Indian Journal of Science and Technology

Physicochemical, Functional, Pasting Properties and Nutritional Composition of Selected Black Gram (*Phaseolus mungo* L.) Varieties

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Abstract

The present work is designed to study the physico chemical, functional, pasting properties, and nutritional composition of selected black gram varieties. (viz., VBN 3, VBN 4, VBN 5, VBN 6, ADT 3, T9, MV, TMV, VBg010 025, VBg010 024, VBg09 005 and CO 6). Thousand grain weight of the selected black gram varieties was recorded to be 33.20 to 40.45 g, seed volume 38.66 to 40.2 ml, seed colour ranged as black, dull black and black and dull black, bulk density 0.06 to 1.07 g/ml, water absorption index 151.00 to 155.10 g/100g, water solubility index 13.0 to 15.6 g %, water absorption 36.6 to 56.6 ml/100g and oil absorption 40.1 to 66.2 ml/100g. The moisture values were in the range of 9.6 to 11.6 g/100g, ash 6.1 to 6.7 g/100g, protein 25.5 to 28.5 g/100g, fat 4.4 to 5.6 g/100g, starch 51.3 to 47.7 g/100g, calcium 106.66 to 134.00 mg/100g, iron 3.0 to 4.4 mg/100g and phosphorus 376.00 to 416 mg/100g. It was observed that black gram varieties, VBN 5, VBg 010 025, CO 6 and T9 had high 1000 grain weight and bulk density. Variety VBN 5 and T9 had higher foaming stability, foaming capacity, peak viscosity, final viscosity, hold viscosity and set back value. Also higher levels of protein, starch, calcium, iron and phosphorus was observed in VBN 5 and low amount of fat and ash .Vamban 5, VBg010 025 and T9 were observed to have good physicochemical characteristics and are hence suitable for further breeding and processing as value added products.

Keywords: Black Gram Varieties, Vamban, Tindivanam, Coimbatore, Aduthurai, Market Variety, Physicochemical, Pasting Properties, Arabinose.

1. Introduction

Black gram (*Phaseolus mungo*) (or) urad is one of the important pulse crops in India. India is the largest producer and consumer of Black gram in the world. It contains about 26 per cent protein which is almost three times that of cereals. Black gram supplies a major share of protein requirement of vegetarian population of the country [1].

Black gram is being grown over an area of 2.42 mega hectare with an annual production of 0.77 mega tonnes with productivity of 324 kg/hectare in the country [2]. Many varieties of black gram are now being released by the

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plant breeders for commercialization and their selection depends on its nutritional value. In recent years there has been increasing interest in the functional potential of plant proteins. In view of the use of black gram flours for various food formulations. It should be noted their functional characteristics have a profound influence on the sensory qualities of the end products. A systematic study of flours from different black gram cultivars would thus be useful, as differences in physicochemical characteristics of the flours influence its suitability for specific end use.

This study aims at screening selected black gram varieties for the physicochemical properties, functional characteristics and pasting properties to facilitate breeding and product development.

2. Materials and Methods

Twelve varieties of black gram viz., (VBN 3, VBN 4, VBN 5, VBN 6, VBg010 025, VBg010 024, VBg09 005, ADT 3, CO 6, MV, T9 and TMV were collected from National Pulse Research station. Vamban, varieties ADT 3 variety was collected from Department of Seed Science and Technology, Agricultural College and Research Institute, Madurai. Variety T9 was collected from Packiam Dhal mill, Madurai. Market Variety was collected from Chellaiya Departmental Store, Madurai and CO 6 was collected from Tamil Nadu Agricultural University, Coimbatore.

3. Materials

3.1 Preparation of Flour

Seeds from various black grams were ground to pass through BS No. 60 mesh sieve (British Sieve Standards) to obtain uniform particle size of the flour. The flour samples were defatted by solvent extraction process using petroleum ether and dried at a temperature of 50 °C for 5 hr in a hot air oven and after cooling packed in air-tight container.

3.2 Physicochemical Properties of Whole Seed and Black Gram Flour

3.2.1 Thousand-kernel weight, volume and bulk density

Whole, dehusked, split dhal samples of black gram varieties were studied for physical characteristics. One thousand kernels were randomly selected from a well-mixed sample and weighed. The volume of 1000 grains was determined by oil displacement method. In brief, the grains were added to a known volume of oil in a graduated flask. The difference between the initial and final volume indicates the volume of the seeds. The ratio between the weight of 1000 grains to its volume was calculated as bulk density. Hadimani and Malleshi [3].

3.2.2 Water absorption index and Water solubility index

Water absorption index and Water solubility index were studied by the method described by Anderson et al. [18]. Flour sample (2.5 g) was dispersed in 30 ml of distilled water, using a glass rod, and cooked at 90°C for 15 min in a water bath. The cooked paste was cooled to room temperature and centrifuged at 3000 × g for 10 min. The supernatant was decanted into a tarred evaporating dish and the sediment was weighed.

The weight of dry solids in supernatant was determined by evaporating the supernatant at 110°C. Water Solubility Index (g /100g) and Water Absorption Index (g /100g) were calculated as per the equation 1 and 2 respectively.

$$WAI = \frac{\text{Weight of the sediment}}{\text{Weight of the flour sample}} \quad \text{Eq (1)}$$

$$WSI = \frac{\text{Weight of dissolved solids in the supernatant}}{\text{Weight of the flour}} \times 100 \quad \text{Eq (2)}$$

4. Water Absorption Capacity

Water absorption capacity (WAC) of flours was measured by the centrifugation method described by Sosulski et al. [4]. The sample (3.0 g) was dispersed in 25ml of distilled water and placed in preweighed centrifuge tubes. The dispersions were stirred, held for 30 min, followed by centrifugation 25 min at 3000 × g. The supernatant was decanted, excess moisture was dried at 50°C for 25 min, and the sample was weighed after cooling.

5. Oil Absorption Capacity

Oil absorption capacity (OAC) of flours was measured by the centrifugation method described by Lin et al. [5].

The sample (1 g) was mixed with 6ml of oil in preweighed centrifuge tubes. The contents were stirred for 1 min with a thin brass wire to disperse the sample in the oil. After a holding period of 30 min, the tubes were centrifuged for 25min at 3000 X g. The separated oil was then removed with a pipette and the tubes were inverted for 25 min to drain the oil prior to reweighing. The average value of three replicates is reported. The WAC and OAC were expressed as grams of water or oil bound per 100g (g $100g^{-1}$) of the sample on a dry basis.

6. Foaming Capacity and Foaming Stability

Foaming capacity (FS) of flours was measured by the volumetric method described by Lin et al. [5]. The dispersions of flour in distilled water (50% w/v, 250 ml) were homogenised using a homogenizer at a high setting for 2 to 3 min. The blend was immediately transferred into a graduated cylinder and the homogenizer cup was rinsed with 10ml distilled water, which was then added to the graduated cylinder. The volume was recorded before and after whipping. Foaming capacity was expressed as the volume increase (%) due to whipping. For the determination of foaming stability, foam volume changes in the graduated cylinder were recorded at intervals of 20, 40, 60 and 120 min of storage.

7. Pasting Properties

Pasting properties of black gram flour was determined using the Rapid Visco Analyzer (RVA starch master 2D. Pertan, Australia).

8. Colour

Colour measurements (L^* a^* b^* values) of the black gram flours was determined using a Lovibond chromometer (Model # Lovibond RT 100) with the Lovibond RT Colour software (Version 3.0). Before measuring the colour of the samples, the instrument was standardized by placing black and white standard plates and L, a and b colour values were recorded. The deviation of the colour of the samples to standard were observed and recorded in the computed interface. L^*values correspond to lightness/darkness and extend from 0 (black) to 100 (white) with higher values corresponding to more lightness. The a^* and b^* values correspond to an object's color dimensions, with a^*values describing a sample's red (+a) to greenness (-a), while b^*values describe a sample's yellow (+b) to blueness (-b). Larger a^* values indicate more redness and larger b^* values indicate more yellowness.

9. Proximate Composition

All samples were analyzed for contents of ash, fat, protein. AOAC [6] and starch [7] moisture (Hot air oven drying method, AOAC [8] calcium, phosphorus and iron were analyzed by dry ashing method. Calcium was determined by the method described, AOAC [7], iron was determined by the method described by AOAC [7] and phosphorus was determined by the method described by Fiske and Subbarao [9].

10. Estimation of Arabinose and Galactose by High Performance Liquid Chromatography

Arabinose and galactose were estimated by HPLC according to the method of Tanaka [10]. Black gram whole seeds were ground to flour and defatted with hexane (1:1 w/v) the fat free black gram flour was then suspended in 15 volumes of distilled water and heated to boiling. The undissolved residues were separated from the black gram milk by centrifugation for 5 minutes at 5,000 rpm. Black gram milk (15 ml) was poured into 35 ml of absolute ethyl alcohol and centrifuged 1900 rpm at 15 min at 37°C. The centrifugate was concentrated and dissolved in 15 ml of distilled water. HPLC analysis were performed with a Shimadzu (Shimadzu Corporation) equipped with Lc10 ATVP pump and refractive index detector. Sample injection was via Rheodyne injector equipped with 20µl sample loop. Carbohydrates were separated on a phenomenex Bond 120 clone 10-µ CHO column The mobile phase consisting of acetonitrile:water (70:30, v/v) was used for separation. Flow rate was fixed at 1 ml/min. Peak identification of the chromatographs was done by comparing the retention times with those of standards.

11. Estimation of Fatty Acid Composition by Gas Liquid Chromatography

The fatty acid composition was estimated by the solvent extraction method of AOAC [6]. Fatty acid composition of black gram was analyzed as methyl esters using gas

liquid chromatography (Fisons, fitted with a flame ionization detector [FID] fitted with a fused silica capillary column 25 m × 0.25 mm (Parma bond FFAP-DF-0.25, Machery-Negal GmbH co., Duren, Germany). The methyl esters of fatty acids were prepared using 14% BF3/MeOH as described by (Morrison and Smith). The operating conditions of gas liquid chromatography were: column temperature 220°C, injection temperature 230°C, and detector temperature 240°C. Nitrogen was used as the carrier gas. Individual fatty acids were identified by comparison with the retention times of standards and were quantified by an online Shimadzu Chromatopack CR6A integrator.

12. Statistical Analysis

All results of triplicate samples were statistically analyzed using Fisher's least significant differences (LSD) test to differentiate the treatment means and the significant level was reported at $P<0.05$. Statistical analysis was performed by using Statistica Version 5.5 (Statsoft Inc., OK, and USA) software. In reporting data, the results of individual samples were reported as the mean ± standard deviation.

13. Result and Discussion

13.1 Physical Parameters of Black Gram Varieties

The physical parameters like thousand grain weight, seed volume, seed colour, bulk density, water absorption index, water solubility index, water absorption and oil absorption were assessed and the results are presented in Table 1.

13.2 Thousand Grain Weight and Bulk Density

The thousand grain weight of black gram varieties ranged from 33.2 g (MV), 36.6 g (ADT 3) 38.1 g (VBN 4) 40.4 g (VBN 3) 40.5 g (VBg010 024) 42.1 g (VBg09 005). Maximum thousand grain weight was observed in VBN 5 (46.6 g) followed by the bulk density measurements for black gram varieties varied from 1.07 to 0.06 (Table 1). Variety T9 had the highest bulk density. The selected black gram varieties showed significant differences in the thousand grain weight and bulk density as observed in Table 1.

13.3 Seed Volume

The seed volume of selected black gram varieties were recorded as 58.0 ml (VBN 5) 50.6 ml (VBN 3) 43.3 ml (CO 6) 42.1 ml (TMV), 38.6 ml (VBN 4), 40.3 ml (VBN 6), 40.6 ml (ADT 3), 44.1 ml (T9), market variety (42.3) ml and VBg010 -024 (50.6) ml respectively. Results showed that the selected black gram varieties exhibited significant differences in the seed volume as seen in VBN 4, VBN 5 and VBN 3 (Table 1).

13.4 Seed Colour

The seed colour of the black gram varieties were observed as black, Dull black (MV, TMV, VBN 4, VBN 5, VBN 6, VBN 3, VBG010 -024, VBg010 -025 and VBG09 -005) and black and dull (CO 6, T9 and ADT 3).

13.5 Water Absorption Index (WAI)

The water absorption index measures the volumes occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. Water absorption index for different black gram flours ranged from 151.0 to 155.1 g/100g as in Table 1. Results showed that highest WAI was observed for TMV and the lowest for VBg 010 025 and VBN 6 respectively. No significant differences were observed in the water absorption index.

13.6 Water Solubility Index (WSI)

Water solubility index as related to the presence of soluble molecule, for the flours ranged from 13.0 to 15.6 g/100g. Result showed that the WSI was highest for VBN 4 and the lowest for VBN 3 respectively. No significant differences were observed in the water solubility index.

13.7 Functional Properties

The Foaming Capacity (FC) and Foam Stability (FS) of flours also differed significantly. The foams produced by black gram flours were relatively thick with FC in the range of 5.71 and 35.68 g per cent (Figure 1). Foaming stability of the flours makes them useful in food systems that require aeration for textural and leavening properties.

Foaming stability is important since the usefulness of whipping agents depend on their ability to maintain the whip as long as possible. Black gram flours showed high foaming stability (> 90%) as their foam did not collapse even after 120 min of storage (Figure 2).

13.7.1 Water absorption

The water absorption of flours ranged from 56.6 to 36.6 ml/100g in Table 1 and the data projected for water

absorption revealed the water absorption was maximum in VBN 4 and minimum in VBN 3. Statistical data revealed that significant differences were observed at 0.05% level.

13.7.2 Oil absorption

The oil absorption of black gram flours ranged from 66.2 to 40.0 ml/100g in Table 1. Market variety black gram flour showed the highest oil absorption. Variety VBg010 025 black gram flour had minimum oil absorption. Statistical analysis of the data revealed that significant differences were observed at 0.05% level.

13.8 Colour Index of Selected Black Gram Varieties Whole and Flour

Colour is the first impression to register for utilization of high protein materials (*L*, *a*, *b*) of the flours and results are shown in Table 4. The varietal differences were observed for various Hunter colour parameters. The mean *L* and *a* value of whole and flours from different black gram varieties were 57.16 to 38.56 and –9.84 to –7.42 respectively. Black gram whole and black gram flour from all black gram varieties showed negative *a* value, which indicated a slight green tint in them. This limits the use of these flours in certain food products. The *b* value ranged from 4.79 to 13.95 (whole) and 7.50 to 14.01 (Flour), with a mean value of 11.14 in whole and 10.51 with flour. Black gram whole and black gram flour from market variety showed the lowest *L* value of 26.95 to 21.00. Variety TMV and VBN 6 exhibited highest *b* value 13.95 to14.01 indicating its comparatively darker and yellow colour, where as interms of the value, variety VBN 3 whole and flour showed the highest *L* 84.97 to 76.00 indicating its lighter colour as compared to other black gram varieties. Hunter colour values given in Table 4.

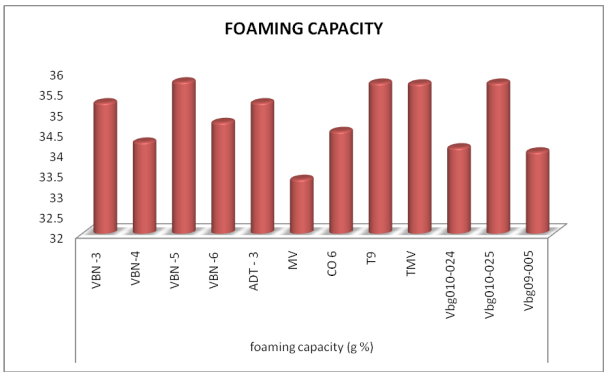

Figure 1. Foaming Capacity of black gram varieties.

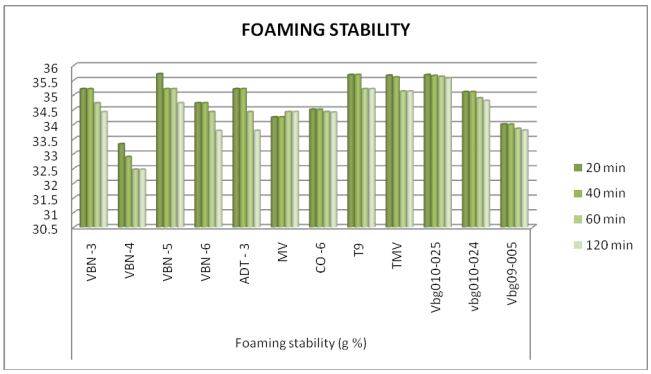

Figure 2. Foaming stability (g %) of black gram varieties.

Table 1. Physical characteristic of black gram varieties

Varieties	Seed Weight (g/1000 grain)	Seed Volume (ml/1000 grain)	Bulk density (w/v)	Water absorption index (g/100 g)	Water Solubility index (g %)	Water absorption (ml/100g)	Oil absorption (ml/100g)
VBN 3	40.4 ± 2.82b	50.6 ± 4.5d	0.79 ±0.01b	154.1 ± 5.8a	13.0 ±2.9a	36.6 ±6.2a	55.9 ±4.7c
VBN 4	38.1 ± 3.15b	38.6 ± 3.8a	0.98 ± 0.02d	154.0 ±5.2a	15.6 ±3.1a	56.6±6.10c	65.2 ±3.9d
VBN 5	46.6 ± 2.52c	58.0 ± 4.8e	0.80 ± 0.02b	153.3 ±4.6a	15.2 ±2.8a	52.6 ±5.9c	47.3 ±4.6b
VBN 6	43.1 ± 2.33bc	40.3 ± 2.5b	0.06 ±0.01a	151.0 ±4.4a	15 .0±3.0a	50.0 ±5.4c	48.5 ±2.9b
ADT 3	36.6 ± 2.44ab	40.6 ± 2.5b	0.90 ± 0.03c	153.6 ± 4.2a	15.2 ±3.2a	52.0 ±4.9c	42.1 ±3.5a
CO 6	45.0 ± 2.82c	43.3 ± 3.2c	1.03 ± 0.01d	151.0 ±4.9a	15 .0± 2.10a	50.0 ±6.3c	43.0 ±3.2a
T9	45.4 ± 3.24c	44.1 ± 2.0c	1.07 ± 0.02e	152.9 ± 3.8a	15.2 ± 2.3a	52.6 ±5.8c	40.1 ±2.8a
TMV	44.1 ± 2.50c	42.1 ± 2.6bc	1.04 ± 0.02de	155.1 ±4.25a	14.9 ± 2.51a	51.0 ±5.7c	65.2 ±2.7d
MV	33.2 ± 2.33a	42.3 ± 2.0bc	0.78 ± 0.01b	152.9 ±4.12a	14.8 ± 2.6a	49.0 ±5.2b	66.2 ±3.6d
VBg010 - 024	40.5 ± 2.80b	50.65 ± 4.4d	0.79 ± 0.01b	152.8 ±4.10a	15.1 ±2.8a	51.5 ±5.5c	47.5 ±4.6b
VBg010 - 025	45.2 ± 3.23c	43.1 ± 2.0c	1.04 ± 0.02e	152.7 ± 3.8a	15.0 ± 2.3a	52.4 ±5.8c	40.0 ±2.9a
VBg09 - 005	42.1 ± 2.33bc	40.2 ± 2.5b	1.04 ±0.01a	153.0 ±4.5a	14 .7±3.0a	48.5 ±5.4c	48.5 ±2.9b

Values are mean ± SD, n = 4; mean in a column with different superscripts differ significantly at P<0.05

VBN 3 – Vamban 3, VBN 4 – Vamban 4, VBN 5 – Vamban 5, VBN 6 – Vamban 6, ADT 3 – Aduthurai 3, MV – Market Variety

CO 6 – Coimbatore 6, T9 – Coimbatore , VBg – Vamban Black gram

Table 2. Chemical characteristics of black gram varieties

Varieties	Moisture (g/100g)	Ash (g/100g)	Fat (g/100g)	Protein (g/100g)	Starch (g/100g)	Calcium (mg/100g)	Iron (mg/100g)	Phosphorus (mg/100g)
VBN 3	10.4 ±1.5b	6.1 ± 0.10b	5.5±0.04d	26.5 ±2.8b	49.0±1.5c	112.3 ±3.8b	3.0 ± 0.4ab	384.0 ±8.0b
VBN 4	11.6 ± 1.3a	6.3 ±0.14b	5.1 ±0.02a	27.1 ±4.2b	49.5 ±1.4c	127.3 ±2.5c	4.0 ± 0.5b	392.0 ±7.0b
VBN 5	9.6 ± 1.2a	6.4 ± 0.13b	4.4 ±0.06c	28.5 ± 3.5a	51.3 ±1.2b	134.0 ±2.3d	4.6 ±0.5b	416.0 ±6.0c
ADT 3	10.7 ± 2.5a	6.3 ±0.08b	5.2 ±0.03b	27.1 ±2.5a	50.4 ±1.8a	126.3 ±2.1c	3.5 ±0.7a	380.0 ±5.0b
VBN 6	11.0 ± 1.4b	6.1 ±0.09a	5.0 ±0.07a	28.2 ±3.2b	48.6 ±1.2c	127.0 ±3.5c	4.0 ±0.6b	382.0 ± 5.0b
CO 6	11.5 ± 2.3a	6.4 ±0.11b	5.1 ±0.01a	26.5 ±3.2b	50.1 ±1.5c	125.0 ±3.7c	4.0 ±0.3b	382.0 ± 6.0b
T9	10.9 ± 1.7a	6.4 ±0.08b	5.4 ±0.01e	27.2 ±4.1b	49.5 ±1.4c	129.0 ±2.8c	4.1±0.5b	384.0± 4.0b
MV	11.6±1.8b	6.7±0.06b	5.5 ± 0.05d	26.2 ±3.3a	48.1 ±1.5a	106.6 ± 3.5a	3.0 ±0.5a	376.0 ± 7.0a
TMV	10.80±2.7a	6.5 ±0.06b	5.6 ±0.02d	25.5 ±2.4a	47.7 ±1.3c	128.5 ±3.1c	4.1 ±0.2b	385.0 ±3.0b
VBg010 -024	10.8 ±2.7a	6.5 ±0.06b	5.6 ±0.02d	27.1 ±2.5a	48.6 ±1.2c	129.0 ±2.8c	4.0 ±0.5b	380.0 ± 6.0b
VBg010 -025	10.2 ±1.5b	6.2 ±0.11b	5.4 ±0.01e	27.4 ± 3.5a	50.8 ±1.8a	134.0 ±2.3d	4.6 ±0.6b	384.0 ± 4.0b
VBg09 -005	11.4 ± 1.4b	6.1 ±0.09a	5.2 ±0.03b	26.2 ±3.2b	49.0 ±1.4c	127.3 ±2.5c	4.1±0.5b	376.0 ± 7.0a

Values are mean ± SD, n = 4; mean in a column with different superscripts differ significantly at P<0.05,
VBN 3 – Vamban 3, VBN 4 – Vamban 4, VBN 5 – Vamban 5, VBN 6 – Vamban 6, ADT 3 – Aduthurai 3, MV – Market Variety, CO 6 –
Coimbatore 6, T9 –Coimbatore, VBg – Vamban Black gram

13.9 Pasting Properties of Black Gram Varieties

The results of Rapid Visco Analyzer (RVA) of black gram flours are summarized in Table 3. The processing characteristics of flours can be predicted by testing the rheological characteristics. The pasting properties of black gram flour samples namely peak viscosity, break down viscosity, final viscosity, hold viscosity, set back viscosity, peak time and pasting temperature were analyzed. The highest values of peak viscosity were found in VBN 5 and VBN 6 flour of black gram variety which were 274 to 359 (RVU) respectively. The break down values from 121.1 in T9 and 48.8 in VBN 6. The final viscosity showed the highest in VBN 6, while the lowest were observed in ADT 3. The pasting temperature and set back viscosity were highest values for 90.4 in CO 6 and 107.1 in T9 (RVU) respectively, whereas T9 and MV flour has the lowest values.

14. Chemical Composition

The selected twelve black gram varieties chemical composition was given in (Table 2). The highest ash content was showed in 6.7 g/100g in MV and 6.5 g/100g VBg010 024 for black gram flour. The lowest fat content was found in VBN 5 4.4 and VBN 6 5.5 g/100g. Highest protein content was recorded in VBN 5 (28.5) followed by VBN 6 (28.2), T9 (27.2) and VBg010 025 (27.4 g/100g). Significant difference (0.05%) level was observed. The highest moisture content was recorded in variety VBN 4 (11.6 g/100g) followed by TMV and VBg010 024(10.80 g/100g) and lowest in VBN 5 (9.6 g/100g). Significant difference was observed in all selected black gram varieties. The highest starch content was recorded in variety VBN 5 (51.3 g/100g) followed by VBg010 025 (50.8 g/100g), CO 6 (50.1) and T9 (49.5 g/100g) respectively. The lowest starch content was observed in TMV (47.7 g/100g). Higher levels of calcium, iron and phosphorus was observed in VBN 5 134, 4.6 and 416 mg/100 g.

15. Fatty Acid Composition of Black Gram

The results showed that the major fatty acid present in VBN 5 was at the level of 28.4 per cent of linoleic acid, (18:2), 21.6 per cent of oleic acid and 4.4 per cent stearic acid. The fatty acid composition of T9 contains of 11.5 per cent of palmitic acid, 9.4 per cent of stearic acid, 29.1 per cent of oleic acid, and 33.8 per cent of linoleic acid. Alpha linolenic acid, arachidic acid and Behenic acid were not detected in T9 black gram variety. The fatty acid composition of black gram varieties given in Table 5.

Table 3. Pasting properties of (RVU) of different black gram varieties

Varieties	Peak viscosity	Break down viscosity	Final viscosity	Hold viscosity	Set back viscosity	Peak time (min)	Pasting temperature (°C)
VBN 3	191.3 ± 7.4c	20.7 ± 1.2a	245.0 ± 6.0c	170.6 ± 6.5d	53.8 ± 2.8a	6.2 ± 0.05b	75.3 ± 2.26b
VBN 6	274.1 ± 8.2d	47.8 ± 3.6d	337.6 ± 7.2f	225.8 ± 5.8f	63.8 ± 3.3b	5.3 ± 0.05a	86.3 ± 1.34d
VBN 4	191.3 ± 7.1c	20.7 ± 2.8a	245.3 ± 6.9c	170.6 ± 6.9d	53.8 ± 3.6a	6.2 ± 0.07b	88.6 ± 3.14d
VBN 5	359.8 ± 8.5e	48.8 ± 3.7d	310.4 ± 7.1e	202.0 ± 7.0e	50.8 ± 2.9a	6.1 ± 0.77b	88.6 ± 4.10d
ADT 3	191.3 ± 7.0c	30.1 ± 2.9c	253.1 ± 6.5d	160.4 ± 4.9c	61.4 ± 3.5b	6.2 ± 0.25b	81.2 ± 4.08d
CO 6	134.8 ± 6.8a	25.5 ± 2.1b	194.8 ± 7.0b	108.3 ± 5.4b	61.3 ± 3.6b	6.1 ± 0.01b	90.4 ± 0.50a
T9	156.2 ± 6.2b	121.1 ± 5.7e	48.5 ± 5.9a	35.1 ± 4.5a	107.1 ± 6.5c	7.1 ± 0.29c	71.4 ± 0.90a
MV	189.8 ± 7.5c	19.9 ± 1.17a	245.6 ± 6.7c	169.8 ± 5.8d	52.8 ± 4.2a	6.4 ± 0.50b	70.7 ± 0.07a

Values are mean ± SD, n = 4; mean in a column with different superscripts differ significantly at P<0.05
VBN 3 – Vamban 3, VBN 4 – Vamban 4, VBN 5 – Vamban 5, VBN 6 – Vamban 6, ADT 3 – Aduthurai 3, MV – Market Variety, CO 6 –
Coimbatore 6, T9 –Coimbatore, VBg – Vamban Black gram

Table 4. Colour values of black gram varieties

Varieties	Whole			Flour		
	L	A	b	L	a	b
VBN 3	84.97 ±6.08	−4.56 ±0.01	8.41 ±1.5	76.00 ±7.10	- 4.50 ±0.03	7.50 ±1.7
VBN 4	40.45 ±6.05	−2.49 ±0.03	4.79 ±1.6	58.42 ±6.70	- 10.48 ±0.02	13.65 ±4.7
VBN 5	59.57 ±4.07	−16.83 ±0.01	10.28 ±1.8	30.34 ±5.13	- 6.74 ±0.02	11.57 ±3.9
VBN 6	63.53 ±7.0c	−9.73 ±0.01	13.75 ±2.2	30.65 ±5.20	- 8.08 ±0.06	14.01 ±4.6
CO 6	60.51 ± 6.14	−9.51 ±0.04	13.70 ±2.4	32.40 ±5.80	-7.51 ±0.05	11.50 ±4.4
TMV	61.12 ±8.12	−10.12 ±0.02	13.96 ±0.05	34.62 ±5.20	-7.45 ±0.04	11.28 ±5.2
T9	59.50 ±4.10	−15.81 ±0.03	10.18 ±2.3	30.31 ±4.25	-6.74 ±0.01	11.26 ±5.6
ADT 3	57.86 ±5.09	−9.43 ±0.02	13.95 ±1.7	33.36 ±5.15	- 6.17 ±0.02	9.31 ±4.9
VBg010 024	40.45 ±6.05	−2.49 ±0.03	4.79 ±1.6	58.42 ±6.70	- 10.48 ±0.02	13.65 ±4.7
VBg010 025	59.50 ±4.10	−15.81 ±0.03	10.18 ±2.3	30.31 ±4.25	-6.74 ±0.01	11.26 ±5.6
VBg09 005	28.95 ±4.09	−10.12 ±0.02	10.28 ±1.4	24.00 ±4.17	- 9.11 ±0.03	10.57 ±4.7
MV	26.95 ±4.09	−10.12 ±0.02	11.28 ±1.4	21.00 ±4.17	- 9.11 ±0.03	11.57 ±4.7

Values are mean ± SD, n = 4; mean in a column with different superscripts differ significantly at P<0.05
VBN 3 – Vamban 3, VBN 4 – Vamban 4, VBN 5 – Vamban 5, VBN 6 – Vamban 6, ADT 3 – Aduthurai 3, MV – Market Variety, CO 6 – Coimbatore 6, T9 –Coimbatore

Table 5. Fatty acids composition (%) of black gram varieties of VBN 5 and T9

Fatty acids	VBN-5	T-9
Palmitic acid,16:0	21.7±2.1a	23.5±0.7 a
Stearic acid,18:0	8.4±0.5 a	10.2±0.6 a
Oleic acid,18:1	26.6±2.3 a	27.1±2.8 a
Linoleic acid,18:2 (n-6)	32.4±3.1 a	39.2±3.6 b
Alpha Linolenic acid, 18:3 (n-3)	3.8±0.3 a	nd
Arachidic acid,20:0	4.5±0.2	nd
Behenic acid, 22:0	2.6±0.3	nd

Values are mean ± SD, n = 4; mean in a column with different superscripts differ significantly at P<0.05
VBN 5 – Vamban 5 and T9 - Coimbarore

16. Sugar and Oligosaccharide Content Present in Black Gram Varieties

The total sugar content of VBN 5 and T9 variety were 80.9 mg/g and 73.6 mg/g respectively. The oligosaccharides present in VBN 5 and T9 were verbascose, stachyose, raffinose, arabinose and galactose. The oligosaccharides present in VBN 5 were 18.9, 9.7, 6.3, 19.8, and 23.6, 11.3 mg/g of verbascose, stachyose, raffinose, arabinose and galactose respectively. The verbascose, stachyose, raffinose, arabinose and galactose of T9 variety contained 15.8, 5.2, 3.8, 16.9, 20.1 and 12.8 mg/g respectively (Table 6).

17. Discussion

The physical property such as thousand grain weight was maximum in VBN 5 (46.6±2.5) and market variety had minimum grain weight (33.2±2.4). Significant difference was observed in their of thousand grain weights in the selected varieties. No significant differences were observed in 40.3±2.5 VBN 5, 40.6±2.5 ADT 3, 43.3±3.2 CO 6 and 44.1±2.9 T9 respectively. Kaur et al. [17] reported that seed mass and seed volume also varied significantly among different black gram varieties, KU-3 variety showed highest seed mass and seed volume of 5.2 g/100 seeds and 4.3 cc/100 seeds respectively, UG-562 variety and UG-1017 variety showed lowest seed weight. The bulk density of the black gram varieties was 1.07± 0.02 in T9 and lower bulk density was 0.06±0.01 in VBN 6. Earlier study focusing on the bulk densities of legume flour play a key role in formulation of weaning foods, from winged bean flour and soy isolate as reported by Kaur and Singh [11].

Higher bulk density in T9 suggests that it was dense than other black gram flour. High volume per gram of protein material is an important relation to packaging. Whole lentil pulse had higher bulk density compared with pigeon pea. [12]. No significant differences were observed in the water absorption index and water solubility index. Extruded products properties depend mostly on water solubility index and water absorption (WA) properties [13]. The water absorption of flours ranged from 56.6 to 36.6 ml /100g as showed in Table 1.

Result showed that the water absorption was highest for variety VBN 4 and the lowest for VBN 3. Oil absorption of the respective black gram flours were 65.2 and 66.2 respectively. VBN 4 and Market variety of black gram flour varieties showed the highest oil absorption. Padmasree et al. [14] reported that the raw cow pea flour had a water absorption capacity of 1.6 g/g flour. Difference in protein structure and the presence of different hydrophilic carbohydrates might be responsible for variations in the water absorption capacity of the flours. The flour with high oil absorption are potentially useful in food products for flavor retention, improvement of palatability and extension of shelf life, particularly in bakery or meat products where oil absorption is desired. The black gram flours foaming capacity range between 35.71 to 35.68 g per cent. The foaming stability and foaming capacity was higher in VBN 5. From these results it is apparent that the black gram polysaccharide exerts higher foam stability [15]. The colour of starch due to the presence of polyphenolic compounds, ascorbic acid and carotene has significant impact on its quality. A low value for chroma and a high value for lightness are desired for the starch to meet the consumer preference. Colour is an important factor to decide the product quality of black gram. The highest values of peak

Table 6. Sugar and oligosaccharide content present in VBN 5 and T9

Parameters	VBN5	T9
Total sugars (mg/g)	80.9	73.6
Verbascose (mg/g)	18.9	15.8
Stachyose (mg/g)	9.7	5.2
Raffinose (mg/g)	6.3	3.8
Arabinose (mg/g)	19.8	16.9
galactose (mg/g)	23.6	20.1
Sucrose (mg/g)	11.3	12.8

Values are mean ± SD, n = 4; mean in a column with different superscripts differ significantly at P<0.05
VBN 5 – Vamban 5 and T9 - Coimbarore

viscosity were found in VBN 5 and VBN 6 flour of black gram variety.

The chemical composition of black gram variety VBN 5 contained high amount of protein, starch calcium, iron and phosphorus in VBN 5 and low amount of fat and ash compared to VBg010 025 and T9 varieties to with values of 28.5, 51.3 g/100g, 134, 4.6 and 416 mg/100g respectively. From the perusal of data it appears that black gram seeds of selected black gram varieties had higher fatty acid composition as reported in T9 which had 11.5 per cent palmitic acid, 9.4 per cent stearic acid, 29.1 per cent oleic acid and 33.8 per cent linoleic acid. Mishra and Pathan, [16] reported that the fatty acid composition of raw and roasted kulthi seeds contained, 21.8 per cent palmitic, 40.8 per cent linoleic, 16.5 per cent oleic acid and 3.06 per cent respectively. This supports the present study. An increase in oligosaccharides and sugar content was observed in VBN 5 compared to variety T9.

18. Conclusion

Among all the 12 varieties VBN 5 and T9 were found to be best in terms of physicochemical properties, functional and pasting properties, oligosaccharide and sugar content.

19. References

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