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Physical, Engineering and Nutritional Properties of Grain Amaranthus Cultivars

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Abstract

Investigation of physicaland engineeringproperties of grain amaranthus is essential for design of equipment for harvesting, processing and value addition. In this research ten grain amaranthus cultivars wereevaluated for physical, engineering and nutritional properties. The axial dimentions, geometric properties and gravimetric properties were determined for grain amaranthus in the moisture content of 10.5± 0.3% (wb).Result showed that grain amaranthus has better axial dimensions namely Length (0.95 - 1.23 mm), Width (0.84 - 1.15 mm), thickness (0.69 to 0.85 mm) and geometric properties including arithmetic mean diameter (0.831 to 1.075 mm), gravimetric mean diameter(0.823 to 1.061 mm), square mean diameter(1.433 to 1.851 mm), equivalent diameter (1.029 to 1.329 mm), sphericity(0.854 to 0.881), aspect ratio(0.868 to 0.933), surface area(2.183 to 3.611 mm^2), shape factor(0.557 to 0.856).Coefficient of static friction of grain amaranthus is against rubber, mild steel surface were higher compared to stainless steel and card board surfaces. The protein,total carbohydrate and fat content of grain amaranthusranged between 9.08 to 12.32 g;62.17 g to 75.03 g; and2.81 to 3.85 g respectively. The crude fibre and ash content of grain amaranthus ranged between 2.36 – 3.96 g and 2.08 – 3.34 g per 100g of grain amaranthusrespectively.

Introduction

The Amaranth, commonly known as rajgira (king seed), ramdana (seed sent by God) is known to be a very nutritious pseudocereal with an exceptionally high protein content as compared to the other cereals. The scientific plant name in Greek "amaranth" means 'immortal', 'everlasting' or 'non-wilting' (Grobelnikmlakar*et al.*, 2009). The genus Amaranth (L.) includes more than 60 species. The species of the Amaranth that are used as a grain are *Amaranthuscaudatus, Amaranthuscruentus*, and *Amaranthushypochondriacus* (Bhat *et al.*, 2015). The grain amaranths are ancient crops having better prospects as potential food and feed resources because of their high grain protein and starch quality (Mlakar*et al.*, 2010). The grain has the potential to contribute for improving nutrition and health, especially in developing countries because of its unique agricultural, nutritional and functional properties. It is fast growing, high yielding, stress resistant, nutritious and nutraceutical properties (Muyonga*et al.*, 2014). The grains are high in lysine, fiber, protein, low in saturated fats, and gluten-free. Nutritionally amaranthus grains have higher protein utilization, higher protein efficiency ratio than traditional cereals such as corn and wheat (Durgadevi and Nazni, 2012). A seed of grain amaranth is composed of 13.1 to 21.0% of crude protein; 5.6 to 10.9% of crude fat; 48 to 69% of starch; 3.1 to 5.0% of dietary fibre and 2.5 to 4.4% of ash. **(**Mburu*et al.*, 2012**)**.It is a terrific source of minerals like calcium, magnesium, and copper, a good source of zinc, potassium, and phosphorus. Amaranth is a rich source of squalene, which is an intermediate triterpene in the cholesterol biosynthesis pathway and act as an emollient, antioxidant, hydrating and antitumor agent. In India amaranth are chiefly grown in Himalayas from Kashmir to Bhutan and also in South Indian hills. It is gaining popularity in the north western pains of India as well as in Gujarat under common name Rajgira(Venskutonis and Kraujalis, 2013). Amaranth can be ground into flour, popped like popcorn, or flaked like oatmeal and used as an ingredient in some foods such as puddings, soups, salad dressings. Products containing amaranth include breakfast cereals, bakery products, gluten-free foods and extruded foods. Development of new product from amaranth will promoteutilization of this raw material for human consumption (Chavez-Jauregui *et al.*, 2015). The physical properties of Amaranth grains, like those of other grains and seeds are essential for design of equipment used for their handling, storing and processing. Knowledge of engineering properties of agricultural materials and their dependence on the moisture content play an important role in the design of machines, structures, processes and controls in analyzing and determining the efficiency of a machine or an operation in developing new products. Such basic information should be of value not only to engineers but also to food scientists and processors who may exploit these properties and find new uses In view of the considerable economic potentials of the grain amaranthus in the food and industries, it is imperative to determine the relevant physical, engineering and nutritional properties of the grain. Hence the specific objective of the study was to determine the physical, engineering and nutritional properties of selected grain amaranthus cultivars.

Material and Methods

Ten selected grain amaranthus cultivars *viz.*, BGA 2, BGA 3, BGA 9, BGA 14, BGA 20, BGA 44, MGA 10, MGA 507, Suvarna and VL-Chuva44 were obtained from Forestry College and Research Institute, Mettupalayam, Tamil Nadu Agricultural University, Tamil Nadu, India. Gains were cleaned by using sieve (BS 80 mesh) to remove foreign matter such as dust, dirt, chaff, immature and broken grains. The initial moisture content of grain amaranthus was determined by standard hot air oven method at 105 ± 5°C until the constant weigh achieved (Altuntas *et al.*, 2005). For desired moisture content levels, the required amount of water from samples were removed using recirculation tray dryer and calculated amount of distilled water added and mixed thoroughly for achieving higher moisture content (Balasubramanian and Visvanathan, 2010). These samples were stored in refrigerator at 5°C in separate self sealable High Density Polyethylene (HDPE) bags for a week to allow the moisture equilibration. Before starting the experiment, the required quantity of the samples were taken out from the refrigerator and allowed to warm up to room temperature. All tests were conducted in the laboratory at an ambient temperature of about 32±2°C and relative humidity of 55-65%.The experiments on different physical, engineering and nutritional qualities of grain amaranthus were conducted at Central Institute of Agricultural Engineering, Regional Centre, Coimbatore.

Determination of physicalproperty

One hundred grain amaranthus seeds were randomly picked with the moisture content of 10 ± 0.3 % (d.b) from each grain amaranthus varieties and the length (L), breadth (B) and thickness (T) were measured by using a digital vernier calliper (± 0.01 mm) and thousand kernel weights measured using digital electronic balance.Using length (L), breadth (B) and thickness (T) measurement the geometrical properties such as arithmetic mean diameter (AMD), geometric mean diameter (GMD), square mean diameter (SMD), equivalent diameter (EQD), sphericity (Sp), aspect ratio (AR) were calculated using the following equations (Balasubramanian*et al.*, 2012).

$$AMD = \frac{L+B+T}{3}$$

$$GMD = \sqrt[3]{LBT}$$

$$SMD = \sqrt{LB + BT + TL}$$

$$EQD = \frac{AMD+GMD+SMD}{3}$$

$$S_p = \frac{GMD}{L}$$

$$AR = \frac{B}{L}$$

Major dimension was used to calculate the surface area (S) of single grain (Jain 1997) as detailed below.

$$S = \frac{\pi GMD L^2}{2L-GMD}$$

The unit volume of single grain (Jain 1997) was calculated as

$$V_t = \frac{\pi GMD^2 L^2}{6(2L - GMD)}$$

Shape factor (λ) based on unit volume and surface area of grain was determined (McCabe and Smith, 1984) as

$$\lambda = \frac{b}{a}$$

where, $a = \frac{V_t}{B^3}$ & $b = \frac{S}{6B^2}$

Bulk density was calculated as the ratio of weight of grain to volume of container. A cylindrical container of volume 95.45 cm^3 was filled with the grain and gently tapped and measure weight and volume of the grain. Average of 5 replications was taken. Care was taken to avoid compaction of grains in the container and filled to full volume. For thousand kernel weight 1000 numbers of grain amaranth were randomly picked from each sample, and weighed on a digital electronic balance.

Determination of frictional property

A laboratory setup was used to measure the static coefficient of friction (μs) of grain amaranthus cultivars on four surfaces including stainless steel, MS sheet, GI sheet, aluminium sheet, cardboard and rubber (Balasubramanian and Viswanathan, 2010). During the experiment, a levelled rectangular wood box filled with grains was moved on the frictional surface with the help of rope and pulley with incremental weight set-up. The frictional force and normal strength was noted and repeated for other surfaces at different moisture content. It was expressed as:

$$\mu s = \frac{F}{N_f}$$

Where, μs: static coefficient of friction, F: measured force in N and N_f: normal strength of the sample.

Determination of nutritional properties

Protein content was determined by lowry's method, fat estimated by soxhlet extraction in Socs plus (Pelican equipment, India) and the ash content was estimated by dry ashing method (AOAC, 2005). The carbohydrate and fibre content were estimated by anthrone method (Sadasivam and Manickam, 2008) and acid and alkali method (AOAC, 2000) respectively.

Results and Discussion

All the values of physical and engineering properties of ten grain amaranthus cultivars are presented in Table 1. The length, width and thickness of grain amaranthus ranged between 0.95 mm and 1.23mm, 0.84mm and 1.15mm, 0.69mm and 0.85mm respectively. The highest length and thickness recorded for BGA 3 grain amaranthus varieties while, the lowest observed in BGA9and BGA 2 grain amaranthus varieties. Abalone et a*l*., (2004) reported that the grain from *Amaranthus cruentus with* moisture range of 9·5 - 43·6% (d.b) *had* the average length, width and thickness of 1·42mm, 1·29mm and 0·87 mm, respectively.

Table 1. Physical and engineering properties of grain amaranthus cultivars

PROPERTIES	BGA-2	BGA-3	BGA-9	BGA-14	BGA-20	BGA-44	MGA-10	MGA-507	SUVARNA	VL-CHUVA-44
LENGTH (mm)	1.23±0.4	0.96±0.5	0.95±0.5	0.97±0.4	1.00±0.2	1.00±0.3	1.11±0.5	1.18±0.6	1.10±0.6	1.05±0.4
WIDTH (mm)	1.15±0.6	0.84±0.8	0.85±0.8	0.86±0.8	0.92±0.6	0.88±0.7	1.01±0.3	1.10±0.3	1.01±0.2	0.92±0.5
THICKNESS (mm)	0.85±0.7	0.69±0.8	0.73±0.8	0.71±0.9	0.75±0.8	0.75±0.8	0.80±0.6	0.81±0.8	0.81±0.8	0.78±0.6
AMD (mm)	1.075±0.2	0.831±0.5	0.842±0.4	0.848±0.4	0.888±0.4	0.876±0.4	0.970±0.3	1.031±0.3	0.971±0.3	0.916±0.2
GMD (mm)	1.061±0.2	0.823±0.3	0.837±0.1	0.840±0.7	0.881±0.6	0.869±0.5	0.960±0.5	1.0180.5	0.962±0.4	0.907±0.8
SMD (mm)	1.851±0.3	1.433±0.2	1.454±0.2	1.462±0.3	1.532±0.2	1.512±0.5	1.672±0.2	1.775±0.3	1.674±0.6	1.579±0.4
EQD (mm)	1.329±0.4	1.029±0.3	1.044±0.5	1.050±0.5	1.100±0.6	1.086±0.8	1.201±0.8	1.275±0.3	1.202±0.2	1.134±0.5
Shpericity (S_p)	0.863±0.8	0.854±0.8	0.880±0.8	0.865±0.9	0.881±0.9	0.870±0.9	0.868±0.8	0.863±0.8	0.879±0.10	0.863±0.7
Aspect ratio (AR)	0.933±0.4	0.868±0.3	0.891±0.2	0.886±0.3	0.917±0.4	0.883±0.5	0.910±0.2	0.933±0.3	0.919±0.21	0.874±0.2
Surface area (S) (mm^2)	3.611±0.7	2.183±0.6	2.245±0.8	2.273±0.5	2.483±0.4	2.421±0.6	2.953±0.4	3.323±0.2	2.959±0.3	2.649±0.4
Shape factor (λ)	0.557±0.8	0.846±0.6	0.927±0.3	0.856±0.8	0.842±0.6	0.808±0.5	0.677±0.10	0.608±0.1	0.702±0.8	0.728±0.5
Unit volume (mm^3)	1.268±0.8	0.375±0.6	0.381±0.3	0.398±0.4	0.475±0.5	0.460±0.1	0.759±0.8	1.037±0.2	0.729±0.8	0.591±0.6
1000 grain weight (g)	0.520±0.9	0.420±0.7	0.400±0.8	0.460±0.7	0.320±0.9	0.600±0.8	0.640±0.7	0.760±0.6	0.720±0.6	0.480±0.9
Bulk density (kg/mm^3)	0.719±0.6	0.641±0.5	0.782±0.8	0.777±0.66	0.814±0.7	0.761±0.5	0.807±0.8	0.811±0.4	0.816±0.3	0.601±0.5

Values are Mean *±SD*

The geometricalpropertiessuch as arithmetic mean diameter (AMD), geometric mean diameter (GMD), square mean diameter (SMD) and equivalent diameter (EQD) as calculated for the ten grain amaranthus were ranged from 0.831mm -1.075mm, 0.823mm – 1.061, 1.433- 1.851mm and 1.029- 1.329mm respectively. The mean sphericity was calculated and obtained between0.854 and 0.88. Similar result was expressed by Abalone et a*l.*, (2004) for *Amaranthus cruentus* where the sphericity ranged from 0.81 to 0.83.and for the basil seeds sphericity ranged between 0.43 to 0.65 (Seyed *et al.*,2008). Sphericity was found to bear a linear relationship with moisturecontent. Similarly the aspect ratio was calculated using length and breadth of the grain and the highest aspect ratio found in BGA 2 and MGA 507 variety of grain amaranthus (0.933) while the lowest found in BGA 3 grain amaranthus (0.868).

The thousand grain weight among the ten cultivars ranged between 0.32g (BGA-20) and 0.76g (MGA-507). Balasubramanian and viswanathan (2010) had also reported similar values for the minor millets in the range 0.20g to 0.49g. The highest unit volume and surface area reported in BGA 2 cultivars (1.268 and 3.611 respectively) where as lowest reported in BGA 3 (0.375 and 2.183 respectively). Higher bulk density was exhibited by Suvana grain amaranthus cultivars where as the lowest bulk density exhibited by VL-Chuva- 44 cultivars.

Coefficient of friction

The coefficient of friction was experimented in six different surface aluminium, stainless steel, mild steel, galvanized iron, card board and rubber) are presented in the Table 2. Among the ten varieties BGA-2 followed by BGA044 verities showed the high values of coefficient of friction in all six surface where as Suvarna variety exhibited the least value of coefficient of friction properties. The reason for the increased friction coefficient at given moisture content may be due to the water present in gains which offers increased adhesive force on contact surface. Among the various contact surfaces rubber, mild steel offer higher coefficient of friction compared to stainless steel and card board surface. Wanget al. (2007) indicted that the flax seed in aluminum sheet had the highest static coefficient offriction at the lowest moisture content (6.21%)followed galvanizediron, plywood and stainless steel. While at the highest moisturecontent (16.29%), plywood had the highest coefficient of friction followed by aluminum sheet, stainless steel and galvanized iron.

Table 2. Frictional properties of grain amaranthus

	Cultivars	Aluminium	Stainless Steel	Mild Steel	Galvanized Iron	Cardboard	Rubber
1	BGA 2	0.202±0.007	0.204±0.005	0.274±0.002	0.255±0.003	0.251±0.007	0.311±0.008
2	BGA 3	0.186±0.003	0.114±0.006	0.184±0.002	0.186±0.006	0.184±0.010	0.258±0.009
3	BGA 9	0.233±0.002	0.169±0.004	0.248±0.003	0.197±0.009	0.195±0.012	0.278±0.011
4	BGA 14	0.228±0.001	0.121±0.005	0.205±0.004	0.183±0.005	0.185±0.010	0.201±0.014
5	BGA 20	0.152±0.006	0.137±0.002	0.230±0.005	0.166±0.10	0.135±0.018	0.246±0.009
6	BGA 44	0.206±0.008	0.135±0.003	0.269±0.006	0.250±0.002	0.249±0.012	0.268±0.011
7	MGA 10	0.234±0.002	0.111±0.004	0.222±0.004	0.160±0.009	0.160±0.014	0.200±0.009
8	MGA 507	0.202±0.006	0.124±0.006	0.250±0.006	0.178±0.007	0.203±0.011	0.295±0.008
9	SUVARNA	0.137±0.005	0.051±0.007	0.197±0.008	0.145±0.004	0.093±0.013	0.145±0.007
10	VL-CHUVA 44	0.208±0.004	0.167±0.005	0.200±0.006	0.226±0.002	0.137±0.009	0.242±0.010

Values are Mean *±SD*

Table 3. Nutrient composition of grain amaranthus cultivars (per 100g)

	Cultivars	Protein (g)	Fat (g)	Carbohydrate (g)	Fibre (g)	Ash (g)
1	BGA 2	11.13±0.03	3.85±0.09	66.33±0.32	3.42±0.07	2.11±0.02
2	BGA 3	9.29±0.07	2.69±0.08	72.09±0.41	2.87±0.06	2.29±0.03
3	BGA 9	12.61±0.06	3.13±0.08	68.37±0.51	2.36±0.05	2.21±0.04
4	BGA 14	13.66±0.04	2.71±0.06	67.54±0.43	2.84±0.08	2.63±0.06
5	BGA 20	14.13±0.05	3.75±0.07	65.43±0.21	2.92±0.07	2.13±0.07
6	BGA 44	13.08±0.02	3.59±0.08	62.17±0.07	3.14±0.04	3.08±0.08
7	MGA 10	11.79±0.03	3.80±0.09	66.29±0.32	3.96±0.06	2.79±0.03
8	MGA 507	12.08±0.06	2.84±0.07	70.54±0.26	3.16±0.05	2.08±0.02
9	Suvarna	9.26±0.05	2.81±0.05	75.03±0.29	2.47±0.08	2.26±0.05
10	VL-Chuva 44	12.34±0.04	2.78±0.03	64.96±0.25	3.67±0.07	3.34±0.04

***Values are Mean** ±SD*

Nutritional properties

The moisture content of selected grain amaranthus cultivars ranged between 9.08 to 12.32 g per cent, 62.17 g to 75.03 g of total carbohydrate and 2.81 to 3.85 g of fat. The maximum protein content was found in BGA cultivar 20 (14.13 g) and lower content in Suvarna (9.26 g) grain amaranthus cultivar. The crude fibre and ash content of grain amaranthus ranged between 2.36 to 3.96 g and 2.08 to 3.34 g respectively. Grobelnik Mlakar *et al*., (2009) reported that four varieties of grain amarantus *A. cruentus, A. hypochondriacus, A. caudatus* and *A. hypochondriacus* hybrids on average composed of 13.1to 21.0 % of crude protein; 5.6 to 10.9 % of crude fat; 48 to 69 % of starch; 3.1 to 5.0 % of dietary fibre and 2.5 to 4.4 % of ash. Burisova *et al.*,(2001) stated that grain amaranthus contain 65- 75 per cent starch, 4 to 5 per cent dietary fibre , 2-3 times higher content for sucrose in comparison to wheat Graimplinger *et al.*, (2007) found that *A.cruentus* in eastern Austria had crude fibre and carbohydrate in the ranges of 3.5 % to 4.2 % and 66.7% to 72.7 % respectively.A study done by Gearhart and Rosentrater (2014) showed that amaranth have 13-18% protein, 6-8% fat, 63% carbohydrates, and 4-14% crude fiber. Nascimento *et al*., (2014) reported the Argentina variety *Amaranthus caudatus* composed of 13.4g protein, 6.43 g fat, 11.30 g fibre, 2.89 g ash and 53.90 g of starch.

Conclusion

Grain amaranthus axial dimensions namely length, width, thickness, geometric properties including arithmetic mean diameter, gravimetric mean diameter, square mean diameter, equivalent diameter, sphericity, aspect ratio, surface area, shape factor and gravimetric properties including volume, 1000 kernel weight, bulk density were also determined for grain amaranth in the moisture content range of 10.5±0.3% (wb). s. The protein, total carbohydrate and fat content of grain amaranthus ranged between 9.08 to 12.32 g; 62.17 g to 75.03 g; and2.81 to 3.85 g respectively. The crude fibre and ash content of grain amaranthus ranged between 2.36 – 3.96 g and 2.08 – 3.34 g respectively. This basic information about grain amaranthus would be beneficial for further grain amaranthus processing and value addition.

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