of friction of split dhal was more compared to dehusked and unhusked dhal. The split dhal surface was rough compared to smooth finish of unhusked and dehusked dhal. The static angle of internal friction of unhusked dhal was lesser than dehusked and split dhal. The type of grain was bold variety. Table 1a shows the coefficient of friction and angle of internal friction of whole, dehusked and split dehusked pigeon pea after milling in 3 different surfaces of wooden, galvanized iron sheet and mild steel. In wooden platform, in static coefficient of friction was more in split dhal ≥ whole pigeon pea ≥ dehusked, in galvanised iron sheet, whole pigeon pea ≤ dehusked ≤ split dhal, in mild steel, coefficient of friction is more in split dhal followed by dehusked and then in whole pigeon pea. In dynamic of coefficient of friction, in wooden platform, split dhal is more and is followed by whole pigeon pea and then in dehusked form, in galvanized iron sheet, dynamic coefficient is more in split dhal ≥ dehusked pigeon pea ≥ whole pigeon pea, in mild steel coefficient of friction is more in split pigeon pea ≥ dehusked ≥ whole pigeon pea. The static coefficient of friction varied for whole pigeon pea from 0.35 to 0.50, in dehusked pigeon pea varied from 0.50 to 0.95 and split pigeon pea varied from 0.50 to 0.95. The dynamic coefficient of friction for whole pigeon pea was from 0.30 to 0.55, in dehusked pigeon pea was from 0.50 to 0.95, in split pigeon pea it is from 0.55 to 1.00, these values were significant at $p \leq 0.005$ using Statistica version software, 6.0 version. Fig.4

Table 4. Observed and predicted values of different physical properties of split pigeon pea

Sn.	Parameters	obs.val	pred.val
1	Moisture content (%wb)	11.67	9.61
2	Length (mm)	4.09	6.00
3	Width (mm)	3.10	4.53
4	Thickness (mm)	2.42	3.72
5	Arithmetic mean ˜,(mm)	3.20	4.75
6	Length/width	1.36	2.47
7	Geometric mean ˜,(mm)	2.11	3.64
8	Sphericity	0.52	1.27
9	bulk density (kg/m^3)	900.00	1012.21
10	surface area (m^2)	0.00	0.94
11	aspect ratio	0.76	1.70
12	true density, (kg/m^3)	1263.23	1166.36
13	porosity (%)	27.73	15.17
14	angle of repose (º)	11.95	14.16
15	1000 kernel weight (g)	50.93	49.47
16	coefficient of friction, static (º)	0.65	1.40
17	angle of internal friction, static(º)	32.39	26.28
18	coefficient of friction, dynamic (º)	0.70	1.39
19	specific gravity (g/cc)	34.37	25.28
20	angle of internal friction, dynamic (º)	1.26	2.10

Table 5. Descriptive statistics of different physical properties of whole pigeon pea

Sn.	Whpigpea	Mean	Median	Mode	Frequency	Minimum	Maximum	Variance	Sd	Skewness	Kurtosis	R2	p
1	MC	8.00	8.00	8.00	4.00	8.00	8.00	0.00	0.00	0.00	0.00	0.99	0.03
2	Length	4.69	4.69	multiple	0.00	4.55	4.84	0.02	0.13	0.08	-2.23	0.99	0.11
3	Width	3.23	3.24	multiple	0.00	2.94	3.51	0.09	0.31	-0.01	-5.82	0.99	0.09
4	Thickness	2.56	2.55	multiple	0.00	2.52	2.61	0.00	0.04	1.09	0.30	0.98	0.13
5	Amdia	3.44	3.47	multiple	0.00	3.20	3.62	0.04	0.19	-0.55	-2.10	0.97	0.02
6	L/W	1.43	1.42	multiple	0.00	1.33	1.55	0.01	0.10	0.63	-0.56	0.95	0.23
7	Gmdia	2.18	2.18	2.18	2.00	2.14	2.20	0.00	0.03	-1.13	2.23	0.99	0.001
8	Sphericity	0.46	0.47	0.47	2.00	0.45	0.47	0.00	0.01	-0.85	-1.29	0.99	0.0009
9	Bulkdensity	931.50	935.00	multiple	0.00	900.00	956.00	555.67	23.57	-0.81	1.08	0.99	0.03
10	Surfacearea	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.02
11	Aspectratio	0.70	0.71	multiple	0.00	0.65	0.75	0.00	0.05	-0.20	-3.20	0.99	0.03
12	Truedensity	1058.05	1060.55	1111.10	2.00	1000.00	1111.10	3769.07	61.39	-0.02	-5.87	0.99	0.03
13	Porosity	13.22	13.73	multiple	0.00	10.00	15.40	5.25	2.29	-1.24	2.22	0.98	0.01
14	Angofrep	12.16	12.18	multiple	0.00	11.86	12.41	0.06	0.25	-0.32	-2.56	0.99	0.01
15	Thkwt	44.70	45.29	46.00	2.00	42.20	46.00	3.21	1.79	-1.28	0.87	0.99	0.001
16	CFS	0.43	0.43	multiple	0.00	0.35	0.50	0.00	0.06	0.00	-1.20	0.91	0.04
17	Aoifs	23.42	23.91	multiple	0.00	19.29	26.57	9.22	3.04	-0.92	1.77	0.99	0.001
18	CFD	0.40	0.38	multiple	0.00	0.30	0.55	0.01	0.11	1.19	1.50	0.99	0.038
19	Sg	1.07	1.08	1.11	2.00	1.00	1.11	0.00	0.05	-0.71	-2.06	0.99	0.03
20	Aoifd	21.48	20.20	multiple	0.00	16.70	28.81	28.34	5.32	1.16	0.95	0.99	0.11

Table 6. Descriptive statistics of different physical properties of dehusked pigeon pea

N.	Dehpigpea	Mean	Median	Mode	Frequency	Minimum	Maximum	Variance	Sd	Skewness	Kurtosis	R2	p
1	Mc	10.00	10.00	10.00	4.00	10.00	10.00	0.00	0.00	0.00	0.00	0.98	0.15
2	Length	3.89	3.75	multiple	0.00	3.65	4.43	0.13	0.36	1.85	3.48	0.99	0.02
3	Width	3.11	3.10	multiple	0.00	2.81	3.41	0.11	0.32	0.01	-5.84	0.99	0.014
4	Thickness	0.63	0.64	multiple	0.00	0.52	0.70	0.01	0.09	-0.53	-2.90	0.96	0.02
5	Amdia	1.41	1.41	multiple	0.00	1.32	1.50	0.01	0.08	0.17	-0.47	0.96	0.19
6	L/W	4.88	4.88	multiple	0.00	4.28	5.48	0.34	0.58	0.00	-4.76	0.99	0.001
7	Gmdia	1.61	1.62	multiple	0.00	1.57	1.64	0.00	0.03	-0.94	1.50	0.97	0.02
8	Sphericity	0.46	0.46	.46	2.00	0.45	0.47	0.00	0.01	0.00	1.50	0.98	0.01
9	Bulkdensity	1394.00	1390.00	multiple	0.00	1296.00	1500.00	8624.00	92.87	0.16	-3.13	0.99	0.04
10	Surfacearea	0.00	0.00	.004	2.00	0.00	0.00	0.00	0.00	-0.85	-1.29	0.99	0.003
11	Aspectratio	0.21	0.22	multiple	0.00	0.19	0.23	0.00	0.02	-0.75	0.34	0.99	0.122
12	Truedensity	3345.36	3389.23	multiple	0.00	2888.80	3714.20	129035.15	359.21	-0.57	-0.85	0.98	0.128
13	Porosity	58.59	58.30	multiple	0.00	53.85	63.92	23.65	4.86	0.16	-4.44	0.99	0.08
14	Anglerepose	13.07	12.90	multiple	0.00	11.80	14.70	1.44	1.20	0.86	1.92	0.99	0.048
15	Thkwt	40.84	40.68	multiple	0.00	38.20	43.80	5.78	2.40	0.33	-0.84	0.99	0.002
16	Cfs	0.76	0.80	multiple	0.00	0.50	0.95	0.04	0.20	-0.69	-1.50	0.99	0.017
17	Aoifs	36.23	37.42	multiple	0.00	26.57	43.53	53.73	7.33	-0.79	0.04	0.99	0.0019
18	Cfd	0.79	0.80	multiple	0.00	0.55	1.00	0.04	0.19	-0.36	0.26	0.99	0.008
19	Sg	3.35	3.41	multiple	0.00	2.89	3.71	0.13	0.36	-0.63	-1.20	0.98	0.15
20	Aoifd	38.41	39.88	multiple	0.00	28.86	45.00	52.36	7.24	-0.87	-0.61	0.99	0.02

represents the selected physical properties of length, width and thickness in whole pigeon pea, dehusked pigeon pea and split dehusked pigeon pea. Table 1 Physio-chemical properties of raw, dehusked and split pigeon pea shows the selected physical properties of milled whole pigeon pea, dehusked whole pigeon pea and split dehusked pigeon pea. Table 7, 8 and 9 shows the pearson correlation coefficient of whole pigeon pea, dehusked whole pigeon pea and split dehusked whole pigeon pea respectively. From the pearson correlation table it is evident that in whole pigeon pea (Table 8), surface area and length (r=0.99), length and thickness (r=0.98), angle of repose with sphericity (r=0.98), static coefficient of friction with sphericity (r=0.99), sphericity and porosity (r=0.98) thousand kernel weight and specific gravity (r=0.99) are most positively correlated two parameters among all selected physical parameters. Least correlated parameters include, thousand kernel weight and width (r=0.00), static angle of internal friction with width (r=0.00), thousand kernel weight with surface area (r=0.00), static angle of internal friction with surface area (r=0.00) in whole pigeon pea. Most negative correlated parameters in whole pigeon pea includes, width and length (r=(-0.98)), length/width and sphericity (r=(-0.98)). From Table 9 thousand kernel weight with length (r=0.97), static coefficient of friction with length (r=0.98), static coefficient of friction with specific gravity (r=0.98), length/width ratio and thickness (r=0.99), porosity and arithmetic mean diameter (r=0.97), length/width ratio and sphericity (r=0.95), length and surface area (r=0.94), angle of repose and aspect ratio (r=0.99), dynamic coefficient of friction and true density (r=0.99), arithmetic mean diameter and porosity (r=0.97), specific gravity and static angle of internal friction (r=0.99), thousand kernel weight and specific gravity (r=0.99). The most negatively correlated terminologies were porosity and length (r=(-0.98), dynamic co-efficient of friction and width (r=0.99), surface area and arithmetic mean diameter (r=(-0.99)), true density and Length/ Width ratio (r=(-0.95)), dynamic coefficient of friction and sphericity (r=(-0.99)), arithmetic mean diameter and surface area (r=(-0.99)), sphericity and aspect ratio (r=(-0.99)), surface area and porosity (r=(- 0.98)), sphericity and angle of repose (r=(-0.98)). Least positively correlated variables include angle of repose and surface area (r=0.01), true density and arithmetic mean diameter (r=0.11), surface area and sphericity (r=0.15). Least negatively correlated includes static angle of internal friction and moisture content (r=(-0.10)), geometric mean diameter and thousand kernel weight (r=(-0.02)), sphericity and arithmeic mean diameter (r=(-0.02)), angle of repose and arithmetic mean diameter (r=0.70), dynamic coefficient of friction and surface area (r=0.08) and angle of repose and surface area (r= 0.01). From Table 10 most positively correlated parameters include, length/width ratio and thickness (r=0.99), true density and arithmetic mean diameter (r=0.99), porosity and arithmetic mean diameter (r=0.99), angle of repose and sphericity (r=0.99), surface area and bulk density (r=0.97), static coefficient of friction and aspect ratio (r=0.99), specific gravity and dynamic coefficient of friction (r=0.99), static angle of internal friction with static coefficient of friction (r=0.99), dynamic coefficient of friction with static coefficient of friction (r=0.99). Most negatively correlated parameters include, bulk density with length (r=(-0.99)), geometric mean diameter with thickness (r=(-0.99)), porosity with Length/Width ratio (r=(-0.99)), true density and bulk density (r=(-0.99)), surface area (r=(-0.99)). Least positively correlated includes aspect ratio with sphericity(r=0.13), dynamic coefficient of friction with sphericity (r= 0.14). Least negatively correlated includes angle of repose and length (r=(-0.19)) and angle of repose with true density (r=(-0.35)).

Table 2 shows the observed and predicted values of different physical properties of raw pigeon pea, dehusked whole pigeon pea (Table 3), dehusked split pigeon pea (Table 4) From the tables, it is observed that the observed and predicted vary linearly with each other. The table 5 shows the descriptive statistics of different physical properties of whole pigeon pea that includes mean, median, mode, frequency, minimum value, maximum value, variance, standard deviation, skewness, kurtosis, R^2 and probability level of significance that of dehusked whole pigeon pea (Table 6), split dehusked pigeon pea (Table 7).

Skewness is a measure of the asymmetry and kurtosis is a measure of peakedness of a distribution. Skewness can be used to obtain approximate probabilities and quantiles of distributions. Skewness indicates the direction and relative magnitude of a distribution's deviation from the normal distribution.

Skewness Analysis

Physical properties

In dehusked pigeon pea, the negatively skewed data

Table 7. Descriptive statistics of different physical properties of split pigeon pea

Sn	Splitpigpea	Nean	Median	Mode	Frequency	minimum	maximum	variance	sd	skewness	kurtosis	R2	p
1	Mc	11.67	11.67	11.67	4.00	11.67	11.67	0.00	0.00	0.00	0.00	0.96	0.20
2	Length	4.09	4.14	multiple	0.00	3.75	4.35	0.06	0.25	-0.95	1.67	0.99	0.004
3	Width	3.22	3.35	multiple	0.00	2.50	3.67	0.29	0.54	-1.00	-0.36	0.99	0.01
4	Thickness	2.43	2.44	multiple	0.00	2.26	2.58	0.02	0.13	-0.33	1.31	0.99	0.05
5	Amdia	2.37	2.42	multiple	0.00	1.16	3.47	1.40	1.18	-0.08	-5.34	0.99	0.01
6	L/W	0.92	0.97	multiple	0.00	0.20	1.52	0.32	0.56	-0.54	0.09	0.99	0.02
7	Gmdia	0.90	1.11	multiple	0.00	-0.77	2.17	2.22	1.49	-0.26	-4.50	0.99	0.06
8	Sphericity	-0.34	-0.08	multiple	0.00	-1.74	0.54	1.19	1.09	-0.74	-1.89	0.99	0.09
9	Bulkdensity	463.97	459.29	multiple	0.00	-2.70	940.00	289647.62	538.19	0.00	-5.99	0.93	0.26
10	Surfacearea	0.00	0.00	0.001	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.01
11	Aspectratio	0.79	0.85	multiple	0.00	0.57	0.88	0.02	0.14	-1.88	3.59	0.98	0.15
12	Truedensity	1261.62	1253.45	multiple	0.00	1111.10	1428.50	16887.53	129.95	0.38	1.56	0.99	0.08
13	Porosity	28.95	30.30	multiple	0.00	15.40	39.80	105.16	10.25	-0.72	0.89	0.99	0.05
14	Anglerepose	11.96	11.92	multiple	0.00	11.59	12.41	0.12	0.34	0.66	1.17	0.99	0.002
15	Thkwt	50.67	49.84	multiple	0.00	45.40	57.60	25.73	5.07	0.95	2.01	0.99	0.002
16	CFS	0.70	0.72	multiple	0.00	0.45	0.90	0.04	0.21	-0.35	-3.29	0.99	0.06
17	Aoifs	34.25	35.40	multiple	0.00	24.23	41.98	67.41	8.21	-0.49	-2.68	0.97	0.19
18	Cfd	0.74	0.75	multiple	0.00	0.50	0.95	0.04	0.20	-0.25	-2.51	0.99	0.001
19	Sg	1.04	1.18	multiple	0.00	0.35	1.43	0.23	0.48	-1.55	2.64	0.96	0.20
20	Aoifd	36.18	37.30	Multiple	0.00	26.57	43.53	61.84	7.86	-0.50	-2.70	0.99	0.004

Table 8. Pearson correlation coefficient of whole pigeon pea

Sn	Param	Mc	Len	Wid	Thk	L/W	Sph	Sa	Asp	TD	Por	AR	Thkwt	CFS	Aoifs	SG
1	mc	1	0.84	-0.76	0.92	0.95	-0.87	0.75	-0.95	-0.99*	-0.95	-0.95	-0.65	-0.79	-0.65	-0.58
2	len	0.85	1	-0.98*	0.98	0.63	-0.47	0.98*	-0.63	-0.88	-0.63	-0.62	-0.16	-0.35	-0.16	-0.06
3	wid	-0.76	-0.98	1	-0.95	-.50	0.33	-1.00	0.50	0.80	0.50	0.50	0.00	0.20	0.00	-0.09
4	thk	0.93	0.98	-0.95	1	0.76	-0.62	0.94	-0.76	-0.95	-0.76	-0.76	-0.32	-0.51	-0.32	-0.24
5	L/W	0.95	0.62	-0.50	0.76	1	-0.98	0.50	-1.00	-0.91	-1.00	-1.00	-0.80	-0.94	-0.86	-0.81
6	sph	-0.86	-0.47	0.32	-0.62	-0.98	1	-0.32	0.98	0.82	0.98	0.98	0.94	0.99	0.94	0.91
7	sa	0.75	0.98*	-1.00	0.95	0.50	-0.33	1	-0.50	-0.80	-0.50	-0.50	0.00	-0.20	0.00	0.09
8	asp	-0.94	-0.62	0.50	-0.76	-1.00	0.98	-0.50	1	0.91	1.00	1.00	0.86	0.94	0.86	0.81
9	td	-0.99	-0.88	0.80	-0.95	-0.92	0.83	-0.80	0.92	1	0.92	0.91	0.59	0.74	0.59	0.52
10	por	-0.94	-0.62	0.50	-0.76	-1.00	0.98	-0.50	1.00	0.91	1	0.99	0.86	0.94	0.86	0.81
11	ar	-0.94	-0.63	0.50	-0.76	-1.00	0.98	-0.50	1.00	0.91	1.	1	0.86	0.94	0.86	0.81
12	thkwt	-0.65	-0.16	.000	-0.33	-0.86	0.95	0.00	0.87	0.59	0.86	0.86	1	0.97	1.00	0.99*
13	cfs	-0.79	-0.35	.202	-0.51	-0.95	0.99	-0.20	0.95	0.74	0.94	0.94	0.97	1	0.97	0.95
14	aoifs	-0.65	-0.16	.000	-0.33	-0.86	0.95	0.00	0.87	0.59	0.86	0.86	1.00	0.97	1	0.99
15	sg	-0.58	-0.07	-.09	-0.24	-0.82	0.91	0.09	0.82	0.52	0.81	0.81	0.99	0.95	0.99	1

*. Correlation is significant at the 0.05 level (2-tailed)

Table 9. Pearson correlation coefficient of whole dehusked pigeon pea

Sn.	Param	mc	Len	wid	thk	amd	L/W	gmd	sph	sa	asp	td	por	ar	thkwt	cfs	aoifs	cfd	sg
1	Mc	1	-0.32	0.68	0.32	0.66	0.40	-0.95	0.68	-0.62	-0.73	-0.66	0.47	-0.79	-0.10	-0.15	-0.10	-0.73	-0.15
2	Len	-0.32	1	0.47	0.78	-0.92	0.73	0.59	0.47	0.94	-0.40	-0.48	-0.98	-0.32	0.97	0.98	0.97	-0.40	0.98
3	Wid	0.68	0.47	1	0.91	-0.09	0.94	-0.42	1.00**	0.15	-0.99*	-1.00*	-0.32	-0.98	0.65	0.61	0.65	-0.99*	0.61
4	Thk	0.32	0.78	0.91	1	-0.48	0.99	-0.02	0.91	0.53	-0.88	-0.92	-0.67	-0.83	0.91	0.88	0.90	-0.88	0.88
5	Amd	0.66	-0.92	-0.09	-0.48	1	-0.41	-0.86	-0.09	-0.99*	0.01	0.11	0.97	-0.06	-0.81	-0.84	-0.81	0.01	-0.84
6	L/W	0.40	0.73	0.94	0.99	-0.41	1	-0.10	0.94	0.46	-0.91	-0.95	-0.61	-0.88	0.86	0.83	0.86	-0.91	0.83
7	Gmd	-0.95	0.59	-0.42	-0.02	-0.86	-0.10	1	-0.42	0.83	0.49	0.41	-0.71	0.56	0.40	0.45	0.40	0.49	0.45
8	Sph	0.68	0.47	1.00**	0.91	-0.09	0.94	-0.42	1	0.15	-0.99*	-1.00*	-0.32	-0.98	0.65	0.61	0.65	-0.99*	0.61
9	Sa	-0.62	0.94	0.15	0.53	-0.99*	0.46	0.83	0.15	1	-0.07	-0.16	-0.98	0.00	0.84	0.87	0.84	-0.07	0.87
10	Asp	-0.73	-0.40	-0.99*	-0.88	0.01	-0.91	0.49	-0.99*	-0.07	1	0.99	0.25	0.99	-0.59	-0.55	-0.59	1.00	-0.56
11	Td	-0.66	-0.48	-1.00*	-0.92	0.11	-0.95	0.41	-1.00*	-0.16	0.99	1	0.34	0.98	-0.66	-0.63	-0.66	0.99	-0.62
12	Por	0.47	-0.98	-0.32	-0.67	0.97	-0.61	-0.71	-0.32	-0.98	0.25	0.34	1	0.16	-0.92	-0.94	-0.92	0.25	-0.94
13	Ar	-0.79	-0.32	-0.98	-0.83	-0.06	-0.88	0.56	-.98	0.00	0.99	0.98	0.16	1	-0.52	-0.48	-0.52	0.99	-0.48
14	Thkwt	-0.10	0.97	0.65	0.90	-0.81	0.86	0.40	0.65	0.84	-0.59	-0.66	-0.93	-0.52	1	0.99*	1.00	-0.59	0.99*
15	Cfs	-0.15	0.98	0.61	0.88	-0.84	0.83	0.45	0.61	0.87	-0.55	-0.63	-0.94	-0.48	0.99*	1	0.99*	-0.55	1.00**
16	Aoifs	-0.10	0.97	0.65	0.90	-0.81	0.86	0.40	0.65	0.84	-0.59	-0.66	-0.92	-0.52	1.00**	0.99*	1	-0.59	0.99*
17	Cfd	-0.73	-0.40	-0.99*	-0.88	0.01	-0.91	.49	-0.99*	-0.07	1.00**	0.99	0.25	0.99	-0.59	-0.55	0-.59	1	-0.55
18	Sg	-0.15	0.98	0.61	0.88	-0.84	0.83	0.45	0.61	0.87	-0.55	-0.62	-0.95	0-.48	0.99*	1.00	0.99*	-0.55	1

*.Correlation is significant at the 0.05 level (2-tailed).

Table 10. Pearson correlation coefficient of split dehusked pigeon pea dhal

Sn	Param	mc	len	wid	thk	amd	L/W	gmd	sph	bd	sa	asp	td	por	ar	thkwt	cfs	aoifs	cfd	sg
1	Mc	1	0.98	-0.85	-0.96	0.99	-0.98	0.91	-0.41	-0.99	-0.99	0.84	1.00**	0.96	-0.34	0.84	0.80	0.84	0.84	0.80
2	Len	0.98	1	-0.76	-0.90	0.97	-0.94	0.84	-0.26	-0.99*	-0.95	0.91	0.98	0.90	-0.19	0.91	0.88	0.91	0.91	0.88
3	Wid	-0.85	-0.76	1	0.96	-0.90	0.93	-0.99	0.82	0.79	0.91	-0.45	-0.86	-0.96	0.77	-0.44	-0.39	-0.44	-0.45	-0.39
4	Thk	-0.96	-0.90	0.96	1	-0.98	0.99	-0.99	0.65	0.92	0.98	-0.66	-0.96	-1.00**	0.59	-0.65	-0.60	-0.65	-0.66	-0.61
5	Amd	0.99	.0.97	-0.90	-0.98	1	-0.99*	0.94	-0.49	-0.98	-0.99*	0.79	0.99	0.98	-0.43	0.78	0.75	0.78	0.79	0.75
6	L/W	-0.98	-0.95	0.93	0.99	-0.99*	1	-0.97	0.56	0.96	0.99*	-0.74	-0.98	-0.99	0.50	-0.73	-0.69	-0.73	-0.74	-0.69
7	Gmd	0.91	0.84	-0.99	-0.99	0.94	-0.97	1	-0.74	-0.86	-0.96	0.56	0.91	0.99	-0.69	0.55	0.50	0.55	0.56	0.50
8	Sph	-0.41	-0.27	0.82	0.65	-0.49	0.56	-0.74	1	0.31	0.53	0.13	-0.42	-0.64	0.99*	0.14	0.20	0.14	0.13	0.20
9	Bd	-0.99	-0.99*	0.79	0.92	-0.98	0.96	-0.86	0.31	1	0.97	-0.90	-0.99	-0.92	0.24	-0.89	-0.86	-0.89	-0.89	-0.86
10	Sa	-0.99	-0.96	0.91	0.98	-0.99*	0.99*	-0.96	0.53	0.97	1	-0.76	-0.99	-0.99	0.46	-0.76	-0.72	-0.76	-0.76	-0.72
11	Asp	0.84	0.91	-0.45	-0.66	0.79	-0.74	0.56	0.13	-0.90	-0.76	1	0.84	0.67	0.20	1.00**	0.99*	1.00**	1.00	0.99*
12	Td	1.00**	0.98	-0.86	-0.96	0.99	-0.98	0.91	-0.42	-0.99	-0.99	0.84	1	0.96	-0.35	0.83	0.80	0.83	0.84	0.80
13	Por	0.96	0.90	-0.95	-1.00**	0.99	-0.99	0.99	-0.64	-0.92	-0.99	0.67	0.96	1	-0.58	0.66	0.61	0.66	0.66	0.61
14	Ar	-0.34	-0.19	0.77	0.59	-0.43	0.50	-0.69	0.99*	0.24	0.46	0.20	-0.35	-0.58	1	0.21	0.27	0.21	0.20	0.27
15	Thkwt	0.84	0.91	-0.44	-0.65	0.78	-0.73	0.55	0.14	-0.89	-0.76	1.00	0.83	0.66	0.21	1	0.99*	1.00**	1.00	0.99*
16	Cfs	0.80	0.89	-0.38	-0.60	0.75	-0.69	0.50	0.20	-0.86	-0.72	0.99*	0.80	0.61	0.27	0.99*	1	0.99*	0.99*	1.00
17	Aoifs	0.84	0.92	-0.44	-0.65	0.78	-0.73	0.55	0.14	-0.89	-0.76	1.00	0.83	0.66	0.21	1.00**	0.99*	1	0.99	0.99*
18	Cfd	0.84	0.91	-0.45	-0.66	0.79	-0.74	0.56	0.13	-0.89	-0.76	1.00	0.84	0.66	0.20	1.00**	0.99*	1.00**	1	0.99*
19	Sg	0.80	0.88	-0.39	-0.61	0.75	-0.69	0.50	0.20	-0.86	-0.72	0.99*	0.80	0.61	0.27	0.99*	1.00	.99*	0.99*	1

*. correlation is significant at the 0.05 level (2-tailed).

includes thickness (-0.53), geometric mean diameter (-0.94), surface area (-0.85), aspect ratio (-0.75), true density (-0.57), static coefficient of friction (-0.69), static angle of internal friction (-0.77), dynamic coefficient of friction (-0.36), specific gravity (-1.20) and dynamic angle of internal friction (-0.87). The positively skewed data includes length (1.85), width (0.01), arithmetic mean diameter (0.17), bulk density (0.16), porosity (0.16), angle of repose (0.86) and thousand kernel weight (0.33) for dehu sked pigeon pea samples. In split pigeon pea the negatively skewed data includes, length (- 0.95), width (-1.00), thickness (-0.33), arithmetic mean diameter (-0.08), length/width ratio (-0.54), geometric mean diameter (-0.26), sphericity (-0.74), aspect ratio (-1.88), porosity (-0.72), static coefficient of friction (-0.35), static angle of internal friction (-0.49), dynamic coefficient of friction (-0.25), specific gravity (-1.55) and dynamic angle of internal friction (-0.50), the positively skewed data includes true density (0.38), angle of repose (0.66) and thousand kernel weight (0.95). The distribution of skewness is between -1.0 to +1.0 and the distribution is said to be normal. (Ayoubi *et al.*, 2011). This coincided with the earlier findings of Swan and Sandilands, 1995.

Kurtosis Analysis

b) Physical properties

In whole pigeon pea, negatively values of kurtosis includes, length (-2.23), width (- 5.82), arithmetic mean diameter (-2.10), length/width (-0.56), sphericity (-1.29), aspect ratio (- 3.20), true density (-5.87), angle of repose (-2.56), static coefficient of friction (-1.20), specific gravity (-2.06), the positively kurtosis values include, thickness (0.30), geometric mean diameter (2.23), bulk density (1.08), porosity

Table 11. Different chemical properties of different pigeon pea

Sn	Category	Mc(%wb)	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Carbohydrate (%)
1	Wh.pigeon pea	8.00	20.30	2.65	2.38	14.15	60.52
2	Dehuspigeon pea	11.67	20.02	2.75	8.17	15.10	53.97
3	Split pigeon pea	10.00	20.72	0.02	0.05	3.93	75.28
	Mean(sd)	9.89(1.84)	20.35(0.35)	1.81(1.55)	3.53(4.18)	11.06(6.19)	63.26(10.92)
	p-value	0.01(s)	0.00(s)	0.18(ns)	0.28(ns)	0.09(s)	0.01(s)

Table 12. Pearson correlation coefficient of different chemical parameters in whole pigeon pea

Sn	Parameters	Protein	Fat	Fibre	Ash	Carbohydrate
1	Protein	1	0.74	-0.40	-0.43	-0.94
2	Fat	0.74	1	-0.91	-0.92	-0.48
3	Fibre	-0.40	-0.91	1	0.99*	0.09
4	Ash	-0.43	-0.92	0.99*	1	0.12
5	Carbohydrate	-0.94	-0.48	0.09	0.12	1

Table 13. Pearson correlation coefficient of different chemical parameters in dehusked whole pigeon pea

Sn	Parameters	Protein	Fat	Fibre	Ash	Carbohydrate
1	Protein	1	0.32	0.99*	0.12	-0.99
2	Fat	0.32	1	0.27	0.97	-0.40
3	Fibre	0.99*	0.27	1	0.07	-0.99
4	Ash	0.12	0.97	0.07	1	-0.21
5	Carbohydrate	-0.99	-0.40	-0.99	-0.21	1

Table 14. Pearson correlation coefficient of different chemical parameters in split dehusked whole pigeon pea

Sn	Parameters	Protein	Fat	Fibre	Ash	Carbohydrate
1	Protein	1	0.14	0.69	-0.69	-1.00**
2	Fat	0.14	1	0.81	-0.81	-0.13
3	Fibre	0.69	0.81	1	-1.00**	-0.68
4	Ash	-0.69	-0.81	-1.00**	1	0.68
5	Carbohydrate	-1.00**	-0.13	-0.68	0.68	1

Table 15. Observed and predicted chemical properties of whole pigeon pea

	whole pigeon pea									
sn	obs. protein	pred. protein	obs. fat	pred. fat	obs. fibre	pred. fibre	obs. ash	pred. ash	obs. carb	pred. carb
1	22.59	21.04	3.40	3.33	2.15	4.02	13.73	13.47	58.13	58.13
2	19.09	18.10	1.65	1.62	3.00	3.87	15.17	15.06	61.09	61.22
3	19.21	20.20	2.90	2.94	2.00	0.72	13.55	13.89	62.34	62.23
4	18.15	19.70	2.60	2.65	8.30	6.84	14.75	14.77	56.20	56.18

Table 16. Observed and predicted chemical properties of dehusked whole pigeon pea

	whole dehusked pigeon pea									
Sn	Obs. Protein	Pred. Protein	Obs. Fat	Pred. Fat	Obs. Fibre	Pred. Fibre	Obs. Ash	Pred. Ash	Obs. Carb	Pred. Carb
1	16.44	16.34	2.70	2.69	7.70	7.81	15.00	15.03	58.16	58.05
2	22.42	22.33	2.70	2.69	8.50	8.60	14.89	14.92	51.49	51.40
3	21.19	21.25	2.85	2.86	8.30	8.24	15.40	15.37	52.26	52.32
4	18.15	18.28	2.60	2.62	8.30	8.16	14.75	14.71	56.20	56.34

Table 17. Observed and predicted chemical properties of split dehusked pigeon pea dhal

	split dehusked pigeon pea									
sn	obs. protein	pred. protein	obs. fat	pred. fat	obs. fibre	pred. fibre	obs. ash	pred. ash	obs. carb	pred. carb
1	19.79	19.79	0.03	0.03	0.05	0.05	3.90	3.90	76.23	76.23
2	18.39	18.39	0.013	0.01	0.04	0.04	4.00	3.98	77.55	77.55
3	23.99	23.99	0.02	0.02	0.05	0.05	3.90	3.90	72.04	72.04
4	22.58	22.58	0.01	0.01	0.045	0.05	3.95	3.97	73.41	73.41

(2.22), thousand kernel weight (0.87), static angle of internal friction (1.77), dynamic coefficient of friction (1.50) and dynamic angle of internal friction (0.95). In whole dehusked pigeon pea positively kurtosis variables include, length (3.48), geometric mean diameter (1.50), sphericity (1.50), aspect ratio (0.34), angle of repose (1.92), static angle of internal friction (0.04), dynamic coefficient of friction, negatively kurtosis variables includes width (-5.84), thickness (-2.90), arithmetic mean diameter (-0.47), length/width (-4.76), bulk density (-3.13), surface area (-1.29), true density (-0.85), porosity (-4.44), thousand kernel weight (-0.84), static coefficient of friction (-1.50), specific gravity (-1.20) and dynamic angle of internal friction (-0.61). In split pigeon pea positively kurtosis variables include, length (1.67), thickness (1.31), length/width (0.09), aspect ratio (3.59), true density (1.56), porosity (0.89), angle of repose (1.17), thousand kernel weight (2.01), specific gravity (2.64), negative kurtosis variables include, width (-0.36), arithmetic mean diameter (-5.34), geometric mean diameter (-4.50), sphericity (-1.89) bulk density (-5.99), static coefficient of friction (-3.28), static angle of internal friction (-2.68), dynamic coefficient of friction, (-2.51) and dynamic angle of internal friction (-2.70). The kurtosis values ranges between 1 to 3 and the distribution is said to be normal (Jeremy Mondejar and Alejandro Tongco, 2019).

Chemical Properties

Small increases in dehulled whole pigeon pea in ash content about 6.25% was found. This coincides with the earlier findings of Wang *et al.*, 2008. The dehusked and whole pigeon pea fibre content was found using fibrast at apparatus after acid washing and alkali washing and ashing in muffle furnace at 550 °C. Protein content of whole pigeon pea dhal was 1.38% greater than dehusked pigeon pea dhal in split dhal protein content is greater by 3.38% than dehusked pigeon pea. The protein content of commonly grown pigeon pea cultivars ranges between 17.9 and 24.3g/100g for whole grain sample (Salunkhe *et al.*, 1986). Fat content in split dhal was negligible as compared to higher fat content in dehusked pigeon pea dhal by 3.64%. Fibre content was negligible in split dehusked pigeon pea and in whole pigeon pea dhal, 70.87% greater than whole

Fig. 18. Descriptive statistics of different chemical properties of whole pigeon pea

Sn	Whpigpea	Mean	Median	Mode	Minimum	maximum	variance	Sd	skewness	kurtosis	R2	p
1	Protein	20.60	20.36	multiple	19.09	22.59	2.99	1.73	0.33	-4.09	0.99	0.36
2	Fat	2.79	3.05	multiple	1.65	3.40	0.62	0.79	-1.61	2.63	0.90	0.08
3	Fibre	2.31	2.13	multiple	2.00	3.00	0.21	0.46	1.89	3.66	0.70	0.55
4	Ash	14.04	13.72	multiple	13.55	15.17	0.57	0.76	1.93	3.79	0.99	0.32
5	Carbohydrate	59.51	59.61	multiple	56.48	62.34	7.20	2.68	-0.13	-3.31	0.41	0.03

Fig.19. Descriptive statistics of different chemical properties of dehusked pigeon pea

Sn.	Dehpigpea	Mean	Median	Mode	Frequency	Minimum	Maximum	Variance	Sd	Skewness	Kurtosis	R2	p
1	Protein	19.55	19.67	multiple	0	16.44	22.42	7.51	2.74	-0.15	-3.33	0.99	0.40
2	Fat	2.71	2.70	2.70	2	2.60	2.85	0.01	0.1	0.71	1.78	0.98	0.13
3	Fibre	8.20	8.30	8.30	2	7.70	8.50	0.12	0.34	-1.53	2.88	0.88	0.34
4	Ash	15.01	14.94	multiple	0	14.75	15.40	0.07	0.27	1.22	1.76	0.98	0.13
5	Carbohydrate	54.52	54.23	multiple	0	51.49	58.16	10.12	3.18	0.26	-3.94	0.99	0.04

Fig.20. Descriptive statistics of different chemical properties of split pigeon pea

Sn	Split pigpea	Mean	Median	Mode	Frequency	Minimum	Maximum	Variance	Sd	Skewness	Kurtosis	R2	P
1	protein	19.55	19.67	multiple	0	16.44	22.42	7.51	2.74	-0.15	-3.33	0.99	0.0001
2	fat	2.71	2.70	2.70	2	2.60	2.85	0.01	0.1	0.71	1.78	0.99	0.042
3	fibre	8.20	8.30	8.30	2	7.70	8.50	0.12	0.34	-1.53	2.88	0.78	0.484
4	ash	15.01	14.94	multiple	0	14.75	15.4	0.07	0.27	1.22	1.76	0.99	0.292
5	carbohydrate	54.52	54.23	multiple	0	51.49	58.16	10.12	3.18	0.26	-3.94	0.99	0.0001

pigeon pea.

Ash content was much lesser in split dhal by 73.97% than in dehusked whole pigeon pea dhal, dehusked pigeon pea dhal, 6.29% is greater than whole pigeon pea dhal. Carbohydrate content in split dehusked pigeon pea dhal, 28.31% than in dehusked pigeon pea, whole pigeon pea is 10.82% greater than dehusked pigeon pea. The different chemical properties of whole pigeon pea, dehusked pigeon pea and split pigeon pea is shown in Table 5. The pearson correlation coefficient of whole pigeon pea, dehusked pea and split dehusked pigeon pea are shown in Table 6, 7&8 respectively using SPSS software 16.0 version. The different chemical properties of whole, dehusked and split pigeon pea are shown in Fig. 5.

Table 15 shows the observed and predicted chemical properties of whole pigeon pea, dehusked whole pigeon pea (Table 16) and split dehusked pigeon pea dhal (Table 17). Table 18 shows the descriptive statistics of different chemical properties of whole pigeon pea, dehusked pigeon pea (Table 19) and split pigeon pea samples (Table 20). The raw pigeon pea seed has higher percentage of carbohydrate (73.53 ± 0.010%), protein (17.83±0.60%) and ash (3.94±0.11%), respectively (Machacon *et al.*, 2018)

Skewness analysis

Chemical properties: In whole pigeon pea, positively skewed variables include, protein (0.33), fibre (1.89) and ash (1.93) and negatively skewed variables include, fat (-1.61) and carbohydrate (-0.13). In dehusked pigeon pea, positively skewed variables include fat (0.71), ash (1.22) and carbohydrate (0.26), negatively skewed variables include protein (-0.15) and fibre (-1.53). In split whole pigeon pea positive variables include fat (0.71), ash (1.22) and carbohydrate (0.26), negatively skewed variables include protein (-0.15) and fibre (-1.53).

Kurtosis analysis

Chemical properties: In chemical properties in whole pigeon pea, negative kurtosis variable include protein (-4.09) and carbohydrates (-3.31), positive kurtosis variables include, fat (2.63), fibre (3.66) and ash (3.79) in dehusked pigeon pea the negative kurtosis include protein (-3.33) and carbohydrate (1.78), fibre (2.88) and ash (1.76). In split pigeon pea samples, the negative kurtosis values include protein (-3.33) and carbohydrate (-3.94) and positive kurtosis variables include fat (1.78), fibre (0.88) and ash (1.78). From Table 6 in whole pigeon pea, the most positively correlated parameters include protein and fat (r=0.74), fibre and ash (r=0.99), fibre and carbohydrate (r=0.09), carbohydrate and ash (r=0.12). The most negatively correlated parameters include, fibre and protein (r=(-0.40), ash and protein (r=(-0.43)) carbohydrate and protein (r=(- 0.94)), fibre and fat (r=(-0.91)), ash and fat (r=(-0.92)), carbohydrate and fat (r=(-0.48)). From Table 7, in de husked whole pigeon pea, positively correlated parameters include, protein and fat (r=0.32), protein and fibre(r=0.99), protein and ash (r=0.12), fat and fibre (r=0.27), fat and ash (r= 0.97) and fibre and ash (r=0.07). The most negatively correlated parameters include, protein and carbohydrate (r=(-0.99)), fat and carbohydrate (r=(-0.40)), fibre and carbohydrate (r=(-0.99)), ash and carbohydrate (r=(-0.21)). From the Table 8, the most positively correlated parameters include protein and fat (r=0.14), protein and fibre (r=0.69), fat and fibre (r= 0.81). The most negatively correlated parameters include, protein and ash (r= (-0.69)), fat and ash (r=(-0.81)), fat and carbohydrate (r=(-0.13)) and fibre and carbohydrate (r=(-0.68)).

CONCLUSION

Arithmetic mean diameter of whole pigeon pea dhal was 9.09% greater than dehusked pigeon pea dhal, 55.94% greater in dehusked pigeon pea dhal than in dehusked split dhal. In whole pigeon pea dhal, length/width ratio was 4.41% greater than in dehusked whole pigeon pea dhal, length/width ratio was 4.41% greater than in dehusked whole pigeon pea dhal, in dehusked split dhal 70.94% greater than de husked pigeon pea dhal. Aspect ratio of whole pigeon dhal was 6.58% lesser than in dehusked whole pigeon pea, 71.05% lesser in dehusked split dhal as compared to dehusked pigeon pea dhal. True density was more in dehusked dhal by 23.18% than whole pigeon pea and in dehusked whole pigeon pea dhal, true density was 61.54% less than de-husked split dhal (A. Tikle and Archana Misra, 2018). True density of split dhal was greater than bulk density of split dhal.

In physical properties the positive kurtosis ranged between 0.09 to 3.59 and negative kurtosis ranged between (-0.36) to (-5.99). The positive skewness ranged between 0.01 to 1.85 and negative skewness ranged between (-0.08) to (-1.88).In chemical properties the positive kurtosis ranged between 0.88 to 3.79 and negative kurtosis is (-3.31) to (-4.09). In chemical properties the positive skewness ranged between 0.26 to 1.93 and negative skewness ranged between (-0.13) to (-1.61), the positive kurtosis ranged between 0.88 to 3.79 and negative kurtosis is (-3.31) to (-4.09). The data distribution is said to be normal.

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