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Studies on functional properties of cassava var. Yethapur Tapioca-2 for its suitability as an ideal industrial substitute for the grain starches

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Abstract
Cassava (*Manihot esculenta* Crantz.) tubers an important staple food of millions of people across the globe is also used for making number of products in food industries and owing to rich contents of vitamins and minerals cassava by-products are used in pharmaceutical industry too. The present study was aimed at to examine the functional properties of flour, starch, pomace and peel of organically grown commercial variety of Yethapur Tapioca - 2. The experiment was laid out in CRD with five replications and the functional properties of cassava samples viz., flour, starch, pomace and peel were studied. Studies revealed that cassava starch recorded the highest water absorption capacity (3.18%), solubility index (37.2%) foaming stability (95.32%) and color value (95.06) followed by cassava flour. The highest water binding capacity of 279.5% was found in cassava pomace whereas, the cassava flour contained the highest foaming capacity (7.54%) and bulk density (0.781g/ml) which also recorded high swelling capacity (40%) at 90 °C followed by starch, peel and pomace. Similarly, other functional properties such as light transmittance, gelatinization etc., were also studied and the scope of using cassava starch as thickening agent in food industries as an alternative source for cereals and legume starch is discussed.

Keywords: Cassava var. YTP-2, flour, starch, pomace, peel, functional properties, industrial use

Introduction
Tapioca alias cassava, scientifically known as *Manihot esculenta* Crantz., is an important staple food crop of over 800 million of inhabitants in South America and parts of Africa and Asia. Cassava produces a starchy tuberous root which is good source of carbohydrates and important vitamins and minerals such as vitamin C, riboflavin, thiamine, potassium manganese and has a good amount of dietary fibre which helps in reducing the body weight. Each 100 grams of cassava tuber has got double the calorific value and carbohydrates as that of sweet potato, another popular tuber vegetable and hence, cassava could be considered not only as an ideal crop for food security but also for nutritional security. Cassava tuber contains flour, starch, pomace and peel which is used to making of various good quality bakery products. Increasing urbanization, population and evolution in food habits in recent years has leads to creating a demand for wheat and wheat based food stuffs such as maida etc., which proved to have its deleterious effect that leads to causing indigestion, obesity, diabetes, hypertension etc., to the consumers. In order to overcome these health problems across ages, there is a necessity to find a suitable alternatives and cassava based food products are one among such safe, nutritious food materials that are equally cheaper too.
Nowadays, tapioca flour is gaining momentum as a go to grain free and gluten free flour. In recent years people are looking at health conscious like weight loss, diabetic issues etc., and hence those people who avoid gluten rich products can use cassava flour as a replacement for wheat flour in baking industry. Cassava flour is extracted by simply peeling of whole root, dried and ground in to powder which contain higher amount of fibre content. Due to this property it can be used as a thickening agent in effectively while preparing of bakery products. Cassava flour contains about 0.56 -1.1% resistant starch which helps to reduce many health issues. Resistant starch gets fermented inside the colon which ultimately feeds the healthy gut bacteria for their growth and development in colon cells.

During this process the resistant starch gets converted into short chain fatty acids and butyrate is one such short chain fatty acids which is important component in colon cells. Butyrate can help to protect people against digestive issues like inflammatory colorectal cancer and also resistant starch aids to improve the insulin level and colon health and reduce the obesity problems and digestive issues.

Cassava starch which contains high amount of amylose and amylopectin can be used as thickening agent for making of sauce, soup and gravies. During starch extraction process the remaining waste is dried and made into powder form called as 'pomace', which is a good source of energy. Cassava peel, a rich source of protein is largely used as a natural coagulant for waste water treatment in the developing countries thereby reducing the usage of chemical coagulant (Banerjee *et al*., 2012) [8]. Cassava peel is a basic raw material for making edible coating and good substrate for mushroom cultivation. Functional properties play an important role in making of quality parameters viz., storage, structure, texture, stability, packaging, flavor of food products (Nawaz *et al*., 2015) [30]. Hence, an attempt has been made to study and characterize the functional properties of different segments of tubers of cassava var. Yethapur Tapioca – 2 which is largely cultivated as a commercial variety in the states of Tamil Nadu and Kerala.

Materials and Methods

Methodology: The study was carried out in Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The following functional properties were studied in the samples of cassava flour, starch, pomace and peel of cassava variety of Yethapur Tapioca -2.

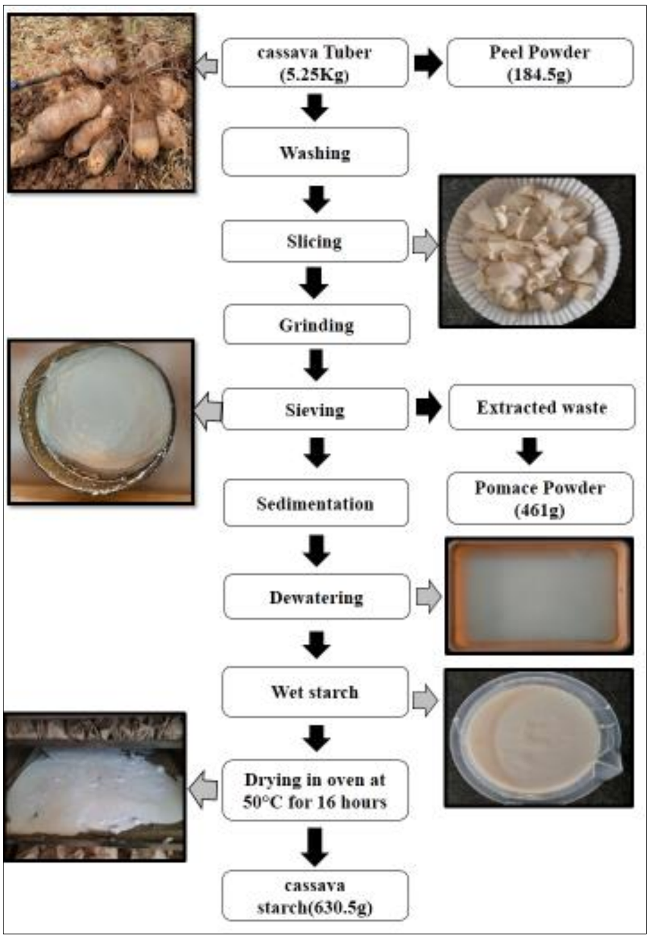

Fig 1: Flowchart for Extraction of Starch

Fig 2: Different Segments of Cassava Powder

2.1 Estimation of Water absorption capacity (WAC):

The water absorption capacity of the cassava samples was estimated by weighing 1.0 g of the cassava sample and suspended with 10 mL of distilled water. It was kept in a water bath at 30 °C with continuous shaking for 30 minutes and centrifuged at 5000 rpm for 10 min. The supernatant was dried in hot air oven (105 °C) for drying. The wet sediment and the dried supernatant were weighed and the results are expressed in per cent (Onwuka, 2005) [31].

$$Water\ Absorption\ Index\ (\%) = \frac{Weight\ of\ wet\ sediment(g)}{Weight\ of\ dry\ sample(g) - Weight\ of\ dry\ supernatant(g)}$$

2.2 Analysis of Water Solubility Index

Water solubility index was analyzed on cassava flour, starch, pomace and peel samples. 0.5 g of cassava samples was taken into 10 ml centrifuge tube and added with 6 ml of distilled water and centrifuged at 5000 rpm for 15 min. The supernatant and pellet was dried in hot air oven and weighed.

$$Water\ Solubility\ Index\ (\%) = \frac{Weight\ of\ dry\ supernatant(g)}{Weight\ of\ dry\ sample\ (g)} * 100$$

2.3 Estimation of Water Binding Capacity

Two grams of cassava samples was taken into a 50 ml centrifuge tube and added with 40 ml of distilled water. The mixture was allowed to agitation for 1 hour at room temperature and the suspension was centrifuged at 2200 rpm for 10 min and weighed and the water binding capacity (WBC) was determined by the method given by Yamazaki (1953) [36] and expressed in percentage.

$$Water\ Binding\ Capacity = \frac{Weight\ of\ wet\ starch\ (g)}{Weight\ of\ starch\ taken\ (g)}$$

Estimation of foaming capacity

The foaming capacity was estimated according to the modified the method of determination as suggested by Mustapha *et al.* (2015) [28] and the homogenization process was done at a blender speed of 160 rpm for 10 minutes. In this method, 2g of cassava sample was dispersed in 100 ml of distilled water. The suspension was homogenized by kitchen blender for 2 minutes and the following formula was used to find the foaming capacity and expressed in percentage.

$$Foaming\ Capacity\ (\%) = \frac{V2 - V1}{V1} * 100$$

Where V1 = volume before homogenization (mL), V2 = volume after homogenization (mL)

Estimation of Foaming Stability

After determination of foaming capacity, the foaming stability was estimated according to Coffman and Garcia (1977) [13] and the foam samples were allowed to stand at room temperature for 8 hours and measurements of initial foam value and final foam value after 8 hours were recorded and foaming stability was calculated by using the following formula and expressed in percentage (%).

$$Foaming\ stability(\%) = \frac{Vr}{Vi} * 100$$

Where Vi = Initial foam value, Vr = foam value of after 8 hours.

Estimation of Bulk density

Bulk density of the cassava sample was determined by the method of Danbaba *et al.*, (2014) [15]. 100 g of flour was weighed and slowly filled in 100 mL measuring cylinder. The bottom of the cylinder was smoothly tapped 10-15 times until there was no further diminution of the sample level. Bulk density estimated and expressed in g/ml.

$$Bulk\ Density = \frac{Weight\ of\ sample\ (g)}{Volume\ of\ sample\ (ml)}$$

Determination of gelatinization temperature (GT)

About 10 gram of the cassava sample was suspended in a 250 ml beaker containing 100 ml of distilled water and the suspension was heated on a hot plate. The gelatinization temperature was recorded by using of thermometer and that bulb was immersed in the slurry and to form a gel.

Determination of swelling power (SP)

The Swelling Power (SP) of cassava was determined by the method of Nattapulwat *et al.*, (2009) [29]. Sample weight of 0.2 gram was suspended in 20 ml of distilled water and the suspension was heated to different temperatures including 50, 60, 70, 80 and 90°C in a water bath for 30 minutes with vigorous shaking for every 5 minutes, respectively. The sample was centrifuged at 3000 rpm for 15 minutes and calculated the weight of the sediment and the results are expressed in%.

$$Swelling\ Power\ (\%) = \frac{Weight\ of\ wet\ sediment}{Weight\ of\ dry\ sample}$$

Measurement of light transmittance (LT)

Light transmittance of cassava was performed by using the method of Wani *et al.*, (2010) [35]. The cassava sample suspension (1% w⁄w dry weight basis) was prepared and heated at 90°C in a shaking water bath for 30 minutes and then it was kept to room temperature condition. The samples were stored in a refrigerator at 4°C for 120 hours and the transmittance was observed at every 24 hours by measuring absorbance value at 640 nm in UV-Visible Spectrophotometer.

Estimation of Syneresis

Syneresis of cassava samples were determined by the method of Morante *et al.*, 2016. Weighed 2 g of cassava sample was heated at 90 °C for 30 min in water bath with continuous stirring. The samples were stored at 120 hours at 4°C in separate tubes. The sample was centrifuged at 3000rpm for 15min and measurements were taken in every 24 hours.

$$Syneresis\ (\%) = \frac{Weight\ of\ water\ released}{Weight\ of\ gel} * 100$$

Determination of Color Index (CI)

The color value of cassava flour, starch, pomace and peel was determined using 3nh bench top spectrophotometer L* value denotes lightness to darkness and a* value represents + value indicates redness followed by – value indicates greenness. In b* value + represents yellowness and – indicates blueness. Black and white calibrations were carried out before taken measurements of sample. Chroma (C) and Hue (h^o) angle were calculated by below formula.

$$Chroma = (a2 + b2)1/2$$
$$Hue = tan - 1(b*/a*)$$

Statistical Analysis

The lab experiment was conducted in duplicates and data were analyzed using SPSS 21.0. Difference between the cassava samples were evaluated by using of ANOVA and Duncan test with 95% level of significance was performed.

Results and Discussion

Effect on water absorption capacity (WAC)

The water absorption capacity is one of the important properties which determine the amount of water held by the sample due to the hydrophilic sites in molecular chains and interaction of water through hydrogen bonding and the results pertaining to water absorption capacity of different segments of cassava in the present study is presented in Table 1.

Table 1: Effect on functional properties of cassava var. Yethapur Tapioca -2

Samples	Water Absorption Capacity (%)	Water Solubility Index (%)	Water Binding Capacity (%)	Foaming capacity (%)	Foaming stability (%)	Bulk density (g/ml)	Gelatinization Temperature (°C)
Flour	2.04±0.08[b]	10.6±0.44[b]	210.5±8.8[b]	7.54±0.31[a]	87.71±3.66[b]	0.781±0.03[a]	69°C±2.88[b]
Starch	3.18±0.13[a]	37.2±1.55[a]	103.5±4.32[d]	0.94±0.03[d]	95.32±3.98[a]	0.704±0.02[b]	67°C±2.8[b]
Pomace	1.46±0.06[d]	6.55±0.27[b]	279.5±11.6[a]	3.84±0.16[b]	92.59±3.91[ab]	0.53±0.02[c]	70°C±2.92[b]
Peel	1.75±0.07[c]	9.27±0.38[b]	176±7.36[c]	1.88±0.07[c]	93.51±3.87[a]	0.68±0.02[b]	76°C±3.17[a]
Mean	2.1075	15.4050	192.37	3.5515	92.2825	0.6737	70.5
SE_D	0.0584	1.4759	5.3592	0.1154	2.4427	0.0180	1.8674
C.D. @ 5%	0.1237**	3.1289**	11.3611**	0.2446**	5.1784*	0.0381**	3.9587**

Mean value ± standard deviation of five replicates. Mean ± standard deviation with the different superscripts is significance at 5% confidence level. * $P < 0.05$, ** $P < 0.01$ and NS – Non Significant

The water absorption capacity of cassava samples varied significantly and the highest WAC was recorded in cassava starch (3.18%) followed by flour, peel while the lowest WAC of 1.46% was found in pomace. The water absorption capacity of cassava samples. It helps to determining the capacity of sample to observe the water and increase the swelling of granules size to maintain the uniformity of structure of food. It is one of the advantageous factors in food industry to improve the yield and uniformity of food products and used as a thickening agent in making of liquid foods. The starch sample had high water absorption capacity which might have been due to high polar amino acid residue of protein possess greater affinity of water molecule (Yusuf *et al*., 2008) [37] and WAC could be influenced by increasing the solubility of flour reducing the amylose content and loss of molecular structure (Hashimoto *et al*., 2003) [19]. Temperature plays a major impact upon the water absorptions of samples (Garg *et al., 2011*) [18] and if the temperature is raised the molecules get enough heat energy that weakens the hydrogen bond between intermolecular and also increases the affinity towards water which implies the granules get integrating with water. In normal room temperature conditions the interaction of water with amylose and amylopectin chains are weak. However in the present study, the water absorption capacity of all samples was found high at room temperature which depicts a good tendency of cassava sample to bind with water. Similar properties were reported in black gram starch by Deshpande *et al*., 1982.

Effect on water solubility index (WSI)

Water solubility is an important property which is closely related to ratio of amorphous and crystalline components of granules (Wani *et al.,* 2016) [34]**.** The water solubility index of cassava samples ranged from 6.55 to 37.2 per cent and the highest WSI (37.2 per cent) was recorded in cassava starch followed by flour while pomace powder recorded the lowest index of 6.55 per cent (Table 1). The difference in WSI leads to difference in degradation of starch and comparatively higher solubility index recorded in cassava starch and flour samples may be attributed to high amount of amylose content in these samples which is easily leached out during the swelling process and the finding is supported by Apea-bah *et al*., (2011) [7] who stated that cassava starch with high solubility index is suitable for making of less cohesive dough in baking.

Effect on water binding capacity (WBC)

The water binding capacity of food stuffs is an important quality parameter as the same determines the product texture and palatability (Tran *et al*., 2001) [33]. In the present study, the binding capacity of samples ranged from 103.5 to 279.5 per cent and the results are presented in Table 1. Among the four samples tried, cassava pomace had a significantly higher water binding capacity (279.5%) than others while the cassava starch recorded the lowest capacity of 103.5% which may be attributed to variation in amylopectin contents, hydrophobic sites of molecules and association of intermolecular interactions of starch polymers (Rincon *et al.*, 1999) [32]. Samples having low water binding capacity may not hold water efficiently while samples with high water binding capacity makes food products brittle and dry during storage (Boye *et al.,* 2010) [9].

Effect on Foaming Capacity (FC)

Foaming properties are important indicator for making of good quality food products such as bread, cake, crackers and ice creams etc. to maintain their structure, texture, consistency and improve the appearance of product in storage conditions. In the current study, significant difference was observed among samples and the highest foaming capacity of 7.54 per cent was recorded in cassava flour followed by pomace, peel and starch (Table 1), The foaming capacity varies based on the surface tension of water and air interface (Akubor, 2007) [4]. Fennama (1996) [17] reported that the protein created interfacial area of foam which is formation of many gas bubbles confined in a solid or liquid**.** Kaushal *et al.*, (2012) [26] revealed that samples with high protein content will increase the foaming capacity and vice versa. The sample having protein content forms a continuous cohesive film between airwave and formed foam (Chandra and Shamser, 2013) [10, 11]. Hasmadi *et al.,* 2020 [20] reported similar finding in cassava var. Tawau and Semporna.

Effect on Foaming Stability (FS)

Foaming stability determines the attractive and repulsion forces between the protein and polypeptide molecules. In the present study, the foaming stability of cassava samples ranged from 87.71 to 95.32 per cent and the results are presented in Table 1. Among the samples, the highest foaming stability of 95.32 per cent was recorded in cassava starch and the foaming stability of cassava starch, pomace and peel were on par. Alleoni (2006) [5] reported that the protein have non polar residues which is increases the stability of the film and vice versa. Samples with high foaming stability forms thin film with less flexible and large air bubbles and these air bubbles easily collapse with each other reducing the foaming stability (Jitngarmkusol *et al.,* 2008) [25].

Effect on Bulk Density: Bulk density measures the compactness or heaviness of flour sample which is helps to determine the porosity of a product and also influencing the design and type of packaging material in food processing industry and plays a major role in pharmaceuticals industry as a drug binder and disintegrant (Chandra *et al.,* 2015) [12]. In the present study, the highest bulk density of 0.781g/ml was recorded in cassava flour sample which was followed by starch (0.704g/ml) that was on par with peel powder while the least BD of 0.53g/ml was observed in cassava pomace (Table 1). Bulk density is an important quality factor in making of food products and reducing the thickness of paste. The results of bulk density represents it depends upon initial moisture content and particle size of the samples (Chandra *et al*., 2013) [10, 11]. The increasing bulk density of flour is more suitable for packaging and transportation. Samples with lower bulk density will be useful for making of formulation of complementary foods (Akpata and Akubor, 1999) [3].

Effect on Gelatinization Temperature (GT)

The process of gelatinization of starch occurs by removal of excess water at particular temperature which it is called point of gelatinization. In this process, the granules absorb water, hydration followed by radial swelling of the starch granules. The results pertaining to the gelatinization temperature of different samples are presented in Table 1. In the current study the point of gelatinization ranged from 67 °C to 76 °C and gelatinization of starch was happened at the lowest temperature of 67°C while the gelatinization temperature of flour, pomace and peel were on par with each other. The study revealed that cassava starch with the highest amylose and amylopectin contents than other samples reached the gelatinization stage at comparatively low temperature.

Effect on swelling power (SP)

In the present study the swelling capacity of the samples was studied on the temperature range of 50°C to 90°C and the results are showed in Figure 1. The swelling power of all the samples gradually increased with the increasing temperature and the highest swelling power of different samples cassava variety Yethapur Tapioca -2 in ranges of 14.4 to 40.0 per cent was recorded at 90 °C. Cassava flour recorded highest swelling capacity (40.0%) followed by starch at 90°C which might be due to negatively charged phosphate monoesters. The granules can absorb up to 30 per cent of excess water at room temperature conditions without swelling (Kerr, 1950) [27] and during heating process, the granules absorb as much of water as possible and expand its structure. When the temperature goes very high the polysaccharides dissolved into the solution and granules were leached out (Hermansson, *et al.,* 1996) [21]. This study revealed that the sample containing waxy starch have higher swelling capacity. The lowest swelling capacity in the cassava pomace might be due low temperature of slurry. Adebowale *et al*. (2006) [2] stated that the starch granules have strongly bonded micellar structure and exhibits high resistance to swelling which leads to lower solubility index. Hoover *et al*., 2010 explained granules swelling and amylose leaching does not occur at a temperature of < 60 °C. Generally, increasing temperature increases the swelling power of granules as was reported in potato starch by Anggraini (2009) [6].

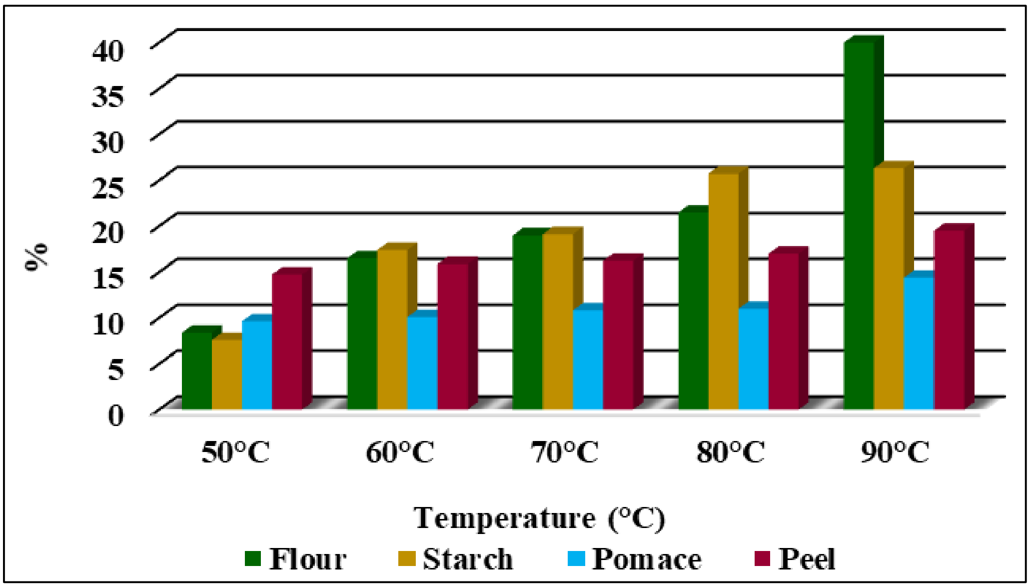

Fig 3: Swelling power of cassava tuber YTP-2

Effect on Light Transmittance (%)

In the current light transmittance of the cassava samples was measured by the absorbance of gel under different intervals of storage period and the results are showed in Figure 3. Results revealed that the light transmittance gel ranged from 3.59 to 0.55 per cent under 4°C after 120 hours which it developed the turbidity. In cassava flour gel was decreased from 21.63 to 0.55 per cent at fixed intervals followed by cassava starch gel. Cassava pomace recorded transmittance from 20 to 1.36 per cent while in peel it ranged from 17.78 to 3.59 per cent. Fig 4 shows that light transmittance of the gel was decreased from 24 hours to 120 hours at 4°C refrigerated condition. This property gives an idea about retrogradation tendency of gels in different storage period which affects the transparency. Due to interactions of amylose – amylopectin increases the storage period which ultimately reduces the transmittance as reported by Hussain *et al*. (2014) [23]. Further, Craig *et al*. (1989) [14] reported light transmittance of corn, wheat, cassava and potato starch gel containing 2.9, 3.9, 6.2 and 9.6 per cent respectively. Due to high refraction light by swelling of granule leads to low light transmittance. On the very first day of storage, 21.63 per cent loss of water was observed in cassava flour and on fourth day of storage (96 hours), the loss of water got stabilized in the samples of cassava starch and pomace with 1.13 and 2.46 per cent respectively at 4°C and variations in light transmittance may be due to effect of amylose reordering or phosphate monoesters as reported by Jane *et al*. (1996) [24]. Further, the results revealed that cassava starch and pomace are not suitable for making chilled foods.

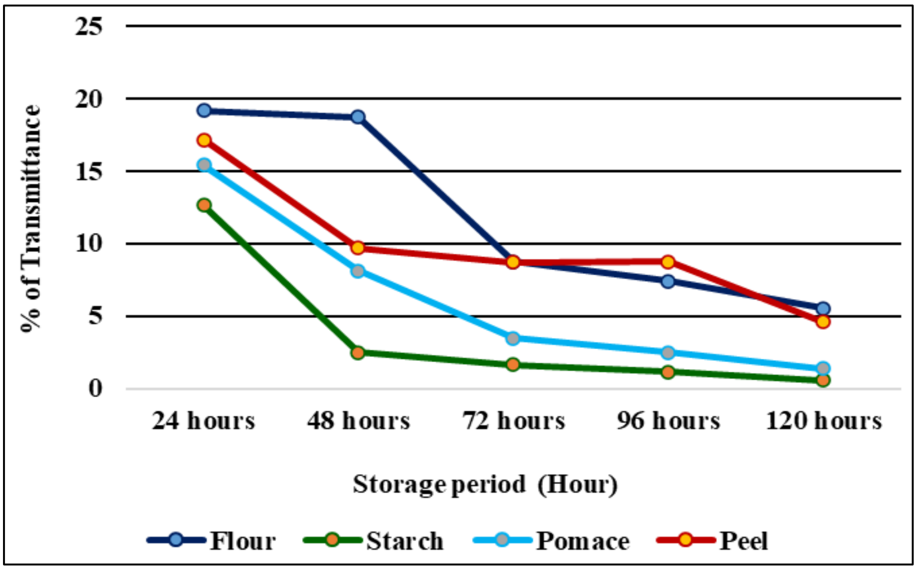

Fig 4: Light Transmittance of cassava tuber YTP-2

Effect on Syneresis

The syneresis of cassava flour in the range of 56.06 to 58.91 per cent showed in Figure 5. The lowest syneresis per cent was recorded in pomace of 20.9 to 25.22% under five different storage conditions. The syneresis per cent was gradually increased in cassava starch which might be presence of amylose content. Due to amylose reordering in flour the syneresis per cent was gradually increased up to 96 hours whereas in 5^{th} day it was declined from 60.25 to 58.91 per cent. From that, cassava flour was not suitable for making of chilled food products.

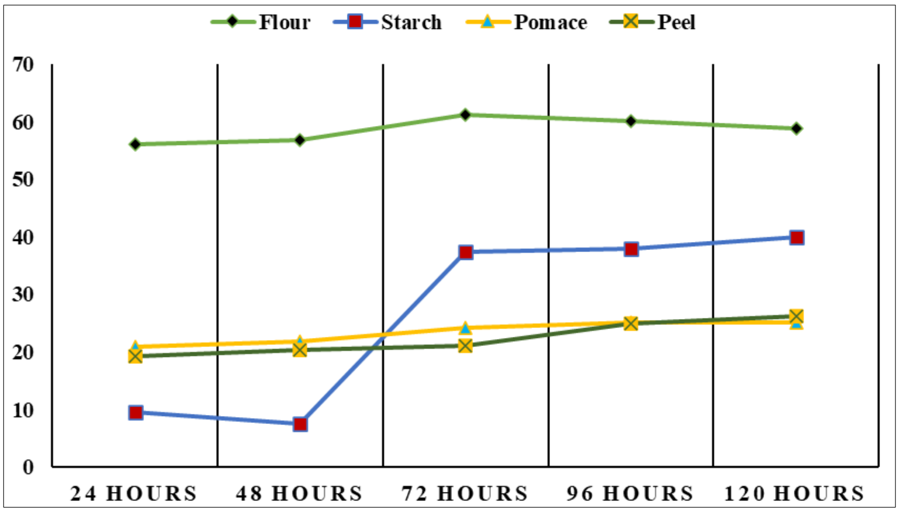

Fig 5: Syneresis of cassava tuber YTP-2

Effect on Color Index

Color is an important quality indicator for making of food products which is influence the appearance and consumer preference. Starch from YTP-2 was slightly whiter (95.06) than flour (93.95) and may be due to oven drying temperature. a* value was higher in cassava pomace (1.34) which is indicated redness and results were presented in Table 2. Cassava starch and flour showed negative value of a* which represents greenness of flour. In b* value was positive in all the samples it indicated yellowness present which is might be due to presence of carotene content which is suitable for making colored products. The highest chroma value was recorded in the sample of peel followed by flour, starch and pomace.

Table 2: Effect on Color Index

Samples	'L' value	'a' value	'b' value	Chroma	Hue
Flour	93.95±3.93	-0.51±0.02	8.14±0.34	8.15±0.34	86.49±3.61
Starch	95.06±3.97	-0.77±0.03	7.61±0.31	7.65±0.36	95.81±4.54
Pomace	85.43±3.57	1.34±0.05	2.69±0.12	3.00±0.24	63.51±5.13
Peel	75.10±3.14	0.57±0.02	11.22±0.90	11.23±0.70	92.91±5.83
Mean	87.38	0.15	7.41	7.50	84.68
SE_D	2.32	0.02	0.32	0.28	3.07
CD @ 5%	4.92**	0.04**	0.68**	0.60**	6.50**

Mean value ± standard deviation of five replicates. Significance @ 5% level

Conclusion

In an attempt to find a suitable healthy alternative for the unhealthy grain starch, the present was aimed at studying and characterizing the functional properties of flour, starch, pomace and peel obtained from tubers of organically grown cassava var. Yethapur Tapioca-2. The functional properties are important indicators in food industries for making of quality food which includes like crystallinity, particle size, swelling capacity, amylose –amylopectin interactions, thickener, structure and texture of food. These properties have specific eminent source. Based on the properties, cassava starch have a higher water absorption capacity, solubility index, binding capacity and foaming stability which is responsible for an important ingredients in food production and reduces the cereal and legume starches which are exploited as staple food in most of the countries. Cassava flour also has better performance in all the properties which can be used in food and non-food industries. The future line of present study may be focused to develop biodegradable films as a better alternative for the synthetic films that may be highly useful in reducing the environmental pollution.

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