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Research paper

Physical Properties of Cassava (*Manihot esculenta crantz*) Root and Physico-chemical Properties of its Starch

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ABSTRACT

In present investigation the physical properties of Cassava root and physico-chemical properties of its starch have been determined. Physical properties of cassava root such as size, shape, True density, Bulk density and porosity was studied. Also physico-chemical properties of cassava starch such as ash content, pH, Moisture content, Gelatinization temperature, Water absorption capacity, Bulk density, Particle size, Swelling volume, Swelling power and Solubility were investigated. The cassava root has average values of length, head diameter (D_H), middle diameter (D_M), tail diameter (D_T), sphericity, true density, bulk density and porosity were 254.58 ± ± 36.44 mm, 44.31 ± 7.11 mm, 38.58 ± 7.42 mm, 22.04 ± 2.80 mm, 1.136 ± 0.027 g/cc, 0.498 ± 0.028 g/cc and 56.14 ± 2.701 % respectively. The cassava starch contains average values of ash content, pH, bulk density, particle size, moisture content, gelatinization temperature, water absorption capacity, swelling volume, swelling power and solubility were 0.61 ± 0.04 %, 5.28 ± 0.45, 0.54 ± 0.054 g/cc, 6.12 ± 1.829 µm, 11.41 ± 0.007 %, 73.00 ± 3.57 °C, 1.09 ± 0.05 g/g, 1.42 ± 0.231 ml, 8.73 ± 0.794 g/g and 1.744 ± 0.335 % respectively.

Keywords: Cassava root, cassava starch, physical properties of cassava root, physico-chemical properties of starch

Cassava (*Manihot esculenta crantz*) also called tapioca belongs to the family *Euphorbiaceae*. It is a root crop with starchy tubers and consumed approximately in 102 countries (FAO, 2006). It is rich in carbohydrates and low in vitamins and minerals, it is poor source of protein. It is widely cultivated in tropical and sub-tropical regions of world. It is mainly cultivated in Africa, Asia and Latin America. World is producing around 250 million tonnes of cassava every year. India produces around 80.6 lakh tonne of cassava production (Nisha, 2015). It is essentially a carbohydrate food with low protein and fat (Ihekoronye and Ngoddy, 1985). Edible part of fresh cassava root contains 32-35% carbohydrate, 2-3% protein, 75-80% moisture (d.b.), 0.1% fat, 1% fibre and 0.75 -2.50% ash (Ihekoronye and Ngoddy, 1985, Oluwole *et al.* 2004). Fig 1 (a) shows the Cassava root.

Starch is one of the most important but flexible food ingredients processing value added attributes for number of industrial applications. Cassava is most important starchy root crop. Starch is isolated from numerous tuber crops as well as cereal grains. It is relatively low cost, high calorific value raw material with desirable physical and chemical properties making it ideal in many food and non-

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Fig. 1 (a): Cassava root

Fig. 1 (b): Cassava starch

food applications i.e. food, textile, cosmetics, plastics, adhesives, paper and pharmaceutical industries. It is renewable and almost unlimited resource material. About 54% of the starches produced globally are utilized for food applications with 46% non-food applications. Starch is the most important, digestible food polysaccharides and is therefore a major source of energy in our diet. The polysaccharides are often used in certain food products mainly for their thickening and gelling properties. The presence of small amounts of these materials can bind large quantity of water, bringing a desirable change in the texture of a food product. Starches from cereals, tubers and roots are widely used as a natural and safe sources in the food industry as stabilizer or texture modifiers (Mishra and Rai, 2006; Gebre-Mariam and Schmidt, 1996). Fig 1 (b) shows the Cassava starch. Cassava starch contributes less than 8 % of the world starch production compared to starches derived from most other plants. This is in spite of its greater paste clarity, viscosity, freeze-thaw stability and its high stability in acidic products. It also has excellent properties for use in non-food production such as pharmaceuticals and thermo bio-plastics. Cassava yields on an average of starch 24-32 % compared to corn that yields about 65 % starch, its processing technique is simpler than corn starch (Integrated cassava Project, 2012).

The use of cassava for starch production faces stiff competition in many countries where it is used to produce many staple products that yield more income to the farmers. India is the highest producer of cassava. Cassava is cultivated in India in 13 states, it is concentrated in the southern region of the country and to a certain extent in northeast region. The crop is concentrated in the Kerala, Tamil Nadu and Andhra Pradesh owing to the favourable climate and efficient utilization. Kerala has a major share in area (1.04 lakh ha) under cassava (43.33 % of cassava area in India) and the maximum production here goes for human consumption. Tamil Nadu has an area of 95,000 ha (40 % of the total area under cassava in India) and 60 per cent of cassava produced is utilized industrially to produce starch, sago and other value added products. Andhra Pradesh has 8.1% of the cassava area and is utilized exclusively for industrial purposes. Konkan region of Maharashtra has potentiality for the cultivation of cassava (ICAR-CTCRI, 2014-15).

Approximately 65% of all cassava produced is used for human consumption, 25% for industrial use, mostly as starch (6%) or animal feed (19%), and 10% is lost as waste (Fish and Trim, 1993). More than 40% of cassava is currently processed, mainly into traditional food products (sago, ethanol, glucose, chips, wafers and pappads). Cassava root is highly perishable can be stored up to 48 hours (Ajala Lola *et al*. 2012). To overcome these limitation requires appropriate strategies and technology for postharvest processing and utilization. Processing provides a means of producing shelf-stable products (thereby reducing losses), adding value at a rural level, and reducing the bulk to be marketed (Dufour *et al*. 2002).

The objective of present work was to study physical properties of cassava root and physico-chemical properties of its starch respectively.

MATERIALS AND METHODS

Raw materials

Cassava for experimentation was procured from the university farm at Central Research Station, Wakawali Dr. B.S.K.K.V. Dapoli. The freshly harvested cassava roots were used to determine physical and physico-chemical properties of root and its starch respectively.

Physical properties of cassava root

1. Determination of size and shape of cassava root

Cassava roots freshly harvested from farm locations were selected of various sizes. 50 roots were considered during experiment. Fifty roots selected randomly from the harvested lots. Whole length of fifty (50) samples of cleaned unpeeled roots were measured with the use of a Digital vernier calliper (0.01 mm L.C.), tape rule and subsequently recorded. The same specimens whose lengths were earlier measured were marked into three portions (head, middle and tail) and their diameters (i.e. D_H, D_M, and D_T) measured along these marked portions from the head to the tail along two perpendicular lines with a Digital vernier calliper and the average values for the readings at each portion of the root were calculated. Thus, three root diameters were obtained for each root.

2. Determination of sphericity of cassava root

The sphericity is the ratio of the surface area of the sphere having the same volume as that of root to the surface area of root (Mohsenin, 1980). The degree of sphericity was calculated from equation (1),

$$\text{Sphericity} = \frac{(abc)^{1/3}}{a} \qquad \ldots(1)$$

Where,

a = head diameter (mm); *b* = middle diameter (mm); *c* = tail diameter (mm)

3. Determination of True density of cassava root

The true density of a root is defined as the ratio of the mass of a root to the solid volume occupied by the sample (Mohsenin, 1980). The mass of single root was determined using electronic balance (make: Contech instrument Ltd., model: CT-6K1) with accuracy 1 mg. The water was taken into 1000 ml graduated cylinder. The single root was deep in water then displaced water was measured in ml. The volume of displaced water was calculated as difference in displaced water minus initial volume of water. The true density was determined using equation (2).

$$\text{True Density} = \frac{\text{Mass}}{\text{Vol.of displaced water}} \qquad \ldots (2)$$

4. Determination of Bulk density of cassava root

The bulk density was determined by using 60 × 40 × 20 cm^3 size gunny bag. The Cassava root filled in the gunny bag of above mentioned dimensions and weight was recorded. The bulk density was determined using equation (3).

$$\text{Bulk Density (g/cc)} = \frac{\text{Mass (g)}}{\text{Vol.of Bag (cc)}} \qquad \ldots (3)$$

5. Determination of Porosity of cassava root

The porosity ϱ of cassava root were computed from the values of true density and bulk density using the relationship given in equation (4) (Mohsenin, 1980),

$$\rho(\%) = \left(\frac{T.D. - B.D.}{T.D.}\right) \times 100 \qquad \ldots (4)$$

Preparation of Cassava starch

Cassava starch was prepared as per procedure discussed by Aseidu (1989). The cassava root after harvesting cleaned, washed and surface moisture was removed and weighed. The cassava tubers were peeled and cut into 3 mm thick slices, the slices were beaten into small fragments and mixed with water with 1:2 proportion then wet grounded. The mixture was screened by using muslin cloth, starch was allowed to settle and decanted. The flow chart for process of starch preparation is represented in Fig. 1 the percentage yield was calculated and the final product was packed in high density polyethylene to prevent moisture and air intake from the atmosphere.

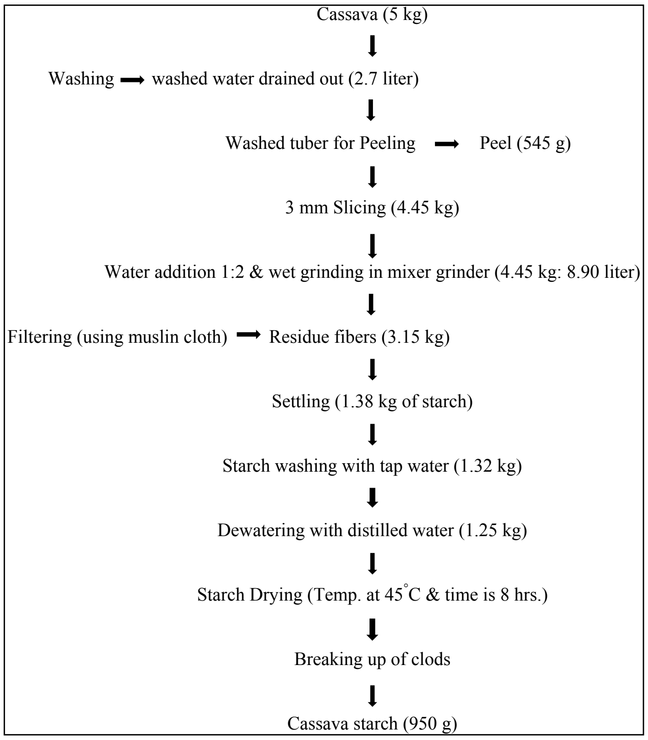

Fig. 1: Flow Chart of Cassava Starch Production (Aseidu 1989)

Physico-chemical properties of Cassava starch

1. Determination of Ash Content

The ash content of cassava starch was determined as per procedure described by (Akpa *et al.* 2012). 15g of sample was weighed into a crucible of known weight. The crucible was put into a muffle furnace and the sample left as ash at 650 °C about 4 hrs. After ashing, the crucible was brought out of the muffle furnace, cooled to room temperature and weighed. The ash content of the sample was calculated using the formula:

% of ash in sample =

$$\frac{\text{Weight of ash in sample}}{\text{Weight of sample}} \times 100 \qquad \ldots(5)$$

2. Determination of pH

The pH of cassava starch was determined as per procedure AOAC, (1984). 5 g of starch sample on dry basis (d.b.), was weighed into beakers and mixed with 20 mL of distilled water. The suspensions was stirred for 5 min using glass rod and allowed to settle for 10 min. The pH of the water phase was measured using a calibrated pH meter.

3. Determination of Bulk Density (Bd)

The bulk density of cassava starch was determined as per procedure described by Narayana and Narasinga (1982). 30 g of cassava starch sample was put into an already weighed 50 ml measuring graduated cylinder (W_1) it was gently tapped to dominate air spaces between the starch in the measuring graduated cylinder and the volume was noted to be the volume of the starch sample used. The new mass of the sample and measuring graduated cylinder was recorded (W_2). Both the volume and mass of the starch sample was determined, the bulk density was computed as:

$$\text{Bulk density} = \frac{W_1 - W_1}{\text{Volume of sample}} \qquad \ldots(6)$$

4. Particle Size Determination

The particle size determination of cassava starch was done by using Image analysis system (Make: Expert vision Labs Pvt Ltd model: KOZO XJD 403) using Biovis Image Plus v4.11 by using digital microscope. Some quantity of cassava starch was taken on the glass slide and sample was put under the microscope observed under 40x. The software gives images of the particles sizes of starch. Also the software gives the particle size range (0 to 5: 5 to 10: 10 to 15 and 15 μm and above) of cassava starch on the computer display.

5. Moisture content in Cassava starch

Moisture content was determined according to Alves *et al.* (2007). 150 g of Cassava starch was dried in an oven for 3 h at 105°C. The samples were transferred to a desiccator and allowed to cool at room temperature and the difference in the weight of starch was used to calculate the moisture content.

$$\text{Moisture content (db)} = \frac{W_m}{W_d} \times 100 \qquad \dots(7)$$

Where,

W_m = weight of moisture, g

W_d = weight of bone dry material, g

6. Determination of Gelatinization Temperature

The Gelatinization temperature of cassava starch was determined as per procedure described by (Akpa *et al.* 2012). 1.5g of cassava starch sample was dissolved in a beaker with 10 ml of distilled water and mixture was stirred, a thermometer sensor (Make: m/s G H Zeal Ltd London, England) was inserted and beaker placed in a water bath. The temperature of water bath was about 75°C. The solution was stirred continuously until its colour became milky and thickened. This is the gel point and the temperature at this point was read off by using thermometer as the gelatinization temperature.

7. Determination of Water Absorption Capacity

Water absorption capacity of cassava starch was determined using the method of Sathe *et al.* (1982). 10 ml of distilled water was added to 1.0 g of cassava starch sample in a beaker, the suspension was stirred using magnetic stirrer for 3 minutes and the 100 rpm the suspension was centrifuged(Make: REmi Electrotechnik Ltd, Model: R-4C DX) at 3,500 rpm for 3 minutes and supernatant measured in 10 cm^3 graduated measuring cylinder. The density of water was assumed to 1 g/cm^3. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant, water absorbed was calculated from excess weight of the sample.

$$\text{Weight (\%)} = \frac{\text{Volume of water absorbed}}{\text{Weight of sample}} \times 100 \qquad \dots(8)$$

8. Determination of Swelling Volume

The swelling volume was determined as per procedure Hirsch and KoKini, (2002). 0.2 g of cassava starch samples were poured into test tubes containing distilled water about 5 ml. The solution was stirred, placed in a water bath heated to 95°C while shaking the sample gently to ensure that the starch granules remain in suspension until gelatinization occurs. The gelatinized samples were held at 95°C in the water bath for 1 hour. The samples were cooled to room temperature under running water and centrifuged for 30 minutes at 1000 rpm. After centrifuging, the swelling volume was obtained by reducing 5 ml (distilled water) minus the volume of swollen sediment in the tube.

9. Determination of Swelling Power

The swelling power was determined as per procedure Hirsch and KoKini, (2002). The swollen sediment obtained in section 2.3.8 was taken for this test. The starch swelling power was calculated as ratio of weight of swollen sediment to initial weight of dry starch. The starch swelling power was determined according to equations (9).

$$\text{Swelling Power} = \frac{\text{Weight of swollen sediment}}{\text{Weight of dry starch}} \qquad \dots(9)$$

10. Determination of Solubility

The solubility was determined as per procedure Hirsch and KoKini, (2002). The supernatant was separated from the sediment obtained in section 2.3.8 was taken for this test. The supernatant put in a metal dish, dried at 105°C for 1 hour, and weighed. The starch solubility was calculated as ratio of weight of dry supernatant to initial weight of dry starch. The starch solubility was determined according to equations (10).

$$\text{Solubility} = \frac{\text{Weight of dry supernatant}}{\text{Weight of starch sample}} \times 100 \qquad \dots(10)$$

RESULTS AND DISCUSSION

Physical properties of cassava root

Table 1 shows the Length, Diameters (head section, middle section and tail section), Sphericity, True density, Bulk density and Porosity of cassava root. The average value of length of cassava root was 254.58 ± 36.44 mm, the average diameters for head, middle and tail were 44.31 ± 7.11 mm, 38.58 ± 7.42 mm and 22.04 ± 2.80 mm respectively. These values are in agreement with Nwachukwu and Simonyan, (2015). They reported that Length and Diameters (head section, middle section and tail section) of cassava root are 261.37 ± 63.86 mm and 60.40 ± 9.62 mm, 50.43 ± 9.43 mm and 28.67 ± 6.58 mm respectively. The average sphericity of cassava root was 0.297 ± 0.024. True density of cassava root was found to be 1.136 ± 0.027 g/cc. Nwachukwu and Simonyan, (2015) reported that true density and bulk density of cassava root was 1.15 g/cm^3 and 0.59 g/cm^3 respectively. Bulk density of agricultural products have been reported to play significant importance in the design of silos and storage bins, maturity and quality evaluation of products which are essential to cassava and tubers marketing (Balami *et al.* 2012). It is applied also in cleaning process to determine the mode of cleaning which should be by water or pneumatic means. Bulk density of cassava root was found to be 0.498 ± 0.028 g/cc. Porosity of cassava root was found to be 56.14 ± 2.701 %.

Physicochemical properties of cassava starch

Table 2 shows the physico-chemical properties of Cassava starch i.e., ash content, pH, Bulk density, Particle size, Moisture Content, gelatinization temperature, Water absorption capacity, Swelling volume, Swelling power and Solubility.

1. Ash Content

The Ash content of cassava starch sample was in the range of 0.55 to 0.68 %. The average ash content of cassava starch was 0.61 ± 0.04 %. The similar results have been reported by Karam *et al.* (2006). The main component of ash or mineral matter in starch was phosphorus which affected pasting properties, swelling power and solubility of starch (Karim *et al.* 2007). The ash content of Cassava, Potato, Sweet Potato, Maize, wheat, Sorghum were 0.31%, 0.25%, 0.28%, 0.46%, 0.60 and 0.63 respectively (Nuwamanya *et al.* 2010).

Table 1: Results of Physical Properties of cassava root

Property	Length (mm)	D_H (mm)	D_M (mm)	D_T (mm)	Sphericity	True Density (g/cc)	Bulk Density (g/cc)	Porosity (%)
Cassava root	254.58	44.31	38.58	22.04	0.297	1.136	0.498	56.14
SD	36.44	7.11	7.42	2.80	0.024	0.027	0.028	2.701

Table 2: Results of Physicochemical Properties of Cassava starch samples

Sample	Ash (%)	pH	Bulk density (g/cc)	Particle size (µm)	Moisture (%)	Gel. Temp. (^{O}C)	WAC (g/g)	Swelling Volume (ml)	Swelling Power (g/g)	Solubility (%)
1	0.58	5.30	0.46	4.87	11.38	74	1.07	1.20	9.15	1.285
2	0.55	5.70	0.56	3.30	12.70	70	1.15	1.25	8.75	1.642
3	0.63	4.66	0.53	8.25	11.50	68	1.10	1.75	7.65	1.988
4	0.61	4.90	0.63	6.51	10.38	78	1.01	1.65	8.16	2.244
5	0.68	5.85	0.56	7.71	11.11	75	1.14	1.25	9.95	1.562
Mean	**0.61**	**5.28**	**0.54**	**6.12**	**11.41**	**73**	**1.09**	**1.42**	**8.73**	**1.744**
SD	**0.04**	**0.45**	**0.054**	**1.829**	**0.007**	**3.57**	**0.05**	**0.231**	**0.794**	**0.335**

2. pH

The pH of cassava starch was ranged between 4.66 to 5.85. The average pH of cassava starch was 5.28 ± 0.45. Oludarc and Macdonald (2010) reported that the pH value of native cassava starch was 6.00. The pH of the starches varied independently for different raw materials. These variations could be due to the influence of the composition of starch and presence of impurities (Sangeetha-Mishra, 2006). Nuwamanya *et al.* (2010) stated that the pH of Cassava, Potato, Sweet Potato, Maize, wheat, Sorghum Starches were 5.17, 8.74, 6.71, 2.35, 5.88 and 3.23 respectively.

3. Bulk density

The bulk density of cassava starch was ranged between 0.46 to 0.63 g/cc. The average bulk density of cassava starch was 0.54 ± 0.054 g/cc. higher bulk density is advantageous in tableting due to reduction in the fill volume of the die. The bulk properties describe the density, packing and flow of a powder mass. High density materials have high diluent power as they substantially reduce powder volume or bulk while improving consolidation and flow (Aulton, 2001). Abida Ali (2014) Stated that the bulk densities of Rice and Corn starches are 0.48 g/cc and 0.55 g/cc. Marcel Tunkumgnen Bayor (2013) stated that the bulk properties describe the density, packing and flow of a powder mass. The sweet potato starch powders had higher bulk density (0.58 g/cc) compared to the commercial Corn starch (0.40 g/cc).

4. Particle size

The particle size of cassava starch was observed between 3.30 to 8.25 μm. The average particle size of cassava starch was 6.12 ± 1.829 μm. Cassava starch granules are mostly round with a flat surface on one side containing a conical pit, which extends to a well-defined eccentric hilum. Under polarised light, a well-defined cross is observed. The granules exhibit wide variation in size range (5 ± 40 μm), and variation in granular size distribution among varieties and during growth period during different seasons (Rickard, 1991). R Hoover (2000) stated that size and shape of Cassava, Sweet potato and Arrowroot starch are 3-40 μm Round, 5-40 μm Round oval and 10-18 μm Round Polygonal respectively.

5. Moisture Content

The moisture content of cassava starch was in the range of 10.38 to 12.70 %. The average moisture content of cassava starch was 11.41 ± 0.007 %. The maximum allowable limit for moisture in starch is 14% (Austin, 1984). Higher values promote growth of organisms which causes odours and off-flavour. Nuwamanya *et al.* (2010) reported that the moisture content of cassava starch was ranged from 14 to 16 %, but in this study it was found that less moisture content. Moisture content may be affected by the environment and the method of storage used for starch and the moisture content of the starch was generally depended upon the duration of the drying process. Nuwamanya *et al.* (2010) stated that the moisture content (MC) varied among different botanical sources of starch with cassava displaying the highest MC (16.5%) compared with other starch among the root and tuber starches. They reported that moisture content of cassava, potato, sweet potato, maize, wheat, sorghum, and millet starch were 16.50%, 13.67%, 9.33%, 13.65%, 10.00 %, 9.20%, 9.30% respectively.

6. Gelatinization Temperature

The gelatinization temperature of cassava starch are ranged between 68 to 78 °C. The average gelatinization temperature of cassava starch was 73 ± 3.57 °C. The stronger the bond between the starches molecules, the higher the amount of heat required to break the inter-molecular bond and therefore, the higher the gelatinization temperature (Singh-Sodhi and Singh, 2005). A. Gunaratne and R. Hoover (2001) stated that gelatinization temperature of potato, true yam, taro, new cocoyam and cassava are 59.6, 75.3, 76.8, 71.5 and 63.5 °C respectively.

7. Water absorption capacity

The water absorption capacity (WAC) of cassava starch was ranged between 1.01 to 1.15 g /g respectively. The average value of WAC of cassava starch was 1.09

± 0.05 g/g. The differences in WAC of starches from different types could probably be attributed to the variation in their granule structure. The engagement of hydroxyl groups to form hydrogen and covalent bonds between starch chains lowers WAC (Hoover and Sosulski, 1986). The loose association of amylose and amylopectin molecules in the native starch granules has been observed to be responsible for high WAC (Soni *et al.* 1987). A. Surendra Babu and R. Parimalavalli (2012) reported that water absorption capacity of elephant foot yam and cush cush yam were 0.64 ± 0.16 and 1.06 ± 0.05 g/g. Abida Ali (2014) reported that water absorption capacity of jhelum rice, kosher rice, PS-43 corn and Shalimar maize were 1.07 ± 0.04, 1.15 ± 0.04 , 1.10 ± 0.02 and 1.01 ± 0.01 g/g respectively.

8. Swelling Volume

The swelling volume of cassava starch samples was ranged between 1.20 to 1.75 ml. The average swelling volume of cassava starch was 1.42 ± .231 ml respectively. When an aqueous suspension of starch is heated, as the temperature increases and exceeds gelatinization temperature, the starch granules become weakened and the intermolecular bonds of the starch molecule become distorted. This enables water molecules to become more attached to the starch molecules. The granules continue to swell as they absorb more water (Gunarantne and Corke, 2007).

9. Swelling Power

The swelling power of cassava starch samples are ranged between 7.65 to 9.95 g/g. The average swelling power of cassava starch was 8.73 ± 0.794 g/g. Abida Ali (2014) reported that swelling power of jhelum rice, kosher rice, PS-43 corn and Shalimar maize were 9.23 ± 0.15, 8.67 ± 0.25, 8.33 ± 0.21 and 8.50 ± 0.17 g/g respectively. Nuwamanya *et al.* (2010) reported that swelling power of cassava, potato, sweet potato, maize, wheat, sorghum, and millet were 8.58, 8.44, 6.88, 3.96, 6.31, 5.25 and 5.16 g/g respectively.

10. Solubility

The Solubility of cassava starch samples are ranged between 1.285 to 2.244 %. The average solubility of cassava starch was 1.744 ± 0.335 %. Abida Ali (2014) reported that Solubility of jhelum rice and kosher rice were 4.00 ± 0.00 and 2.00 ± 0.00 %. Nuwamanya *et al.* (2010) reported that solubility of cassava, potato, sweet potato, maize, wheat, sorghum, and millet were 1.230, 0.770, 0.577, 0.997, 0.247, 0.803, and 0.205 % respectively.

CONCLUSION

Results of the present study shows that cassava starch has very good characteristic as compare to other starches. The cassava root has average values of length, head diameter (D_H), middle diameter (D_M), tail diameter (D_T), sphericity, true density, bulk density and porosity were 254.58 ± 36.44 mm, 44.31 ± 7.11 mm, 38.58 ± 7.42 mm, 22.04 ± 2.80 mm, 1.136 ± 0.027 g/cc, 0.498 ± 0.028 g/cc and 56.14 ± 2.701 % respectively. The cassava starch contains average values of ash content, pH, bulk density, particle size, moisture content, gelatinization temperature, water absorption capacity, swelling volume, swelling power and solubility were 0.61 ± 0.04 %, 5.28 ± 0.45, 0.54 ± 0.054 g/cc, 6.12 ± 1.829 µm, 11.41 ± 0.007 %, 73.00 ± 3.57 °C, 1.09 ± 0.05 g/g, 1.42 ± 0.231 ml, 8.73 ± 0.794 g/g and 1.744 ± 0.335 % respectively. So it is concluded that cassava starch is useful for many food and non-food industry applications. Engineering properties of cassava root samples are important for designing peeling and starch extraction machine.

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