# PHYSICO-CHEMICAL PROPERTIES OF STARCH FROM SELECTED TEN SPECIES OF *CURCUMA* L. (ZINGIBERACEAE) SEEKING ATTENTION

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***Abstract***
*Genus Curcuma L. of the family Zingiberaceae are good sources of edible starch and is being exploited by tribals or natives. The edible and non-edible applications of starch mainly depends on their physico-chemical properties. Crude starch powder was isolated from the rhizomes of ten selected Curcuma species from south India viz. C. aeruginosa, C. amada, C.aromatica, C. aurantiaca, C. caesia, C. haritha, C. longa, C. montana, C. zanthorrhiza, C. zedoaria, and also Maranta arundinacea, and examined their major physico-chemical properties. Among the isolated crude starch powders from rhizomes, starch was the major constituent ranging from 76.67-82.18%. The amylose and amylopectin content showed minor differences among the candidate species but, C. haritha, showed highest amylose content (36.55%) and the lowest was in C. zanthorrhiza (21.25%). C. zanthorrhiza and C. montana, showed highest and lowest amylopectin content (58.75% and 29.14%) respectively. All the candidate species have comparatively good swelling power (23.76-36.14ml/g), solubility (17.76-23.14%), in-vitro enzyme digestibility (18.01-23.05%) and final viscosity (1023cP- 7041cP). Starch from C. haritha and C. montana with low digestibility coupled with low solubility indicates its quality to act as resistant starch and could be a future food for diabetic patients. The final viscosity of most of the candidate Curcuma species except C. longa are much greater than the popular starch source such as cassava and maize which indicates its potential as source for industrial starch.*

**Keywords:** Digestibility, Solubility, Starch, Swelling power, Viscosity.

Received: 19.03.2020 Reviewed: 14.05.2020 Accepted: 29.05.2020

## 1. INTRODUCTION

The genus *Curcuma* L. (Zingiberaceae) had wide spread distribution in South and South East Asia with about 104 species (Mabberly, 2017). The highest diversity is in India (45 species), with the main center of distribution is in south India. *Curcuma* species are known for its medicinal significance against ailments but, this minor tuber crop have not received much attention as source for starch. In India, for a century, *Maranta arundinacea* (‘arrowroot’/ ‘kua’), native to North America, was considerably popularized for their starch and edible tubers. To the contrary, since long back, as mentioned in Ancient Ayurvedic texts as well as in the 18$^{th}$ century treaty *Hortus Malabaricus* ‘kua’ was used popularly as a source of edible starch. Leong-Skornickova *et al.*, (2008) recognized the ‘kua’ mentioned in *Hortus Malabaricus* was *C. zedoaria*, indicating that, till the advent of *Maranta*, different native *Curcuma* species have been used as ‘kua’. Very few species of *Curcuma* are still exploited by tribals or natives in different parts of the country for their starch (Nedunchezhiyan *et al.*, 2005). The present study focused on analysis of the physico-chemical properties of starch from under-exploited *Curcuma* species from southern India and its comparison with *M. arundinacea*, the popular starch yielding tuber crop.
Starch is the major carbohydrate of plants, it is stored in fruits, roots/tubers and seeds/grains (Madineni *et al.*, 2010). Depending on its physico-chemical properties, starch was extensively used in various food and non-food applications. Though the starch is mainly used as food, it can be easily converted chemically and biologically in to diverse products.

Industrial demand for starch as an ingredient of various processed foods and non-food applications is depends up on its physical and chemical properties (Whitaker and Tannenbaun, 1997). It perform various functions in food industry such as stabilizer and bulkening agent (Zeeman *et al.*, 2010). Since starch is easily digestible and fine textured, its physico-chemical properties and interaction with other constituents are intent to the food industry.

## 2. MATERIALS AND METHODS

### 2.1. Isolation of crude starch powder:

Fresh mature rhizomes of ten *Curcuma* species were obtained from the Medicinal Garden of Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram. *Curcuma* species selected for starch isolation were *C. aeruginosa* Roxb., *C. amada* Roxb., *C.aromatica* Salisb., *C. aurantiaca* Zijp, *C. caesia Roxb., C. haritha* Mangaly & M. Sabu, *C. longa* L., *C. montana* Roxb.*, C. zanthorrhiza* Roxb *and C. zedoaria* (Christm.) Roscoe. For comparison *Maranta arundinacea* L., was also subjected to the study. Crude starch powder was isolated from the rhizomes through traditional method with slight modification to the procedure by Kokate (1994). Harvested rhizomes were cleaned, chopped in to fine pieces, followed by grinding with water to get smooth paste. The paste was mixed well in water, and filtered through fine cotton cloth. The residue on cloth was washed several times and the residual water allowed to settle for 7-8hours was decanted. The sedimented starch paste was well dried in sunlight for 3-4 hours and stored in air tight containers for further analysis.

### 2.2. Physico-chemical characterization:

The isolated crude starch powder was estimated for their starch (Padmaja *et al.,* 2005), amylose content was determined and the amylopectin content was calculated (Williams *et al*., 1970) using the following equation,

$$\text{Amylopectin} = 100\text{-Amylose } (\%)$$

Physico-chemical properties of the crude starch powder such as swelling power and solubility (Padmaja *et al.,* 2005), *in-vitro* enzyme digestibility (Singh *et al.,* 1982) and Pasting properties (Padmaja *et al.,* 2005) such as peak viscosity, break down, set back, final viscosity and pasting temperature were determined using a Rapid Visco Analyser (RVA-4, New port Scientific, Warriewood, Australia) controlled by thermocline for Windows software with standard procedures.

## 3. RESULTS AND DISCUSSION

The isolated crude starch powder from *C. aurantiaca*, *C. caesia*, *C. haritha* and *C. montana* tubers observed as pure white as *Maranta arundinacea*, while that from *C. aeruginosa*, *C. amada*, *C. aromatica* and *C. zedoaria* were off-white, whereas the powder from *C. longa* and *C. zanthorrhiza* were yellowish due to the presence of yellow pigment curcumin (Fig.1).

### 3.1. Starch: Amylose and Amylopectin composition

The edible and non-edible applications of the crude starch powder were mainly determined by its various physico-chemical properties. Starch molecule is composed of an amorphous region, amylose and crystalline region, amylopectin. The amylose content of the starch is important because amylose largely determines the gelling ability of the starch. In the isolated crude powder of all the selected species, starch was the major constituent ranging from 76.67 to 82.18%. *C. haritha* showed highest starch component in its crude powder (82.18%), which is higher than *Maranta* (81.21%) followed by *C. montana* (81.06%) and *C. zanthorrhiza* (80.00%) (Fig 2). All the candidate species were, with considerably good amylose content, among them, *C. haritha* showed the maximum as 36.55% and *C. zanthorrhiza* showed the minimum as 21.25%. High amylose content is the criterion for good edible starch and also beneficial for the manufacture of extruded and fried snacks with desirable features, particularly low expansion, high crispiness and reduced fat uptake. Amylopectin content showed highest in *C. zanthorrhiza* and lowest in *C. montana* as 58.75% and 29.14% respectively.


**Fig.1. Crude starch powder isolated from *Curcuma* species and *Maranta arundinacea***

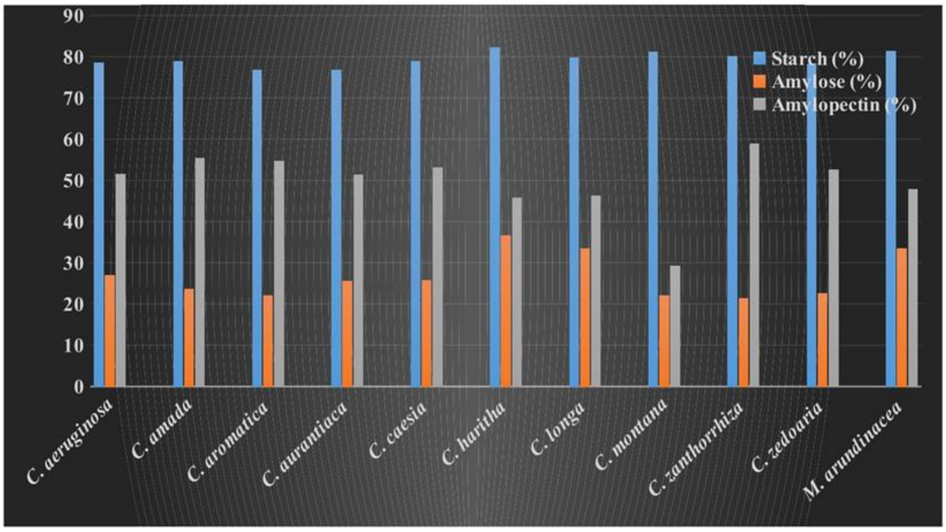


**Fig. 2. Starch: Amylose and Amylopectin composition of crude starch powder**

High proportion of amylopectin molecules contributed to the increased swelling power (Sasaki and Matsuki, 1998). The amylose content may vary within the same botanical variety because differences in geographic origin and culture conditions (Gao *et al*., 2014).

**3.2. Swelling power and Solubility**

Swelling power and solubility are the two important properties of the starch, which determined its specific functional property when utilized for food products. It measures the ability to swell and leach soluble materials when heated above gelatinization temperature. In the present study, all the candidate species have comparatively good swelling power ranges 23.76-36.14ml/g and solubility 17.76-23.14%, which was comparable to *Maranta* starch powder (35.38ml/g and 28.74% respectively) (Table 1). The highest swelling power was obtained for *C. caesia* (36.14 ml/g), which was higher than *M. arundinacea*, whereas lowest for *C. longa* (23.76ml/g).

**Table 1. Physico-chemical characteristics of crude starch powder**

| SI. No. | Species | Swelling power (ml/g) | Solubility (%) | *In vitro* enzyme digestibility (%) |
|---|---|---|---|---|
| 1. | *C. aeruginosa* | 27.33±0.28 | 23.14±0.75 | 19.01±0.2 |
| 2. | *C. amada* | 26.90±0.52 | 22.35±0.64 | 19.22±0.2 |
| 3. | *C. aromatica* | 26.43±0.17 | 21.14±0.53 | 23.05±0.1 |
| 4. | *C. aurantiaca* | 33.75±0.32 | 19.48±0.24 | 18.01±0.2 |
| 5. | *C. caesia* | 36.14±0.99 | 20.21±0.53 | 20.15±0.1 |
| 6. | *C. haritha* | 34.43±0.54 | 17.76±0.76 | 15.95±0.2 |
| 7. | *C. longa* | 23.76±0.29 | 22.05±0.54 | 19.98±0.6 |
| 8. | *C. montana* | 32.35±0.76 | 18.16±0.87 | 16.34±0.5 |
| 9. | *C. zanthorrhiza* | 26.75±0.65 | 20.92±0.97 | 20.28±0.5 |
| 10. | *C. zedoaria* | 28.19±0.86 | 20.23±0.79 | 19.23±0.4 |
| 11. | *M. arundinacea* | 35.38±0.12 | 28.74±0.32 | 23.92±0.6 |

The swelling power of potato starch ranges 26.29-48.61ml/g (Kaur *et al*., 2007), *Dioscorea esculenta* 24.27ml/g, cassava 30.6ml/g (Moorthy, 2002) and different *Curcuma* species ranges 18.75-29.3 ml/g (Thaha, 2013). Swelling power of most of the candidate starches except *C. longa* were within the range of potato starch (26.29-48.61 ml/g). Increased swelling power of starch granules could easily broke down by sheer forces (Lee *et al*., 1997). The solubility was maximum for *C. aeruginosa* (23.14%) and minimum for *C. haritha* (17.76%) (Table 1). Considerably high solubility of candidate *Curcuma* species except *C. haritha* and *C. montana* indicates its high value as food. Though the starch from *C. haritha* and *C. montana* possess less solubility, it was highly valued as resistant starch (RS), since low soluble or insoluble starches function as dietary fiber. Different parameters such as starch source, temperature, heating period, stirring and centrifuging conditions etc. are affected by the swelling power and solubility of starch.

The swelling power and solubility provide the indication of extent of interaction between starch chain within the amorphous and crystalline domains and are influenced by the character of amylose and amylopectin (Chan *et al*., 2009; Leach *et al*., 1959). According to Kumoro *et al*. (2012) greater swelling power shows harmonious with higher solubility, however, they observed there is no direct correlation between swelling and solubility. In the present study, swelling power of starch powder from four *Curcuma* species such as *C. aurantiaca, C. caesia, C. haritha, C. montana* showed a pattern that tend to decrease in contrast to its solubility but, in the rest of six species there were no direct correlation with swelling power and solubility as in *M. arundinacea*. The high swelling power results in to high digestibility indicating its ability to use as edible starch (Nuwamanya *et al*., 2009). Food eating quality is often connected with retention of water in swollen starch granules (Falade and Okafor, 2015). These two physico-chemical properties of the starch powder may influence the quality of bakery products (Kusumayanti *et al*., 2015) where it is used as an ingredient. Starch powder having lower swelling power and solubility will not swell well and thus may not be suitable for bakery products.

### 3.3. *In-vitro* enzyme digestibility

Enzyme digestibility of starch is an important individual component in many processed food products which is one of the main criterion for its application in food. It plays an important role in the rapid assessment of the quality of starch present in food and relates with how a food from starch is likely to behave *in vivo*, in terms of the rate and extent of sugar release from the available starch. All the candidate *Curcuma* species except *C. haritha* and *C. montana* have considerably good enzyme digestibility. Starch from *C. aromatica, C. caesia* and *C. zanthorrhiza* possess high quality edible starch by considering the two important physico-chemical property solubility and *in-vitro* enzyme digestibility and very well comparable to that of *Maranta* starch.

Starch from *C. haritha* (15.05%) and *C. montana* (16.34%) with low digestibility together with low solubility (Table 1), expressed the favourable physico-chemical properties to perform as resistant starch (RS). Resistant starch is defined as the sum of starch or products of starch degradation not absorbed by the small intestine in healthy individuals (Champ *et al*., 1999). Unripe banana, *Canna edulis*, taro starches (Srikaeo *et al*., 2011) and *C. rakthakanda* (Dan and Thaha, 2015) have lowest digestibility with significant amount of resistant starch. Baghurst *et al*., (1996) and Nugent (2005) proposed the resistant starch as pharma food for diabetic patients, since small intestine cannot absorb resistant starch and act it as dietary fibre. Based on these information, the results in the present study on starch from *C. haritha* and *C. montana* with less solubility and digestibility are obviously sources of resistant starch, and could be a future medicated food for diabetic patients. Various factors contribute to the digestibility of starch include granule morphology, amylose-amylopectin ratio, molecular structure, degree of breaking, and the physical stage etc. (Thaha, 2013). Higher digestibility of starch is the benchmark for the production of various identical functional foods such as noodles, pasta etc. which indicates the industrial significance of such starch.

### 3.4. Pasting properties (Viscometry)

Pasting is the phenomenon, following gelatinization in the dissolution of starches. Considering its edible value, pasting property is a crucial factor for starch, and is chiefly correlated to its viscosity. Viscosity of starch granules is mainly influenced by the granule size, shape, swelling power, amylopectin-amylose entanglement and amylose and amylopectin granular interaction (Hoover, 2001). The pasting profile of the crude starch powder from the candidate *Curcuma* species were analysed and graphically represented using Rapid Visco Analyser (Fig. 3).

Pasting properties point out to its significance in various non-food applications, because pasting profile indicates how the starch will behave during processing. As heating continues, an increase in viscosity observed, which reflects the process of pasting. Pasting temperature is the temperature at which the onset of viscosity increase. Viscosity increases with continued heating, until the rate of granule swelling equals to the rate of granule collapse, which is denoted as peak viscosity (PV).

Among the candidate *Curcuma* species, starch powder with the highest peak viscosity was observed for *C. montana* (6242.0cP) followed by *C. aurantiaca* (4394.0cP), *C. haritha* (4906.0cP), and *C. caesia* (4054.0cP), whereas the lowest value was for *C. longa* (543.0cP) (Table 2). The peak viscosity starch from of different tuber crops were *Canna edulis* (3442.0cP), *Canna indica* (951.0cp), *Maranta arundinacea* (2201.0cP) (Thaha, 2013), cassava (3417.0cP), cocoyam (2637.0cP), ginger (2384.0cP), and potato (6889.0cP) (Tetchi *et al*., 2007).

Peak viscosity of *C. montana* starch is close to that of cassava starch, whereas others did not match with the previously reported value.

**Table 2. Pasting properties of crude starch powder**

| Candidate species | Viscosity parameters (cP) | | | | Pasting temperature (°C) |
|---|---|---|---|---|---|
| | PV | BD | FV | SB | |
| ***C. aeruginosa*** | 3882.0 | 402.0 | 5236.0 | 1756.0 | 84.85 |
| ***C. amada*** | 2821.0 | 108.0 | 4164.0 | 1451.0 | 89.50 |
| ***C. aromatica*** | 2363.0 | 34.0 | 3058.0 | 729.0 | 85.75 |
| ***C. aurantiaca*** | 4394.0 | 330.0 | 6294.0 | 2230.0 | 82.25 |
| ***C. caesia*** | 5054.0 | 238.0 | 5866.0 | 2050.0 | 82.35 |
| ***C. haritha*** | 4906.0 | 572.0 | 6677.0 | 2343.0 | 82.70 |
| ***C. longa*** | 543.0 | 102.0 | 1023.0 | 582.0 | 92.10 |
| ***C. montana*** | 6242.0 | 1153.0 | 7041.0 | 1952.0 | 82.35 |
| ***C. zedoaria*** | 2324.0 | 59.0 | 3977.0 | 1712.0 | 86.55 |
| ***C. zanthorrhizha*** | 2217.0 | 17.0 | 3636.0 | 1436.0 | 88.15 |
| ***M. arundinacea*** | 2349.0 | 885.0 | 1991.0 | 527.0 | 78.20 |

**PV- Peak Viscosity, BD- Break Down, FV- Final Viscosity, SB- Set Back**

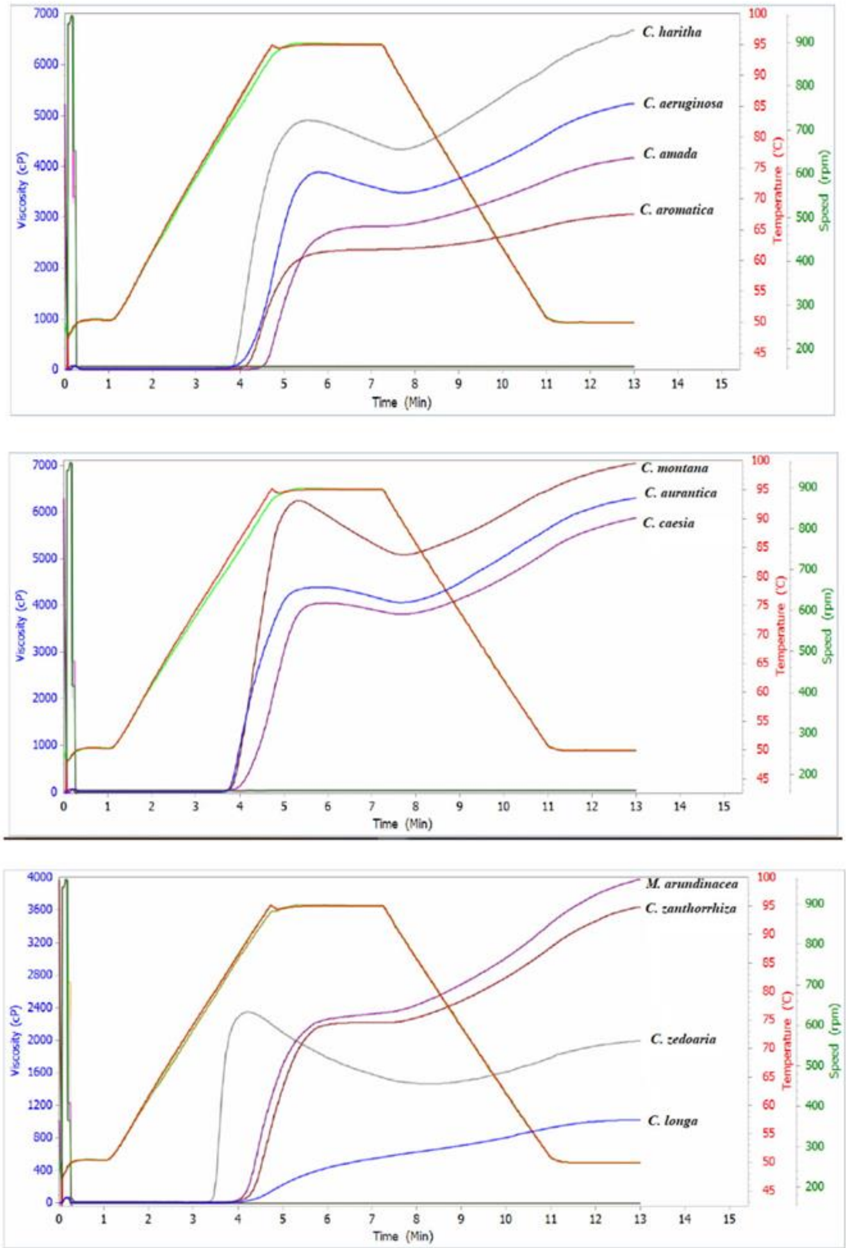


**Fig. 3. Pasting profile of crude starch powder of species studied**

Peak viscosity (PV) reflects the swelling extent or water binding capacity and often connection with the final product quality because, the swollen and collapsed starch granules are very well related to the texture of cooked starch.

Once peak viscosity is attained, a drop in viscosity or break down (BD) is observed due to disintegration of starch granules. The break down is a measure of the ease of disrupting swollen starch granules and indicates the degree of stability during cooking (Adebowale and Lawal, 2003). *C. montana* showed maximum BD value (1153.0cP), whereas *C. zanthorrhiza* showed minimum value (17.0cP). Viscosity again raises, when cooking stage begins *i.e.* set back (SB), which is due to retrogradation of starch, especially amylose. Set back is an indicator of final product texture and is connected to syneresis. The highest set back value was showed by *C. haritha* (2343.0cP) and lowest by *C. longa* (582.0cP). The lower set back viscosity during cooking indicates higher resistance to retrogradation (Sanni *et al*., 2001). Viscosity of starch normally stabilizes at a final viscosity or cold paste viscosity, which is correlated to the capacity of starch to form viscous paste or gel after cooking and cooling (Batey and Curtin, 2000). The final viscosity (FV) value was higher for *C. montana* (7041.0cP), while lowest for *C. longa*. Other species such as *C. haritha* and *C. aurantiaca* possessed higher values nearer to *C. montana* (Table 2). The major source for our commercial starch is maize, because the final viscosity of maize (4084.0cP) which is much higher than cassava (2521.0cP) and rice (2261.0cP). The final viscosity of all the candidate *Curcuma* species except *C. longa* were much greater than that of popular starch sources such as cassava and rice. Out of these, six species (*C. aeruginosa*, *C. amada*, *C. aurantiaca*, *C. caesia*, *C. haritha* and *C. montana*) have greater final viscosity than maize, the commercial starch. All these indicates the potentiality of *Curcuma* starch as source for industrial starch. High viscosity starch has enormous industrial applications as well, which is commonly used in textile and paper industry, particularly for sizing because of their high adhesive range. The final viscosity is positively correlated with the granule size and peak viscosity, as revealed in the viscosity profiles, since starch with larger granule made a thicker gel up on cooling. The properties of the gel made by different starches would be mainly determined by granule size, molecular composition and structural properties of the starch polymer.

The pasting temperature of *C. longa* showed a higher value (92.10°C) followed by *C. amada* (89.50°C) and *C. zanthorrhiza* (88.15°C) as compared to other starches (Table 2). The increased viscosity of starch in water mainly contributes to the swollen granules and the amount of solubilized carbohydrate mentions to amylose, further heating and shearing at high temp (95°C) leads to the weakening and susceptibility of starch granule to shear damage. The differences in pasting properties of starch among candidate *Curcuma* species observed might be due to the difference in branch chain length, distribution of amylopectin, crystallinity, granular size, distribution and presence of other components.

## 4. CONCLUSION

The starch powder from most of the candidate *Curcuma* species had almost similar physico-chemical properties and comparable to *Maranta arundinacea*, the popular starchy tuber crop. Comparatively good starch content, amylose and amylopectin composition and the physico-chemical properties indicate its potentiality in different functional areas. The results suggest that starch from most of the candidate *Curcuma* species could be used as an alternative for *M. arundinacea* starch powder and as new a raw material for food and non-food industry. Moreover, due to considerably low solubility and enzyme digestibility, the starch from *C. haritha* and *C. montana* are resistant starch, and could be a future food for diabetic patients.

## ACKNOWLEDGEMENTS

The authors are most grateful to the Director, JNTBGRI, Palode, Thiruvananthapuram, for providing facilities. The first author is thankful to University of Kerala for providing Research Fellowship. CTCRI, Sreekariyam, Thiruvananthapuram is also acknowledged for the analysis of crude starch powder.

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