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Evaluation of physicochemical and flow properties of cassava flour

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Abstract
The physicochemical and flow properties of cassava flour were evaluated. The purpose of the study was to determine the moisture, ash, fat, protein, fibre, pH, amylose content and also determine the bulk density, tapped density, compression index and hausner ratio of the cassava flour. The moisture content affects the flow properties of the flour. The result revealed that the moisture content of the cassava flour ranges of 9.52 therefore the bulk and tapped density was decreased ranged from 0.421 g/cc and 0.710 g/cc respectively. The C.I and hausner ratio was high as the standard values therefore according to the result the flowability of the cassava flour was poor.

Keywords: Protein, density, tapped, moisture, flour

Introduction
Cassava (*Manihot esculenta*) also called "yucca" is a woody shrub of the *Euphorbiaceae* family that is native to South America. The edible starchy tuberous root of cassava is consumed worldwide. It is presently grown as an annual crop in subtropical and tropical regions of the world. It serves as the third most important food source in the tropics after cereal crops such as rice and maize (Bala *et al*., 2015) [7]. Tamil Nadu is the largest producer of cassava and the second most important staple food crop in sub-Saharan Africa, providing an average of 285 cal day−1 per person (FAO, 2000). Tuber crop are cultivated in India mainly in the southern, eastern and north-eastern states. Cassava is grown in India in an area of 0.23 million hectares with a total production of 6.5 million tonnes. It is cultivated in India in about thirteen states (out of 32 states and union territories) with major production in the South Indian states of Kerala (142,000ha) and Tamil Nadu (65,700 ha). (Edision, 2007) [16]. Cassava is generally considered to have a high content of dietary fibre, magnesium, sodium, riboflavin, thiamin, nicotinic acid and citrate (Bradbury and Holloway, 1988) [9]. Cassava has drought-resistant root which offers it a low-cost vegetative propagation with flexibility in harvesting time and seasons (Haggblade *et al*., 2012) [22]. It is one of the root crops with growing food and industrial applications.

Cassava flour contains carbohydrates, which are the main energy source for the body. It can replace grain-based flour or a gluten-free flour mix. It is an excellent energy source (80-90% carbohydrate) forming an important source of energy in the human diet worldwide (Laswai *et al*., 2017) [29]. Cassava flour comes in many forms, it is in calories, fat, and sugar as compared with other gluten-free flours, such as coconut or almond, cassava flour has low-fat content. Cassava flour is a valuable product obtained from cassava roots after processing, Due to its special properties such as its clear appearance, low off-flavor tendency and ideal viscosity; it is regarded as a vital ingredient in the food industry (Dixon *et al*., 2005) [15]. It is a good substitute for wheat flour in bakery and other products. Cassava flour (CF) refers to the dry, fibrous and free-flowing particulate product obtained from cassava roots (Shittu *et al*., 2016) [42]. It is a staple food for over 800 million people in the tropics. It is cultivated over a wide variety of soils (Chisenga *et al*., 2019) [13-14]. Cassava roots have high nutritional value, and they are rich in carbohydrates, which the carbohydrate yield is 40% and 20% higher than in rice and corn, respectively (Bala *et al*., 2015) [7].

The main advantage of this flour Cassava flour that it is grain-free and nut-free flour and is naturally gluten free and a great flour to use in baking and cooking therefore people who avoid gluten can use it as a replacement for wheat flour in term of taste and texture. Cassava flour is recommended in the diet of celiac patients who are strictly adhered to gluten-free food products (Briani *et al*., 2008; Niewinski 2008) [10]. Celiac disease, an autoimmune disease caused by the interaction of gluten in genetically predisposed individuals (Marsh, 1992) [32]. A strict gluten-free diet can fully restore health and improve the quality of life in patients with celiac disease and is therefore the basic line of treatment (Stern, 2008) [44]. There is a need for the development of a range of gluten-free products as the demand for these products is increasing worldwide with the increase in the number of individuals diagnosed with celiac disease (Arendt and Bello, 2008) [5]. Gluten-free products are developed by using flours that are gluten free, however, persons with celiac disease have a lower intake of fiber as compared to a control group of people on normal diet (Grehn *et al*., 2001) [20], it is imperative to keep in view the fiber content of the new gluten-free products. Cassava flour is highly recommended in the diet of celiac patients with strict adherence to gluten-free food products (Briani *et al*., 2008; Niewinski 2008) [10].

Material and Methods

The analysis was carried out in the laboratory of college of post-harvest technology and food processing, Sardar Vallabh Bhai Patel University of Agriculture and technology in Meerut. The physicochemical and flow properties of cassava flour were studied.

Collections of samples: The sample of raw cassava was procured from the local market outlet at I.N.A sabji mandi, New Delhi.

Cassava Flour: The cassava roots were processed into flour as shown in fig.1. Cassava roots were washed in potable water to remove soils and dirt from their skin and peeled it by using kitchen knife. The peeled roots were washed and cut into chips slices by using vegetable and fruit slicer (Sandeep Instrument) after that it was dipped into distilled water for a while then it was dried by using tray dryer (Biogen) for at 60°C for 6 h. After drying, the dried chips were milled into flour by powder grinder after that it was collect and sieved it for obtaining fine flour. Then the flour was packed into air tight low density polyethylene pouches of food grade, purchased from registered suppliers and stored at room temperature. All the chemicals used in this study were of analytical grade.

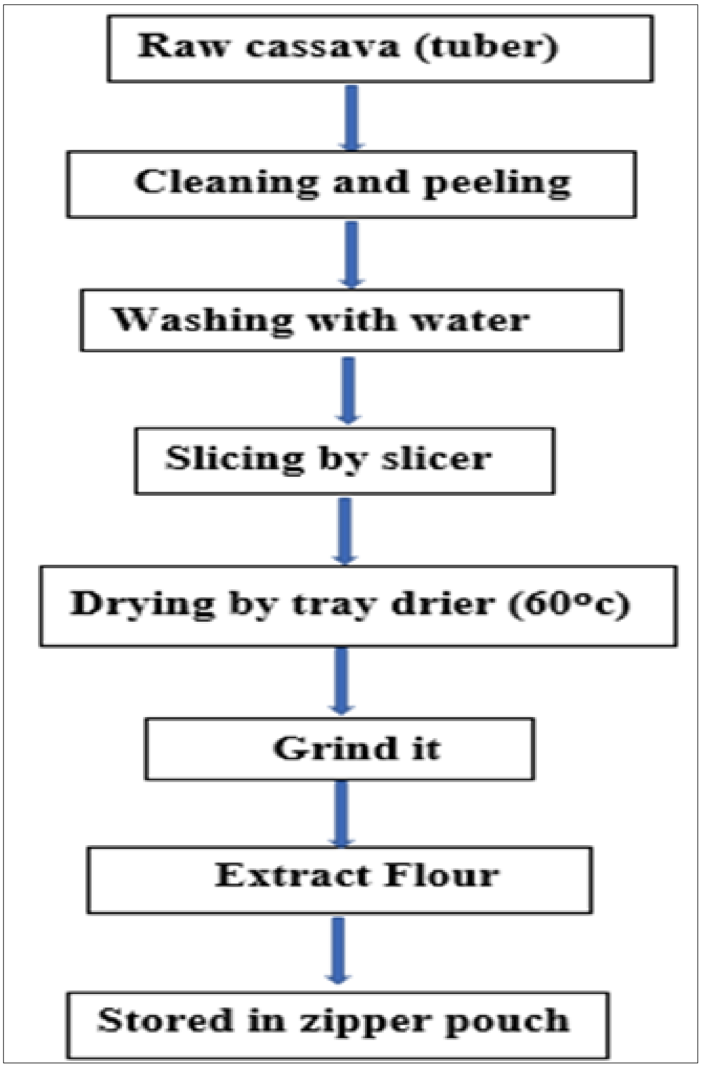

Fig 1: Process of the production of cassava flour

Physicochemical properties of cassava flour

Amylose content: Amylose content of the starch was determined according to the method described by Williams *et al*., (1970) [47]. Approximately 20 mg starch sample was taken and mixed with 10ml of 0.5N KOH. The resulting mixture was then transferred to 100 ml volumetric flask and diluted up to the mark with distilled water. An aliquot of starch solution (10 ml) was pipetted into 50 ml volumetric flask. To this, 5 mL of 0.1N HCL was added, followed by 0.5 ml of iodine reagent (dissolved 10 g KI + 1 g iodine in water and made up to 500 ml). The volume was diluted to 50 ml, allowed to stand for 5 min and absorbance was measured at 625 nm by UV Spectrophotometer (Lasany). Blank was prepared by diluting 1 mL of iodine reagent in 50mL of distilled water.

Ash content: The ash content of the flours was determined by using oven method (AOAC, 2012) [2]. Approximately 2 g of the sample was weighed, transferred in pre-weighed porcelain crucible and charred using gas flame till smoke ceases. The crucible was then transferred to muffle furnace (Sandeep Instrument) maintained at 550±5°C and incinerated till the light grey ash was obtained. The crucible was then cooled in a desiccator and weighed. The percent ash content was calculated as:

$$\text{Ash \%} = \frac{W_2 - W_1}{W} \text{X } 100$$

Where, W = Weight of the sample; W_1 = Weight of empty crucible; W_2 = Weight of crucible + ash

PH: The pH of each sample was determined using digital pH meter (Biogen). For pH measurement 1g of sample was mixed with 25 mL distilled water at 23 ± 2 °C (Wani *et al.*, 2014) [46].

Moisture: Moisture content of all the samples was determined using AOAC, (2012) [2] standard method. Accurately weighed sample (5g) was taken in previously dried and weighed petri-dish. The petri dish along with sample was placed in the oven (Omni) maintained at 105 ± 1ºC till the constant weight was obtained. The sample was analyzed in triplicates and the mean was taken. The percent moisture content was calculated as:

$$\text{Moisture content (\%)} = \frac{(W_2 - W)}{(W_1 - W)} \times 100$$

Where, W = Weight of empty petri dish; W_1 = Weight of petri dish with sample before drying; W_2 = Weight of petri dish with sample after drying to constant weight.

Fat Content: Fat content was determined by using automatic fat extraction unit (Socsplus Extraction system, Pelican Chennai). Weigh 5g of each sample; transfer the sample to the thimble. Firstly, take the initial weight of the beaker and fix the thimble to the thimble holder then place the thimble into the beaker. Take solvent approximately 75 ml of petroleum ether was poured through the sample in a Soxhlet apparatus in a beaker. Insert the beaker with solvent into the extraction system; also ensure proper sealing of beaker and the open the tap water to the water condenser. Then switch 'ON' the power then set the required boiling temperature in the PID controller. Also ensure boiling of solvent and keep the stopper in the extractor in closed position. After completion of boiling, increase the temperature to evaporate the solvent and ensure that condensation of solvent in the condensation compartment. When the level touches below the thimble, open the stopper slowly and allow the recovered solvent to flow drop by drop through the thimble. After that stop adding the solvent, once the solvent level touches the bottom of thimble then close the stopper. Then ensure that the condensation of solvent in the condensation compartment. Then recover solvent till the last drop in the beaker and takeout the beaker from the system also takes out the thimble from the beaker. Keep the beaker inside hot air oven at 100 °C for 1 h, to remove solvent vapors then take the final weight of the beaker to find out fat. Place an empty beaker into the system then the stopper and the flow the solvent to the beaker. The recovered solvent can be used for subsequent extractions. The crude fat content was calculated by using the following equation:

$$\text{(\%) Fat} = \frac{\text{W2} - \text{W1}}{\text{W}} \times 100$$

Where, W_2 = Final weight of the beaker after drying, W_1 = Initial weight of the beaker,
W = Weight of the sample

Protein Content: Protein content was determined by using automatic Kjeldhal (Kelplus nitrogen estimation system, Pelican Chennai). Approximately 2g sample was taken in a macro digestion tube. 1g mixture of K_2SO_4:$CuSO_4.5H_2O$ was added followed by 10 ml of concentrated sulphuric acid. Digestion at 405°C was carried out on the digestion block till clear blue solution was obtained and allows the water supply continuously till the end of the experiment. After cooling the tubes, the digest was made to 100 ml with water and stored in a plastic bottle till further use. Blank sample was prepared by taking only sulphuric acid and the K_2SO_4:$CuSO_4$ mixture. Distillation of the digested sample was carried out on a semi-automatic distillation unit with the help of the software which is attached to the system. Then 10 ml of the digest was transferred into a distillation tube. After adding 10 ml of 40% NaOH, distillation was carried out for 3 minutes. The distillate was collected in 10 ml of 4% boric acid solution containing mixed indictor. It was titrated against NH_2SO_4 and the volume of sulphuric acid used was recorded.
The nitrogen percent was calculated by the following formula (Pelican):

$$\text{N (\%)} = \frac{14.01 \times 0.1\text{N} \times (\text{Initial value} - \text{Blank value})}{\text{Sample weight} \times 1000} \times 100$$

Protein (%) = N × 6.25

Fibre content: Fibre content was determined by using automatic fibre extraction unit (Fibraplus estimation system, Pelican, Chennai). Crude fibre was estimated by following standard method of AOAC (2012) [2]. 5 g fat free and dried sample was transferred to a glass crucible. Insert the crucible in to the hot extraction system by lowering the handle and ensure that the proper sealing for crucible with the extraction. Then open the tap water to the condenser, keep the individual valves in close position and keep the vacuum/pressure valve in vaccum position. Pour the dilute acid from the top of the extractor up to the mark into the extractor. Ensure there is no leakage of regent then start boiling. After boiling is over, keep the individual valve in open position. Keep the control valve in vaccum position and ensure filtration of acid reagent through the crucible. If the filtration is stopped because of clogging of sample, keep the control valve in pressure position then keep the individual valves in close position. Press the air switches instantaneously then immediately brings the individual valve open position; the control valve is brought to vaccum position for filtration. Then wash the crucible with water and filter, repeat the same procedure too for alkali extraction also. After alkali digestion is completed remove the crucible from the main unit then switch on the hot air oven. Keep the crucible inside the hot air oven to remove the moisture, then take the crucible out from the hot air oven and cool for some time. Take the initial weight of the crucible and after taking out from out from the hot air oven. Keep the crucible inside the muffle furnace then set the required temperature in the muffle furnace. Then ensure the ashing of in organic matter of the extracted material and take the crucible out from the muffle furnace and cool for some time after sometime take the final weight of the crucible. Crude fibre was estimated by the following formula:

$$\% \text{ of crude fiber} = \frac{W2-W1}{\text{Weight of smple}} \times 100$$

Where, W=Weight of sample; W_1=Weight of the crucible + weight of treated sample after oven drying; W_2=Weight of the crucible + weight of ash

Total carbohydrate content: The carbohydrate content was determined by difference as described in Emmanuel *et al*., (2012) [18].
Carbohydrate content (%) = 100 − (moisture + ash + protein + lipid + fiber)

Determination of energy content: The total energy content (kcal) of the sample will be obtained by (Pearson, 1976).
Energy = 4× [Protein (%) + Carbohydrate (%) + [9 × Fat (%)]

Physical Properties of flour

Bulk Density: The bulk density was determined as described in Eleazu *et al*., (2014) [17] by adding 50 g of flour sample to a graduated cylinder, and the volume recorded.

$$\text{Loose bulk density (g/mL)} = \frac{Bulk\ mass\ of\ sample}{Bulk\ volume}$$

Tapped bulk density: The flour samples were gently filled into 10 mL graduated plastic cylinders. The bottom of the cylinder was gently tapped on a laboratory bench covered with foam several times until there was no further diminution of the sample level. The weight of the sample was calculated and the bulk density was calculated as weight of sample per unit volume of sample (Kaur *et al*., 2005).

$$\text{Tapped density (g/mL)} = \frac{Mass\ of\ tapped\ sample}{Tapped\ volume}$$

Carr's Index (CI): Flowability and Compressibility Index was determined using the following equation (Schwartz *et al*., 1975).

$$C.I = [\frac{TD-BD}{TD} \times 100]$$

Where, C.I = Compressibility Index, TD = Tapped density, BD = Bulk density

Hausner's Ratio: This was calculated from the ratio of the tapped bulk density to poured bulk density (Apeji and Musa, 2011) [4].

Powder porosity: This was derived from the values of true and bulk densities when fitted into the equation:

$$\varepsilon\ (\%) = [1 - \frac{Db}{Dt} \times 100]$$

Where, ε is the porosity, Db is the bulk density and Dt is the true density.

Result and Discussion

The Chemical Composition of the cassava flour

The result from proximate analysis composition is shown in Table 1. Moisture was found to be 9.52%. This study shows that the moisture content is low when compared to others types of flour described by (Kumar *et al*., 2021) [28]. Usually, the high-quality flour contains 9% to 12% moisture content (Hsu *et al*., 2003) [26] if moisture levels are higher than 12% so the flour is prone to microbial growth while low level are suitable for the storage and have long shelf life hence the moisture parameter play an important aspect to shows the presence or absence of water content which help shown an idea about its chemical, physical changes during storage period (Hasmadi *et al*., 2020; Passos *et al*., 2013) [36] therefore, in the present study showed low moisture content which is suited for the storage.

Table 1: Proximate composition of the cassava flour (n=3)

S. No.	Parameters	Cassava Flour
1.	Moisture (%)	9.52±0.10
2.	Ash (%)	2.81±0.00
3.	Fat (%)	0.75±0.00
4.	Protein (%)	1.64±0.01
5.	Fibre (%)	2.09±0.01
6.	Amylose (%)	17.62±0.02
7.	pH	5.83±0.04
8.	Carbohydrate (%)	83.16±0.00
9.	Energy (k/cal)	346.05±0.001

The ash content value was found to be higher ranges 2.81% as compared to result obtained in cassava flour which were grown in Tawau and semporna region (Hasmadi *et al*., 2020) in which ash content ranged 2.43% and 2.19%. Ash content shows the presence of mineral content which is used as a measurement of quality of flours in the food industry. The fat content was found to be 0.75% higher as compared to the result of cassava flour ranged 0.6% described by (Haiqin *et al*., 2019) [23]. Higher fat determines the stability of the flour if the flour had higher amount of fat will lead to rancidity and prone to oxidation and there will be the chances to the microbial growth. Therefore, in present study the fat was suited in industrial use while higher fat level was not, moisture also co-relate with the moisture content of the flour. The fibre content was found 2.09% as similar result showed in cassava flour planted in semporna ranged 2.09%. **(**Grundy *et al*., 2016) [21] has been reported that the higher level of cassava flour has tendency to lose moisture during drying due to weak water-fibre interaction. The fibre content was higher with the increase in the age of the plant while protein and lipids were decreased described by (Oluwaniyi and Oladipo,

2017) [35]. The protein was found 1.64%, the protein level was low as compared to the wheat flour ranged 11.35% and cassava flour (from 07/0593 and 01/1412) cultivar ranged 2.16% and 2.83% (Bashir *et al*., (2016); Falade *et al*., (2019) [8, 19] while some data showed lower protein values in the range 0.3-0.6% (Charles *et al*., (2004); Montagnac *et al*., (2009) [12, 31] than the present study respectively. Most important advantage the cassava flour doesn't contain gluten protein hence it can be used to developed GF foods as a material in the production of biscuit to improve the nutritional value of the products by Haiqin *et al*., 2019 [23]. The amylose content is an important aspect for food processing because it affects the gelatinization and retrogradation properties. In the present study showed lower amount of amylose ranges 17.62% almost similar value were found in cassava flour (for 01/1235 variety) described by Dixon, 2005 [15] Therefore, it is quite important that the amylose content be quantified for food processing and quality by Peroni *et al*., 2006 [37] also it is responsible for the gelling characteristics of cooked food. In present study the pH value of cassava flour was found to be 5.83 as ranging between 5.07 to 6.65 has been reported by Apea-Bah *et al*., (2011) [3]. The neutral pH was found in both cassava flour which was grown from Tawau and Semporna has been reported by Hasmadi *et al*., 2020. Higher pH value ranged 6.22 was reported by (Muzanila *et al*., 2000) [32] in cassava flour were analyzed in Tanzania**.** In present study the pH was found to be mild acidic which influence the physicochemical and functional properties and also to maximize the application of cassava flour in food industries especially in bakery products (Aryee *et al*., 2006). Carbohydrate is a chief source of energy which is required for the human consumption. The carbohydrate and energy of the cassava was found 83.16% and 346.05 k/cal. The higher carbohydrate was found in the present study as compared to the various type of flour which was described by Kumar *et al*., 2021 [28] while energy levels were higher than the present study of the cassava flour.

The Density and the Flow Properties of the cassava flour

The density and the flow properties of the cassava flour is shown in table 2. Basically, density gives an insight into the packaging character of powders. Bulk density measures the compactness of the flour without the impact of any pressure. In present study the bulk density of cassava flour was found to be 0.421 g/cc, similar result shows in cassava flour (Zambia variety) by Chisenga *et al*., 2019 [13-14] while the high bulk density of cassava flour in the range 0.59 g/cc has been described by Eleazu *et al*., (2014) [17].

Table 2: Density and flow properties of the cassava flour

S. No.	Parameters	Cassava flour
1.	Bulk density (g/cc)	0.421±0.002
2.	Tapped density (g/cc)	0.710±0.001
3.	Porosity (%)	40.62±0.30
4.	Carr index (%)	40.63±0.30
5.	Hausner ratio	1.685±0.008

Values expressed are average ± SD (standard deviation)

As per Oladunmoye *et al*., (2010); [34] Chandra *et al*., (2013); [11] Akapata and Akubor, (1999) [1] reported that the low bulk density in flour had low protein and fat content and would be used in the formulation of complementary foods while high bulk density indicates high protein and fat content and would be suitable for use in food preparation. The bulk density depends on the initial moisture content and particle size of the sample. Bulk density is an essential quality factor in food industries for making food products. Since, low bulk density flour is needed for making instant food products by Sharma *et al*., 2012. [41] The tapped density of a powder represents its random dense packing. Tapped density of cassava flour was found 0.710 g/cc higher than bulk density this is due to some factors *viz* size, solid density, geometry and surface properties of the flour material (Iwe *et al*., 2016) [27] while porosity was found 40.64 percent. The low tapped density indicates the non-cohesive properties of the material. Higher tapped density is suitable to the packaging and the greater amount of material is packed with in a constant unit volume (Toan, 2018) [45]. Similar type of studies on yellow flesh cassava flour **(**01/1368 cultivar) has been reported by (Falade *et al*., 2019) [19]. Porosity is a measure of void space present in a material. Porosity is one of the main indicators that determines the quality of bakery products and characterizes their structure, volume and level of digestibility. The porous structure is most characteristic of bakery products and determines their quality (Petrusha *et al*., 2018) [38].

Carr index in fresh casava flour was found 40.63 percent while Hausner ratio was 1.685. As per Staniforth (1996) [43], Carr's index and Hausner's ratio are a measure of the flowability and compressibility of a powder respectively. The Carr's percentage indicates the aptitude of a material to diminish in volume while Hausner's index shows the antiparticle friction. The values of Carr index in cassava flour were found 40.63 percent which was higher than the 15% for good flowability. It means cassava flour indicate that poor flowability. Hausner ratio was also found 1.685 which was higher than 1.25 for good flow. It seems that the Huasner ratio indicates that poor flow property of fresh cassava flour. The same results showed by (Raigar and Mishra, 2017) [39] in Potato flour. The score of Carr index (%) of 5–10, 12–16, 18–21 and 23-28 represent excellent, good, fair and poor flowability **(**Falade, 2019) [19] respectively. Hausner value less than 1.25 indicates good flow and greater than 1.25 indicates poor flow (Staniforth (1996) [43].

Conclusion

From the research of the study the cassava flour had low moisture, fat was present so it can be used in food industry mainly for bakery and also influence the storage stability of the flour which affects their shelf life. It is gluten free, due its unique characteristics can be used as a replacement for wheat flour. It is also recommended especially for celiac suffering patient to consume gluten-free products.

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