Original Research Article

Comparative Analysis of Physical and Functional Properties of Colored Horse Gram Varieties (*Macrotylomauniflorum*) and its flour.

ABSTRACT

Pulses has important role in contributing to food and nutritional security and replenishing soil nutrients having a huge potential in addressing needs like future global food security, nutrition and environmental sustainability. Horse gram (*Macrotylomauniflorum*) is a minor, under-exploited legume of tropics and subtropics grown under dry-land agriculture. The present study was conducted with the objective tomaximize the utilization of horse gram and its flour physical and functional properties. Hundred grain weight and density (3.33 g,1.29 g/ml) was higher in cream colored variety and it was lighter, redder (less green), yellower (less blue) than brown and black colored varieties. Thickness of varieties varied significantly, highest being in brown (2.18 mm) colored variety. Hydration capacity, hydration index, swelling capacity and percent germination (2.92 g/100 grains, 0.93, 3.83 ml/100 grains and 91.66 %) varied significantly with highest being in brown colored variety. Maximum amount of all the flours passed through 52 BSS standard sieve having 300 µ sieve opening. Loose bulk density was high in brown colored flour (0.41 g/ml) whereas tapped bulk density was high in cream colored flour (0.63 g/ml). Cream-colored horse gram flour was lighter (L^* value being 78.72), redder (a^* value being 5.78) and yellower (b^* value being 16.84). There was significant difference in the functional properties of flour. The black colored flour had highest water absorption capacity (2.31 ml/g), oil absorption capacity (2.15 ml/g), swelling power (9.14 g/g), foaming capacity (36.23 %) and foaming stability (32.13 %) than other two flours. The wettability, flowability and cohesiveness of all three flours were good, fair and low respectively. Thus brown and black colored varieties had better physical and functional properties than cream-colored variety. The brown and black colored flour had highest loose bulk density whereas cream colored flour had highest tapped bulk density. Black colored flour had highest water and oil absorption capacity, swelling power, foaming capacity and foaming stability.

Keywords:*Horse gram varieties, flour, physical properties, functional properties, particle size distribution,* L^*, a^*, b^*

1. INTRODUCTION

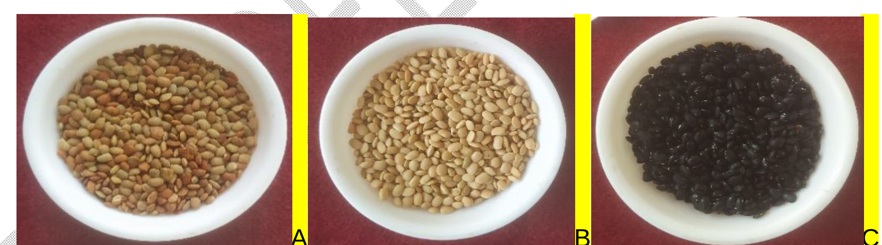
Pulses are the cheap and important source of protein in the Indian diet apart from being the staple food in many parts of the world. Thus, they contribute to food and nutritional security of the country. Pulses are consumed as whole grains, split dhals, flour, animal feed etc. Horse gram (*Macrotylomauniflorum*) is an under-exploited legume [1] whose technological potential as a foodstuff is highlighted in this study. In terms of nutrition, it is a real asset. It is a rich source of protein, iron and neutraceutical components such as polyphenols and tannins [2]. "However, its consumption is limited due to presence of several anti-nutritional factors such as phytic acid, trypsin inhibitors and saponins. Thus several processing methods like soaking, germination, boiling, pressure cooking are used to reduce the level of anti-nutritionalcomponents and increase their bioavailability. Horse gram is also used as a natural medicine to treat several ailments such as kidney stones, obesity, cold, cough, menstrual problems"etc[3]. Horse gram is commonly called as *Kutlhi* (Hindi), *Kollu* (Tamil), *Ullavalu*(Telugu),*Mudhira*(Malayalam), *Kurti-kalai*(Bengali), *Huruli*(Kannada). Physical parameters of grains are important for its physical appearance and description apart from having role in threshing operations since it allows the passage of specific size of the grains and various unwanted materials whereas functional properties reflect the complex interaction between the composition, structure and physico-chemical properties of food components [4] and also required to evaluate how different food components behave in specific systems. Thus,the present investigation was undertaken with the objective to maximize the utilization horse gram and its flour physical and functional properties.

2. MATERIAL AND METHODS

Threecolored horse gram varieties [brown(GPM-6), cream (kalaghatagi local) and black(CRHG-22)] were procured from seed unit, University of Agricultural Sciences, Dharwad. The seeds were cleaned to remove the extraneous matter. Furtherthese grains were milled into their respective flour and kept in a cool and dry place prior to use. Physical properties and functional properties of both grains and respective flour were carried out using the standard procedure as mentioned below

2.1 Physical properties of horse gram varieties

Physical properties like hundred-kernel weight, hundred kernel volume, bulk density,color analysis(L^*, a^*, b* value) length, breadth and length to breadth ratio of three horse gram varieties (Fig 1) were assessed.



A. Brown colorhorse gram B. Cream colored horse gram C. Black colored horse gram

Fig 1: Different colored horse gram varieties

2.1.1 Hundred grain weight

. "Weight of selected hundred intact grains in triplicates was recorded using electronic weighing balance and average was calculated. The mean weight was expressed in g/100 grains"[5].

2.1.2 Hundred grain volume

Volume of weighed hundred horse gram grains was measured using water displacement method. Known volume of water was taken in measuring cylinder and hundred randomly selected grains were dropped in it. “The rise in volume was recorded in ml. The volume of grains was calculated by subtracting the initial volume from final volume”[5].

2.1.3 Bulk density

Bulk density was calculated from weight and volume of horse gram using the formula

$$\text{Bulk density (g/ml)} = \frac{\text{Weight (g)}}{\text{Volume (ml)}}$$

Bulk density was expressed as g per ml [5].

2.1.4 Color analysis

The samples were subjected to color assessment in Konica Minolta spectrophotometer of model CM 2600/2500d All the colored horse gram varieties were selected randomly and were packed in transparent pouches and readings were taken in triplicates. The color was assessed for L* (lightness/ black to white), a* (redness/ redness to greenness) and b*(yellowness/ yellowness to blueness).

2.1.5 Thickness

The average thickness of randomly picked ten grains were measured in (mm) with the help of digital verniercalipers having least count 0.01 mm [6].

2.1.6Length, breadth and L/B ratio

The average length and breadth of the randomly picked ten grains were measured in (mm) with a help of digital verniercalipers having least count 0.01 mm. The length/ breadth ratio was obtained by dividing the length of a single grain by the corresponding breadth to determine the size and shape [6].

2.2 Functional properties of horse gram varieties

Functional properties like hydration capacity, hydration index, swelling capacity, swelling index and per cent germination were assessed for horse gram varieties.

2.2.1 Hydration capacity

Hydration capacity was measured by soaking weighed hundred horse gram seeds overnight in beaker with 100 ml of water. Next day, water was drained off and grains were dried using filter paper to remove superfluous water and weighed [7]. Hydration capacity was calculated using the formula;

$$\text{Hydration capacity of seeds (g/100 grains)} = \frac{\text{Weight after soaking (g) - Weight before soaking (g)}}{\text{Number of seeds (100 grains)}}$$

2.2.2 Hydration index

Hydration index was calculated by using formula:

$$\text{Hydration index} = \frac{\text{Hydration capacity}}{\text{Weight of seeds}}$$

2.2.3 Swelling capacity

Hundred horse gram seeds were counted and volume was noted by water displacement method. The grains were soaked overnight. Further, water was drained off next day and volume was noted [7]. Then, the swelling capacity was measured using formula:

$$\text{Swelling capacity (ml/100 grains)} = \frac{\text{Volume of seeds after soaking (ml)} - \text{Volume of seeds before soaking (ml)}}{\text{Number of seeds (100 grains)}}$$

2.2.4 Swelling index

Swelling index was calculated using formula:

$$\text{Swelling index} = \frac{\text{Swelling capacity}}{\text{Volume of seeds}}$$

2.2.5 Percent germination

Hundred grains were placed in a petriplate on a filter paper dampened with water and the lid was closed, kept in incubator and allowed to germinate for 24 hrs. Further germinated grains were counted and expressed in percentage [8].

2.3 Physical properties of horse gram flour

Physical properties of flour such as particle size distribution, loose bulk density, tapped bulk density and color analysis and of three colored horse gram flour (Fig 2) was analyzed.

(A)Brown color horse gram flour (B)Creamcolor horse gram flour (C)Blackcolor horse gram flour

Fig 2: Different colored horse gram flour

2.3.1 Particle size distribution

About hundred grams of flour was weighed and passed through different meshes of BSS sieves from 25, 30, 36, 44, 52 and 60 with sieve opening of 600, 500, 420, 355, 300 and 250 microns respectively. The samples were passed from bigger to smaller mesh size. The sample above the mesh was weighed and the reading was recorded. Percentage was calculated [9].

2.3.2 Loose bulk density

Loose bulk density of flour was determined by pouring flour sample into a 10 ml graduated measuring cylinder. Weight of the sample was measured when the sample volume reached 1 ml. The loose density was calculated by dividing weight with the volume of the obtained flour [10].

2.3.3 Tapped bulk density

A standard graduated cylinder of 100 ml capacity was taken for the bulk density measurement. Initially, the empty measuring cylinder was weighed, and then 20 g of flour was added in the cylinder then tapped for 20-25 times to a vertical distance of 10 mm to pack the flour particles tightly and recorded the volume of weighed sample. The tapped bulk density (TBD) of flour was determined by following formula [10].

$$\text{Tapped bulk density (g/ml)} = \frac{\text{Weight of the sample at recorded volume (g)}}{\text{Volume of sample (ml)}}$$

2.3.4 Color

Color of horse gram flours was assessed by the procedure outlined in2.1.4

2.4 Functional properties of horse gram flour

Functional properties like water absorption capacity, oil absorption capacity, swelling power, solubility, foaming capacity and stability, wettability, followability and cohesiveness was assessed for horse gram flours**.**

2.4.1 Water Absorption Capacity

Water absorption capacity was assessed by the method of [11]. Known volume of flour (5 g)was weighed and added to the pre-weighed centrifuge tube (W_1). To this 30 ml of water was added and stirred with a glass rod for 5 min. The contents were allowed to stand for 30 min and then centrifuged at 11000 rpm for 25 min. The free liquid was poured off. Inner side of tube were wiped off with tissue paper. The centrifuge tube was weighed again (W_2). The water absorption capacity was calculated using the formula:

Water absorption capacity, WAC (%) = $\frac{W2 - W1}{5} \times 100$

2.4.2 Oil Absorption Capacity

Oil absorption capacity was assessed by using [12] method. One gram of flour was mixed with 10 ml of refined vegetable oil in pre-weighed centrifuge (W_1). The tubes were stirred for one min for complete dispersion of sample and the sample was centrifuged at 3000 rpm for 25 min. The separated oil was then removed and tubes were inverted on absorbent paper to drain off the remaining oil prior to reweighing (W_2). The oil absorption capacity was calculated using the formula:

$$\text{Oil absorption capacity, OAC (\%)} = \frac{W_2 - W_1}{1} \times 100$$

2.4.3 Swelling power and solubility

Swelling power and solubility were estimated as per [13]. About five hundred mg (W_1) of the sample was weighed, placed into centrifuge tube and the centrifuge tube with sample was weighed (W_2). Twenty ml of distilled water was added (V_E) and heated for 30 min in a water bath at 90°C, with occasional stirring, the tubes were cooled and centrifuged at 5000 rpm for 10 min. The supernatant was decanted into a pre-weighed (W_4) petriplate dried at 105°C and weighed (W_5). The inner side of the centrifuge tube was wiped, dried and weighed (W_3). Percent swelling power and solubility were calculated using the following formulae:

$$\text{Swelling power (g/g)} = \frac{W_3 - W_2}{W_1}$$

$$\text{Solubility (\%)} = \frac{W_5 - W_4 \times V_E}{V_E} \times \frac{100}{W_1}$$

2.4.4 Foaming capacity and foaming stability

Foaming capacity and foaming stability were determined as described by [14]. One-gram sample was added to 50 ml distilled water in a graduated cylinder. The suspension was mixed and shaken for 5 min to form a foam. The volume of foam after whipping for 30 sec was expressed as foaming capacity. Where, AW: After whipping, BW: Before whipping the volume of foam was recorded 1h after whipping to determine foaming stability as percent of the initial foam volume.

$$\text{Foaming capacity} = \frac{\text{Volume of foam (AW)} - \text{Volume of foam (BW)}}{\quad} \times 100$$

Volume of foam (BW)

2.4.5 Wettability

"Two grams of the sample was weighed and transferred to a beaker containing 80 ml water. The behavior of the powder was observed on the water surface immediately after adding the sample. After 30 min observation, the material was stirred on the magnetic stirrer sufficiently fast to form a vertex which reached the bottom of the beaker and the stirring continued for one min, after which the grade describing wettability was recorded as excellent, good, fair and poor according to the time and behaviour of the dispersion" [15].

2.4.6 Flowability [Carr Index (CI)]

The flowability of flour was expressed as Carr Index (CI) in terms of tapped density (pT) and bulk density (pB) as described by [16].

$$CI = \frac{pT\text{ (Tapped density)} - pB\text{ (bulk density)}}{pT\text{ (Tapped density)}} \times 100$$

Chart 1: Classification of flour flowability based on Carr Index (CI)

CI %	Flowability
< 15	Very good
15-20	Good
20-35	Fair
35-45	Bad
>45	Very bad

2.4.7 Cohesiveness (Hausner Ratio)

Cohesiveness of the flour was evaluated in terms of Hausner ratio (HR), calculated from bulk density (pB) and tapped density (pT) as suggested by [16].

HR = pT/ pB

Chart 2: Classification of flour cohesiveness based on Hauser Ratio (HR)

Hauser Ratio	Cohesiveness
< 1.2	Low

1.2 – 1.4	Intermediate
>1.4	High

2.5 Statistical analysis

The experimental results were carried out by different statistical methods in SPSS statistical packages (16.0). Mean, standard deviation was used to interpret data. One-way ANOVA (Analysis of variance) was used to know the significant difference among the different colored horse gram varieties.

3. RESULTS AND DISCUSSION

3.1 Physical properties of coloredhorsegram varieties

Table 1 shows the physical properties of coloredhorsegram varieties. There was significant difference (*P= 0.01*) between the coloredhorsegram varieties for hundred grainweight and color values (L*, a*, b*) used in the study. Whereas there was no significant difference in hundred grain volume and bulk density between coloredhorsegram varieties. The hundred-grain weight and hundred grain volume of brown, cream and black colored variety were 3.14g, 3.33 g, 3.20g and 3.66ml, 2.66 ml and 2.66 ml respectively. When compared to brown (control) colored variety, black was on par whereas cream colored variety had higher hundred grain weight. Seed weight is important criterion for selecting variety for processing into different end products[17]. The difference in seed weight is attributed mainly due to environmental factors and variations in weight of cotyledon, embryo and seed coat because Seed weight is mostly contained in the kernel (Cotyledons and embryo). The cotyledons, which make up about 88.8 per cent and seed coat takes about 11.1 per cent of the seed weight [18]. The bulk density of varieties ranged from 0.87 to 1.29 g per ml. The L*, a*, b* value of cream color variety was higher (63.64, 8.25, 18.23) indicating its white, red and yellow shade followed by brown (53.23, 7.41, 14.03) and black colored variety (39.18, 0.03, -0.79) indicating its black, green and blue shade respectively. When compared to brown (control) the L*, a*, b* value for cream flour was higher and that for black color flour was lower.The difference in color value is mainly attributed to color of seed coat. Similar results were also found by [19].

Table 1. Physical properties of coloredhorsegram varieties

Horsegram variety	100 grain weight (g)	100 grain volume (ml)	Bulk density (g/ml)	L^* (Lightness)	a^* (Redness)	b^* (Yellowness)
Brown (Control) (GPM-6)	3.14 ± 0.01^b	3.66±0.57	0.87±0.14	53.23 ± 0.025^b	7.41 ± 0.010^b	14.03 ± 0.01^b

Cream (kalaghatagi local)	3.33±0.01 ^{a}	2.66±0.57	1.29±0.32	63.64±0.020 ^{a}	8.25±0.010 ^{a}	18.23±0.02 ^{a}
Black (CRHG-22)	3.20±0.05 ^{b}	2.66±0.57	1.24±0.29	39.18±0.025 ^{c}	0.03±0.010 ^{c}	-0.79±0.01 ^{c}
C.D.	0.06**	NS	NS	0.06 **	0.06**	0.06**
S. Em.±	0.01	0.33	0.15	0.08	0.08	0.08
F value	26.64	3.00	2.22	813.53	613.00	122.22

**Note: Values are mean ± S.D. of three replications, Values with same superscript in the same column are not significantly different from each other, S.Em: Standard Error of Mean, C. D: Critical Difference, *Significant @ 5%, **Significant @ 1%, NS-Non significant*

Grain dimensions are important in cleaning and also in threshing operations because it allows the passage of specific sized grains and to eliminate unwanted materials [4]. The dimensions (thickness, length, breadth, L/B ratio) of coloredhorsegram varieties is shown in Table 2**.** There was significant difference (*P=0.01*) between the coloredhorsegram varieties for thickness. Whereas there was no significant difference in length, breadth and length to breadth ratio among coloredhorsegram varieties. The thickness ranged from 1.98 to 2.18 mm highest being in brown and lowest in black colored variety. When compared to brown (control) the thickness of cream colored variety was on par whereas less for black colored variety. The length, breadth and length to breadth ratio among the coloredhorsegram varieties ranged from ranged from 5.33 to 5.50 mm, 3.81 to 3.87 mm and 1.39 to 1.44 respectively.Variation in thickness of the seeds might be attributed to drought resistant grain crops being hardy in nature, have a thick endosperm and also in the genetic variations. [7] and [20] found the similar results with slight variations.

Table 2. Dimensions of coloredhorsegram varieties

Horsegram variety	Thickness (mm)	Length (mm)	Breadth (mm)	L/B ratio
Brown (Control) (GPM-6)	2.18±0.12 ^{a}	5.41±0.24	3.87±0.17	1.40±0.08
Cream (kalaghatagi local)	2.17±0.10 ^{a}	5.33±0.16	3.83±0.12	1.39±0.05
Black (CRHG-22)	1.98±0.08 ^{b}	5.50±0.20	3.81±0.20	1.44±0.11

C.D.	0.09**	NS	NS	NS
S. Em.±	0.03	0.06	0.05	0.02
F value	11.86	1.71	0.31	1.15

*Note: Values are mean ± S.D. of three replications, Values with same superscript in the same column are not significantly different from each other, S.Em: Standard Error of Mean, C. D.: Critical Difference, **Significant @ 1%, NS-Non significant*

3.2Functional properties of coloredhorsegram varieties

Functional characteristics are required to evaluate hardness, permeability of seed coat and hydration ability of grains [21]. Table 3 shows the functional properties of coloredhorsegram varieties. There was significant difference (*P=0.01*) between the coloredhorsegram varieties for hydration capacity, hydration index, swelling capacity and per cent germination. Whereas there was no significant difference in swelling index between coloredhorsegram varieties. Brown color variety recorded highest hydration capacity (2.92 g/100 grains), hydration index (0.93), swelling capacity (3.83 ml/100 grains) and per cent germination (91.66) followed by black (2.64 g/100 grains, 0.82, 3.50 ml/ 100 grains and 89) and cream colored variety (2.51 g/100 grains, 0.75, 3.00 ml/ 100 grains, 88) respectively. When compared to brown (control) the hydration capacity, hydration index and swelling capacity was less for black colored variety followed by cream colored variety. When compared to brown (control) the percent germination for cream colored variety was less followed by black colored variety.Variation in hydration and swelling capacity may be attributed to hardness of seed coat that hinders the permeability of water inside the grain and the reason for variation in percent germination among the varieties may be due the differences in other functional characteristics and physical properties. [22] found similar results.

Table 3. Functional properties of coloredhorsegram varieties

Horsegram variety	Hydration Capacity (g/ 100 grains)	Hydration Index	Swelling Capacity (ml/ 100 grains)	Swelling Index	Per cent germination
Brown (Control) (GPM-6)	2.92±0.03 [a]	0.93±0.015 [a]	3.83±0.28 [a]	1.06±0.23	91.66±1.52 [a]
Cream	2.51±0.04 [c]	0.75±0.012 [c]	3.00±0.50 [c]	1.13±0.12	90.00±1.00 [b]

(kalaghatagi local)					
Black (CRHG-22)	2.64±0.06 ^{b}	0.82±0.034 ^{b}	3.50±0.50 ^{b}	1.33±0.16	88.00±1.00 ^{c}
C.D.	0.10**	0.03**	0.40**	NS	1.38**
S. Em.±	0.03	0.01	0.14	0.06	0.40
F value	48.61	45.38	2.71	1.67	11.38

**Note:* *Values are mean ± S.D. of three replications, Values with same superscript in the same column are not significantly different from each other, S.Em: Standard Error of Mean, C. D: Critical Difference, **Significant @ 1%, NS-Non significant*

3.3 Physical properties of flour from coloredhorsegram varieties

Particle size distribution of flour from coloredhorsegram varieties is shown in Table 4. There was significant difference (*P= 0.01*) between the flours of coloredhorsegram varieties for particle distribution. Particle size distribution of flour was calculated by passing the flour through various BSS standard sieve number having different pore size ranging from 600 to 180 microns. About 83 per cent of all coloredhorsegram flour had particle size of 300 microns followed by 250 microns (4 %), 600 microns (3.5 %), 355 and 420 microns (3 %), 500 microns (2.5 %) and 180 microns (2 %) each. Thus, it was observed that majority of the particles in all the three coloredhorsegram flour passed through 52 BSS standard sieve having 300 microns. There was no significant difference in particle size distribution between the varieties when compared to control.Particle size of flour depends on how fine or coarse the flour has been milled and its use in the product.

Table 4. Particle size distribution of flour from coloredhorsegram varieties

BSS Standard Sieve Number [Sieve Opening(µ)]	**Horsegram flour (%)**		
	Brown (Control) (GPM-6)	**Cream** (kalaghatagi local)	**Black** (CRHG-22)
25(600)	3.46±0.04 ^{c}	3.44±0.08 ^{c}	3.49±0.09 ^{c}
30(500)	2.53±0.05 ^{f}	2.55±0.08 ^{f}	2.53±0.06 ^{f}
36(420)	2.93±0.08 ^{e}	2.92±0.03 ^{e}	2.91±0.04 ^{e}
44(355)	3.06±0.07 ^{d}	3.07±0.04 ^{d}	3.04±0.07 ^{d}

52(300)	82.23± 0.05 ^{a}	82.25±0.04^{a}	82.24±0.03 ^{a}
60(250)	3.66±0.07^{b}	3.65±0.04^{b}	3.67±0.04 ^{b}
85(180)	2.10±0.04 ^{g}	2.1±0.02 ^{g}	2.10±0.04 ^{g}
C.D.	0.09**	0.09**	0.11**
S. Em.±	0.03	0.03	0.03
F value	942.55	837.02	723.35

**Note: Values are mean ± S.D. of three replications, Values with same superscript in the same column are not significantly different from each other, S.Em: Standard Error of Mean, C. D: Critical Difference, **Significant @ 1%*

Physical properties of flour from coloredhorsegram varieties such as loose bulk density, tapped bulk density and color (L*, a*, b*) is shown in Table 5. There was significant difference (*P=0.01*) between the flours of coloredhorsegram varieties for loose bulk density, tapped bulk density and color. Density is another major criterion, which measures the heaviness of flour,and it is influenced generally by the particle size of the flour.Brown and black colored flour registered high loose bulk density (0.41 g/ ml) followed by cream colored flour (0.34 g/ ml) whereas high tapped bulk density was found in cream colored flour (0.63 g/ ml) followed by brown (0.6 g/ ml) and cream coloredhorsegram flour (0.57 g/ ml). When compared to brown (control) the loose bulk density of black colored flour was on par whereas it was less for cream colored variety. The tapped bulk density of cream and black colored flour was on par with brown colored flour (control). The higher tapped density may be attributed to its higher weight of seeds and hence more seed volume.High density of horse gram flour in the present study indicate that the flours are heavy in nature and thus are suitable in the preparation various foods. According to [23], higher density is desirable for greater ease of dispersibility of flours in any liquid medium. [20] and [24] also found similar results.

Color is a major criterion that directly results in the final appearance and acceptability of product.The lightness (L* value) of brown, cream and black colored flour was 78.34, 78.72 and 72.15 respectively. Thus when compared to control the lightness for cream coloredflour was high whereas less for black. The redness (a* value) of brown, cream and black colored flour was 2.84, 5.78 and 0.26 respectively. Thus when compared to control the redness for cream colored flour was high whereas less for black. The yellowness (b* value) of brown, cream and black colored flour was 11.08, 16.84 and 5.25 respectively. Thus when compared to control the yellowness for cream colored flour was high whereas less for black. The changes in color value can be attributed to the color of seed coat and bright color of flour may also be attributed to presence of higher amount of polyphenols and tannins.

Table 5. Physical properties of flour from coloredhorsegram varieties

Horsegram variety	Loose bulk density (g/ml)	Tapped bulk density (g/ml)	L* (Lightness)	a * (Redness)	b * (Yellowness)
Brown (Control) (GPM-6)	0.41±0.01[a]	0.60±0.01 [ab]	78.34±0.04 [b]	2.84±0.02 [b]	11.08±0.02 [b]
Cream (kalaghatagi local)	0.34±0.01[b]	0.63 ± 0.01 [a]	78.72±0.03 [a]	5.78±0.03 [a]	16.84±0.03 [a]
Black (CRHG-22)	0.41±0.01[a]	0.57 ±0.09 [b]	72.15±0.02 [c]	0.26±0.03 [c]	5.25±0.01 [c]
C.D.	0.06**	0.06**	0.03**	0.03**	0.036**
S. Em.±	0.01	0.01	0.08	0.01	0.01
F value	505.33	14.97	333.26	260.39	161.62

*Note: Values are mean ± S. D. of three replications, Values with same superscript in the same column are not significantly different from each other, S.Em: Standard Error of Mean, C. D: Critical Difference, **Significant @ 1 %*

3.4 Functional properties of flour from coloredhorsegram varieties

Functional properties of flour from coloredhorsegram varietiesis illustrated in Table 6. There was significant difference (*P= 0.01*) between the flours of coloredhorsegram varieties for water absorption capacity, swelling power and foaming capacity. The water absorption capacity of brown colored flour (control) was 2.16 ml per g which was on par with cream color flour (2.17 ml/g) whereas it was 2.31 ml per g for black colored flour. Water absorption capacity is the capacity of the flour to be associated with water molecules under limited condition [25]. Difference in the water absorption capacity may be probably due to the variation in the starch granules, inherent differences in amorphous and crystalline areas among starch and also due to protein content. The swelling power of brown color flour (control) was 8.15 g per g whereas it was 6.92 and 9.14 g per g for cream and black colored flour respectively. The difference in the swelling power and solubility may be attributed to the characteristics of amylose and amylopectin, their structure, degree, length and conformations, besides the presence of non-carbohydrate content [26] and [27]. Similar results of swelling power and solubility was reported by [28]. Foaming properties are much important in the maintenance of the texture and structure of different food products (ice creams and bakery products) during and after processing. The foaming capacity of brown color flour (control) was 32.18 per cent whereas it was 31.34 and 36.23 per cent for cream and black colored flour. There was significant difference (*P= 0.05*) between the flours of coloredhorsegram varieties for oil absorption capacity and foaming stability. The highest oil absorption capacity was found in black colored flour (2.15 ml/g) followed by brown (control) and cream colored flour (2.09 and 2.08 ml /g) respectively.Fat absorption capacity has been attributed to the physical entrapment of oil and it is important, since fat acts as flavour retainer and increase the mouth feel of foods. [29] revealed that the enhanced ability of flour to absorb and retain water and oil may help to improve binding of the structure, enhance flavour retention, improve mouth feel and reduce moisture and fat losses of food products. "The foam stability of the flour depends on the presence of the flexible protein molecules which may decrease the surface tension of water"[30]. The highest foaming stability was found in black colored flour (32.13 %) followed by brown (control) and cream colored flour (30.45 % and 29.15 %) respectively. According to [31], ability to form stable foam depends on sufficient intermolecular (protein-protein) interaction and thus degree of cohesion.There was no significant difference between the flours of coloredhorsegram varieties for percent solubility. The wettability for all the three flour was good whereas followabilityand cohesiveness was fair and low for all the three colored flour respectively.

Table 6. Functional properties of flour from coloredhorsegram varieties

Horsegram variety	**Water Absorption Capacity (ml/g)**	**Oil Absorption Capacity (ml/g)**	**Swelling power (g/g)**	**Percent solubility (%)**	**Foaming Capacity (%)**	**Foaming Stability (%)**	**Wettability**	**Followability**	**Cohesiveness**
Brown (Control) (GPM-6)	2.16±0.03 ^{b}	2.09±0.03 ^{b}	8.15±0.02 ^{b}	35.21±0.13	32.18±0.12^{b}	30.45±0.11^{b}	Good	Fair	Low
Cream (kalaghatagi local)	2.17±0.01 ^{b}	2.08±0.03 ^{b}	6.92±0.02 ^{c}	35.01±0.29	31.34±0.31^{c}	29.15±0.31^{c}	Good	Fair	Low

Black (CRHG-22)	2.31±0.02[a]	2.15±0.01[a]	9.14±0.04 [a]	35.56±0.30	36.23±0.22[a]	32.13±0.23[a]	Good	Fair	Low
C.D.	0.06**	0.06*	0.06**	NS	0.98**	0.76*			
S. Em.±	0.05	0.05	0.05	0.14	0.45	0.28			
F value	33.55	5.33	887.98	3.49	12.28	16.64			

**Note: Values are mean ± S. D. of three replications, Values with same superscript in the same column are not significantly different from each other, S.Em: Standard Error of Mean, C. D: Critical Difference, *Significant @ 5%, **Significant @ 1%, NS-Non significant*

4. CONCLUSION

There were differences in the physical as well as functional properties of both horse gram varieties and their respective flours.Hence one variety cannot be compared with other variety in terms of physical and functional properties. However brown and black colored varieties had better physical and functional properties than cream colored variety. The brown and black colored flour had highest loose bulk density whereas cream colored flour had highest tapped bulk density. Black colored flour had highest water and oil absorption capacity, swelling power, foaming capacity and foaming stability.Physical and functional properties evaluation is critical for optimizing their use in food and nutrition applications. By evaluating attributes such as hydration capacity, swelling power, and absorption capacities, the study provides a comprehensive analysis that can guide both agricultural practices and product development. The detailed comparison between varieties highlights their diverse applications and potential benefits, contributing to the broader understanding of minor legumes' roles in sustainable agriculture and nutrition.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etchave been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

REFERENCES

1. Prasad S K, Singh M K. Horse gram-an underutilized nutraceutical pulse crop: a review. Journal of Food Science and Technology. 2015; 52(5): 2489-99.
2. Messina M J. Legumes and soybeans: An overview of their nutritional profiles and health effects. The American Journal of Clinical Nutrition. 1999; 70(3): 439-450.
3. Patil C K, Bhattacharjee A. Seed potentiation of a horsegram cultivar by herbal manipulation. International Journal of Medicinal Plants Research. 2013; 2(1): 152-155.
4. Brennan J G, Butters J R, Cowell N B, Lilly A E V. Food Engineering Operations. 2nd ed., Applied Science Publication, London; 1981.
5. Mannuramath M, Yenagi N. Evaluation of little millet cultivars for physical, nutritional and processing qualities. Academic and Law Serials. 2014; 10(2):131-140.
6. Yadav R B, Khatkar B S, Yadav B S. Morphological, physiochemical and cooking properties of some Indian rice (*Oryzasativa*L.) cultivars. Journal of Agriculture and Technology.2007; 3: 203-210.
7. Bhokre C K, Joshi A A, Rodge A B. Determination of physico-chemical and functional properties of different genotypes of horse gram. Asian Journal of Dairy and Food Research. 2015; 34(4):307-318.
8. Barakoti L, Bains K. Effect of household processing on the in-vitro bioavailability of iron in mungbean (*Vignaradiata*). Food and Nutrition Bulletin. 2007; 28(1): 18-22.
9. Kurahatti S. Formulation of little millet (*Panicummillare*) based composite mix and its quality evaluation. M.H. Sc. Thesis. University of Agricultural Sciences, Dharwad, Karnataka, India; 2010.
10. Goula A M, Karapantsios T D, AchiliasD S, Adamopoulas K G. Water sorption isotherms and glass transition temperature of spray dried tomato pulp. Journal of Food Engineering. 2008; 85: 73-83.
11. Quin J R, Paton D. A practical measurement of water hydration capacity of protein materials. Cereal Chemistry. 1983; 56: 38-44.
12. Sosulski F W, Elkowicz L, Reichert R D. Oligosaccharides in eleven legumes and their air-classified protein and starch fractions. Journal of Food Science and Nutrition, 2002; 47: 498-502.
13. Schoch T J, Swelling power and solubility of granular starches. In: Methods in carbohydrate Chemistry, New India Publishing Agency, New Delhi; 1964.

14. Bhavsar G J, Sawate A R, Kshirsagar R B, Chappalwar V M. Studies on physico-chemical characteristics of buckwheat and its exploration in bread as functional food. International Journal of Engineering and Research Technology. 2013; 2 (1):3971-3980.
15. Abdalla A A, Ahmed U M, Ahmed A R, El-TinayA H, Ibraim K A. Physicocemical characterization of traditionally extracted pearl millet starch. Journal of Applied Sciences Research. 2009; 5(11): 2016-2027.
16. Jinapong N, Suphantharika M, Jamnong P. Production of instant soymilk powder by ultra-filtration spray drying and fluidized bed agglomeration. Journal of Food Engineering. 2008; 84: 194-205.
17. Henshaw F. Varietal differences in physical characteristics and proximate composition of cowpea (*Vignaunguiculata*). 1st ed. [ebook] IDOSI. 2015. http://www. idosi.org/wjas. .
18. Sidhu J S, Gill M S, Bains G S. Milling of paddy in relation to yield and quality. Journal of Agricultural and Food Chemistry. 1975; 23(6):1183-1185
19. Herath H M, Gunathilake K G, Eashwarage I S, Sivakumaran K, Ranathunga R A. Physico-chemical and *in-vitro*glycemic indices of popular pulse varieties grown in Sri Lanka. International Journal of Food Science and Nutrition. 2018; 3(5): 137-143.
20. Abhirami K, G Sashidevi, G Hemalatha, K Thangaraj. Comparison of physico-chemical, functional and cooking properties of selected horse gram varieties. International Journal of Chemical Studies. 2018; 6(3): 135-139.
21. Singh G D, Wani A A, Kaur D, Sogi D S. Characterization and functional properties of proteins of some Indian chickpea (*Cicer arietinum*) cultivars. Journal of the Science of Food and Agriculture. 2008;10 (9): 3144-3156.
22. Jain S, Vishakha S, Shipra C. Chemical and physicochemical properties of horse gram (*Macrotylomauniflorum*) and its product formulation. Journal of Dairying, Foods and Home Science. 2012; 31(3):184-190.
23. Padmashree T S, Vijayalakshmi L, Pultaraj S. Effect of traditional processing on the functional properties of cowpea (*Vignacatjany*) flour. Journal of Food Science and Technology. 1987; 24: 221-224.
24. Joshi A A, Bhokre C K. Physico-chemical analysis of four varieties of horse gram. Journal of Bioinfolet. 2015; 12 (3 B): 683- 686.
25. Alfauomy G A, Ibrahmin O S, Ali M M. Physico-chemical characteristics of starches from different cereal grains. American Journal of Food Science and Technology. 2017; 5(4): 125-134.

26. Srichuwong S, Suharti C, Mishima T, Isono M, Hisamatsu M. Starches from different botanical sources: contribution of starch structure of swelling and pasting properties. Carbohydrate Polymers. 2005; 62(1): 25-34.
27. Ahmed A M, Zhang C, Liu Q. Comparison of physicochemical characteristics of starch isolated from sweet and grain sorghum. Journal of Chemistry. 2016. http://dx.doi.org/10.1155/2016/7648639.
28. Khatun A. Nutritional composition, processing for value addition and anticalcifying properties of selected horse gram genotypes. M.Sc thesis, University of Agricultural Sciences, Bangalore; 2009.
29. Sreerama Y N, Sasikala V B, Pratape V M. Nutritional implications and flour functionality of popped/expanded horse gram. Food chemistry.2008; 108(3):891-899.
30. Sathe S K, Desphande S S, Salunkhe D K. Functional properties of winged bean [*Psophocarpustetragonolobus* (L.) DC] proteins. Journal of Food Science. 2002; 47: 503-509.
31. Hettiarachchy N S, Griffin V K, Gnanasambandmam R. Preparation and functional properties of a protein isolate from defatted wheat germ. Cereal Chemistry. 2000; 73(3): 363-367.