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STUDIES ON PHYSIOCHEMICAL PROPERTIES OF FOOD GRAINS BAJRA (*PENNISETUM GLAUCUM*), RAGI (*ELEUSINE CORACANA*) AND RICE (*ORYZA SATIVA L.*)

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Abstract : Bajra (*Pennisetum glaucum)* also known as finger millet, is most widely grown crop in the world. It is excellent source of micronutrients like iron and zinc. Ragi (*Eleusine coracana*) is a cereal with higher calcium content. Rice *(Oryza sativa L.)* is also a cereal with rich source of proteins and carbohydrates. Many food products are being prepared with ragi and bajra to substitute the rice which is a main source of the poor man food in India. The physiochemical properties of these foods play crucial role in processing by various methods. In the present investigation, the physical properties of these foods, such as length, breadth, density, bulk density, porosity, true density, angle of repose, geometric mean diameter, sphericity, protein, fat, ash, crude fibre were determined. The length and breadth of grains were measured using the vernier. The moisture content of the collected samples was estimated using the hot air oven method. The density, bulk density, porosity, and true density of bajra, ragi and rice food grains were found using standard methods given by AOAC, 1990. The angle of repose, geometric mean diameter and sphericity of grains were also measured. Finally, the results were analyzed in significance for the designers and processors in designing food processing equipment.

***Key Words* -**Bajra, Ragi, Rice, Physiochemical properties, process equipment

I. INTRODUCTION

The physiochemical properties of food grains have a set of characteristics which are essential for understanding the quality, processing suitability and nutritional value of food grains. Food grains are the staple food worldwide which provides essential nutrients and energy for healthy life. Physiochemical properties of food grains include length, breadth, moisture content, density, bulk density, porosity, true density, angle of repose, geometric mean diameter and sphericity. Physiochemical properties influence the behavior of food grains during, the processing such as cooking, baking, sorting, grading, milling, extrusion etc. physiochemical properties have effect on safety and quality of food grains. The physiochemical properties are essential in various stages of food supply chain, from production from field to consumption. Measuring the length and breadth of the grains have a great importance as it influences the product quality, storage space, packing density of the grains. Grains size is used to study the properties such as flowability, porosity. Low moisture content helps in preserving the quality of the grains during the storage. High moisture content causes growth of mold, bacteria and deteriorate the nutritional properties of grains. Bulk density and density are determined to know the efficiency of storage of grains in bins, bags and silos. Bulk density also affects the processes such as mixing, milling and packaging. Porosity influences the storage capacity of grains. Higher porosity allows grains of higher storage volume. Angle of repose is an important parameter for flowability.

II. MATERIALS:

2.1. MATERIALS: The food grains such as Bajra, Ragi and Rice are obtained from the Ushodhaya market in Vidya Nagar, Hyderabad.
The equipment used such as vernier calipers and screw guage are obtained from $JIT_{®}$ $Chuar\ Brand$. The equipment for fat analysis SoxTRON Sox-4 is obtained from Tulin equipment’s. The equipment for protein analysis is obtained from KjelTRON Tulin equipmments

III. METHODS

2.2.1. PHYSICAL PROPERTIES:

i. Length:

The length of grains effects the processing efficiency, cooking quality, texture, mouthfeel and overall consumer acceptance. so, it is important to measure the length of food grains. The length of grain is determined using the vernier calipers. The grain is fixed length wise between the jaws in vernier calipers. The main scale, vernier scale and least count are noted (Method No: FSSAI 03.058:2023). The length is calculated using formula

$$L = \{M.S.R + (L.C + V.S.R)\} \rightarrow (1)$$

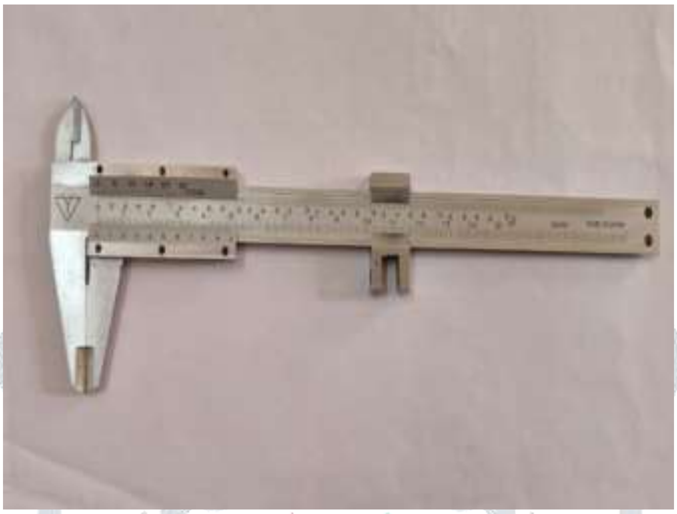

Figure 1: vernier calipers

ii. Breadth:

The breadth of the grains is determined using the screw gauge. Measuring the grains breadth helps in assessing the uniformity of grains. Measuring dimensions helps in determining the packing density and storage space of the product. The grain is fixed breadth wise between the jaws of the screw gauge. The head scale, pitch scale and least count are noted. (Method No: FSSAI 03.058:2023). The breadth is calculated using the formula

$$Breadth = \{H.S.R + (P.S.R + L.C)\} \rightarrow (2)$$

Figure 2: screw gauge

iii. Density:

Density is defined as the ratio of the weight by volume. To determine the density first take 10ml of toluene in a measuring jar and then slowly add the grains of the sample weighed 10grams into the jar and observe that the level of toluene rises and this is noted as the rise in volume. Now the ratio of the weight of the sample taken to rise in volume gives the density of the grains, it is given by

$$Density\left(\frac{g}{ml}\right) = \frac{weight\ of\ sample\ taken}{rise\ in\ volume} \rightarrow (3)$$

iv. Bulk Density:

Bulk density is defined as the mass of the particles of the food material divided by the bulk volume. Bulk density is also called as apparent density. The bulk density is important in separating and grading of grains. The bulk density values of bajra, ragi and rice were determined by standard method which is given by (AOAC 1990).

$$Bulk\ density\left(\frac{g}{cm^3}\right) = \frac{weight\ of\ grains}{volume\ of\ the\ container} \rightarrow (4)$$

v. Porosity(ε):

Porosity is the measure of the void spaces or open spaces within a material, and it is usually expressed as a percentage. It indicated the number of pores in the bulk of food grains. The percentage of porosity is measured using the following relation (Mohsenin, 1986):

$$Porosity(\%) = \frac{true\ density - bulk\ density}{true\ density} \times 100 \rightarrow (5)$$

vi. True Density:

True density of grains was determined as the ratio of grain sample weight to the true volume of the sample. The true density of the food grains was determined using the following relationship.

$$\rho_t = \left(\frac{100}{100 - \varepsilon}\right)\rho_b \rightarrow (6)$$

vii. Angle Of Repose:

When the grains are poured onto a surface, a heap is formed. The repose angle is influenced by the grain properties (moisture content, morphology, and particle distribution etc). The angle of repose is the steepest angle relative to the horizontal plane on which a material can be piled without the surface material sliding (IS: 6663-1972).

$$Angle\ of\ repose = \tan^{-1}\frac{2h}{D} \rightarrow (7)$$

viii. Sphericity:

Sphericity is defined as the surface area of a sphere of the same volume as that of the particle divided by the actual surface area of the particle. This shows the shape character of particle relative to the sphere.

$$Sphericity = \frac{lwt^{1/3}}{l} \rightarrow (8)$$

ix. Geometric Mean Diameter:

A measure of the central tendency of particle size composition of substrate materials sometimes used as an index of quality of spawning gravels. It helps in characterizing the grains physical properties including flowability, porosity, packing density. It is crucial in food processing for control over grains size distribution which impacts products quality. The size such as length, width and thickness of the food grains are measured. The following equation is used to measure the geometric mean diameter of grains in mm (Mohsenin, 1986).

$$Geometric\ mean\ diameter = lwt^{1/3} \rightarrow (9)$$

2.2.2. CHEMICAL PROPERTIES: PROXIMATE ANALYSIS:

i. Moisture Content:

Moisture content of the samples was determined using the hot air oven method. Three samples of each five grams were taken and kept in the hot air oven at 105±10ºC for half an hour. After half an hour, the samples were taken out and placed in a desiccator and cooled. This process was repeated until the constant reading was attained. (Method No: FSSAI 03.006:2023). The moisture content was calculated using the following formula

Moisture content (%) = $Moisture\ content = \frac{w_3 - w_2}{w_1} \times 100 \rightarrow (10)$

Figure 3: Hot air oven

ii. Determination Of Ash Content

About five grams of the sample was weighed accurately into a porcelain crucible. This was transferred into a muffle furnace set at 600°C and left for about 4 hours. About this time, it had turned into white ash. The crucible and its content were cooled to about 100°C in air then to room temperature in desiccators and weighed. The percentage ash was calculated from the formula below. (AOAC 1995)

$$\% \, of Ash = \frac{weight \ of \ ash}{weight \ of \ sample} \times 100 \rightarrow (11)$$

Figure 4: Muffle furnace

iii. Determination Of Protein Content:

Proteins are polymers of amino acids, the majority of which are of amino acids having general formula $NH_2CHRCOOH$ may be distinguished from fats & carbohydrates is being the only macro nutrient in food containing nitrogen. (AOAC 976.05(2005))

Reagents:

- Concentrated H_2SO_4
- Catalyst titrates
- 40% NaOH solution
- O.1 N NaOH
- O.1 N H_2SO_4
- Methyl red indicator

Procedure:

Take 0.55g of sample in digestion tube of instrument & add 25ml concentrated H2SO4 and 1-2 catalyst stabilizers. Adjust temperature to 370°C and keep for digestion for 4-6 hours till the solution becomes blue in colour. Remove the tube from 0.1N H2SO4 solution in a titration flask, placing on the distillation unit attach a tube containing digested sample to distillation until the press start button to affect a metered addition of NaOH& to initiate steam distillation stops add 5 drops to yellow color. This is the end point. Now using 25ml of 0.1N HCl with 0.1N NaOH in burette.

$$\%Nitrogen = \frac{1.4 \times normality \times blank\ sample \times kjeldhal\ factor}{weight\ of\ sample} \rightarrow (12)$$

$$\%\ Protein = (Nitrogen\% \times conversion\ factor) \rightarrow (13)$$

Figure 5: Kjeldhal

iv. Estimation Of Fat Content:

Rise all the collection vessels and place them in oven with the temperature about 100^{0}c and also the samples. if all the moisture were removed from the collection vessels, place the desiccator to bring to room temperature. now weigh the empty collection vessels and let the weight be W1. This is initial collection vessels weight. Now insert the thimble in the S.S.Spring thimble holder and place it on the collection vessels. weigh the sample and transfer them to the thimble. let the sample weight is 3grams. Pour the solvent in the collection vessels and the volume is $3/4^{th}$ of the volume of the vessel. load the collection vessels in the system. switch ON the system and set the boiling point of solvent as the boiling temperature. the boiling temperature may be 100^{0}cmore than the solvent's maximum boiling point. leave the process about 45 - 60mins. After the process time, increase the temperatureto solvent recovery temperature. Now do the rinsing about 2times in order to collect the remaining fat that may presentin the sample. Now took out all the collection vessels from the system and put them in a hot airoven. After 15-20mins, take out all the beakers and place them in a desiccator about 5mins take out all thimble is holders and weigh the collection vessels. This is the final weight of the collection vessels. By substituting the following formula, the amount of fat present in the sample can be calculated. (AOAC Official Method 2003)

$$\%fat = \frac{W_2 - W_1}{W} \times 100 \rightarrow (14)$$

Figure 6: SoxTRON

v. Estimation Of Fiber Content:

The method is based on the solubilization of non-cellulosic compounds by sulphuric acid and KOH solution. Determine separately the sample moisture by heating in an oven at 105ºC to constant weight.Cool in a desiccator then weigh accurately 1gm of grinded sample.

Approximately with 1g and 1.25% sulphuric acid up to the 150ml notch crucible, after preheating by the hotplate in order to reduce the time requirement for browning. Add 3 to 5 drops of n-octanol as antifoam agent. Boil 30mins exactly from the onset of browning. Connectto vacuum for draining sulphuric acid. Wash 3 times with 30ml of hot deionized water connecting each time to compressed air for stirring the content of crucible. After draining the last wash, add 150ml of preheated KOH 1.25%, 3-5 drops of antifoaming agent n-octanol. Boil for 30mins, filter and wash three times with water by stirring each time by compressed air to coolthe crucibles and remove the alkali residues. Then wash three times the crucible content with 25ml of acetone. Remove the acetone, stirring each time by compressed air. Remove the crucibles and determine the dry weight after drying in an oven at 105ºC for an hour or upto a constant weight. When ash content is also required, the crucibles are placed in a muffle furnace, at 550^{0}C for 3 hours and reweighed after cooling in a desiccator.

The difference in weight in comparison to the previous weight represents the crude fibre content without ash. (AOAC, 2005)

$$\%\, Crude\ fibre = \frac{F_1 - F_2}{F_0} \times 100 \rightarrow (15)$$

IV. RESULTS AND DISCUSSION

Table 1: physical properties of food grains

Physical properties	bajra	ragi	rice
Length(mm)	2.89	3.86	6.30
Breadth(mm)	2.34	2.41	2.56
Density (g/ml)	0.95	1.14	0.96
Bulk density(g/cm³)	0.52	0.54	0.94
Porosity(%)	45.2	52.63	2.08
True density(kg/m³)	1315	1125	1361
Angle of repose	24°	28°	37.6°
Sphericity	0.81	0.95	0.54
Geometric mean diameter(mm)	2.52	1.603	3.11

Table 2: Chemical properties of food grains

Chemical properties	bajra	Ragi	rice
Moisture content (%)	9.7	11.9	11.67
Ash(g)	1.37	2.04	0.56
Protein(g)	10.96	7.16	7.94
Fat(g)	5.43	1.92	0.52
crude fiber (g)	11.49	11.18	2.81

Physiochemical properties have significant importance in designing, processing, handling, transportation and storage. The length, breadth and density are important in sorting, grading and separation process in food grain processing. Quality of food grains is also depend on the bulk density of grains. Porosity and density of grains are important which affect the hardness of kernel, milling, drying rate etc. Angle of repose is useful in determining the slope stability and structure. Sphericity is very important for grains as it affects the flowability, density and porosity. The grains which have high sphericity will flow more easily, pack together with great efficiency and has less void spaces between each other. These will have impact on storage, processing, and transportation of grains. The post-harvest moisture content of Bajra is 10-14%. The bajra taken from the market is of 9.7% moisture. The post-harvest moisture content of ragi is 10- 14%. The ragi taken from the market is dried which is of 11.9% moisture content. The post-harvest moisture content of rice is 18- 24%. The rice taken from the market is dried which is of 11.67%. Different physical properties such as length, breadth, moisture content, density, bulk density, porosity, true density, angle of repose, geometric mean diameter, sphericity, ash content, protein, fat and crude fiber were determined and results obtained are presented in the Table 1 and Table 2

V. Conclusion:

It can be concluded that the main importance of studying physical properties were considered as the basic data in designing the machinery and equipment used during the harvesting and in the post-harvest such as storage operations. These are important in sorting, grading and many other processing operations to produce the high-quality product. The physical properties such as length, breadth, density, bulk density, porosity, true density, angle of repose, geometric mean diameter, sphericity, protein, ash, fat, crude fiber was determined. The moisture content of bajra, ragi and rice are 9.7%, 11.9%, 11.67%.

VI. Nomenclature:

$M.S.R$ = main scale reading

$L.C$ = Least Count

$V.S.R$ = Vernier Scale Reading

$H.S.R$ = Head Scale Reading

$P.S.R$ =Pitch Scale Reading

ρ_b = Bulk density, g/cm³

ρ_t= True density, g/cm³ and

ε = Porosity, per cent

h=Height of the pile

D=diameter of the pile

l is length

w is width

t is thickness

w_3 is weight of petriplate and sample before drying, g

w_2 is weight of petriplate and sample after drying, g

w_1 is weight of sample taken, g

W= Weight of sample

W_1= Weight of empty collection vessel

W_2= Weight of collection vessel containing fat

F_1 is weight of the residue in the crucible after digestion

F_2 is weight of the ash in the crucible

F_0 is weight of the sample in the crucible

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