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RESEARCH ARTICLE

Traditional and novel foods from indigenous flours: Nutritional quality, glycemic response, and potential use in food industry

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Starchy plant sources traditionally utilized for preparing breakfast foods are currently vastly underutilized. The present study investigated the proximate composition, glycemic index (GI), and factors affecting the GI of breakfast foods such as *roti*, *pittu*, porridge, and a novel food, muffin made with flour from some such underutilized plant sources. The glycemic responses were estimated according to FAO/WHO guidelines. Non-diabetic apparently healthy individuals aged 22–30 years (n = 10) participated in the study. The crude protein in foods ranged from 1.2 to 8.0 g/100g fresh weight (FW) basis. Muffin made with *Caryota urens* flour had the highest fat content with other foods having fat above 6 g/100 g FW except for *C. urens* porridge. Insoluble (IDF) and soluble (SDF) dietary fiber contents in foods were low, ranging from 1.2 to 5.7 g/100 g FW and 0.8 to 3.0 g/100 g FW, respectively. *Roti* made with *C. urens*, *Cycas circinalis*, and *pittu* made with *Vateria copallifera* were categorized as low GI foods (relative to white bread), with corresponding GI ± standard error of the mean values of 57 ± 4, 66 ± 6, and 67 ± 7, respectively. *C. circinalis pittu* elicited a medium GI (72 ± 4), whereas *C. urens* porridge and muffin elicited a high GI (92 ± 9 and 128 ± 11), respectively. If not counteracted by factors such as high fiber or protein, wet processing elicited higher glycemic responses. The starch granular structures and molecular weight distribution patterns correlated with corresponding GI values obtained in this study. The data prove that the traditional flour sources elicit health benefits and could be utilized in food preparation as a substitute for wheat and rice flour.

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1 Introduction

Food preparation utilizing indigenous flour obtained from seeds, fruits, or from other parts of plants is a common practice in the South-East Asian countries. In Sri Lanka, flour and scrapings obtained from the seeds of *Cycas circinalis* and *Vateria copallifera*, the pith of the *Caryota urens*, and the seed shoot of *Borassus flabelifer* are few of such examples. These flour preparations had been used traditionally as starchy bases for a variety of food preparations. According to folklore, many of these flour-based preparations are supposed to have health benefits such as hypocholesterolemic and hypoglycemic effects. However, the use and also the knowledge of such starchy bases have declined with time and had been replaced with highly refined (70% extraction) wheat or rice flour. The increased intake of refined carbohydrates is cited as one reason for the rise in NCDs in Sri Lanka as elsewhere in Asia [1]. Incidentally, the prevalence of the diabetes in urban and rural population is 16.4 and 8.9%, respectively [2].

The decline in usage of these flour varieties is also due to the fact that cultivation of these plants being not systematic

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Abbreviations: DC, digestible carbohydrates; **FW,** fresh weight; **GL,** glycemic load; **HMWC,** high molecular weight carbohydrates; **IDF,** insoluble dietary fiber; **LMWC,** low molecular weight carbohydrates; **MMWC,** medium molecular weight carbohydrates; **SDF,** soluble dietary fiber and growth being restricted to few areas of the country. The flour of *C. urens* is obtained from the hull and is available only when the tree is mature. For production of flour, the tree needs to be felled. However, the recent interest in growing *C. urens* tree to popularize export of treacle, jaggery, and toddy makes these trees a good source of flour for the future. Data on *C. urens* (*kithul*) flour indicate the flour to have potential as a thickener, stabilizer, and an emulsifier in food industry [3, 4]. Large-scale processing of starch is done in India, approximately 100–300 kg pith is obtained from one tree which is subjected to starch extraction (Fig. 1). It was reported that chemical composition of *Caryota* starch is not influenced by the age, agronomic practices, or palm species [5]. *Caryota* palm pith was reported to have an amylase inhibitor and thus low in vitro starch digestibility [6].

Similarly, seeds, such as those of *Vateria* and *Cycas*, could be cultivated for use as starchy bases. Further, *Cycas* seed flour is reported to have toxic compounds [7]. However, data on nutritional quality of flour or foods prepared with these flours, which are vastly underutilized despite their potential to be used in food preparations, are scarce. Thus, the main objectives of this study were to use such flours to prepare some traditional foods (*roti*, *pittu*, and porridge) and a novel food (muffin), to study their proximate compositions, effect on glycemic response by determining the GI, and to study the factors that affect the glycemic response and GI of foods.

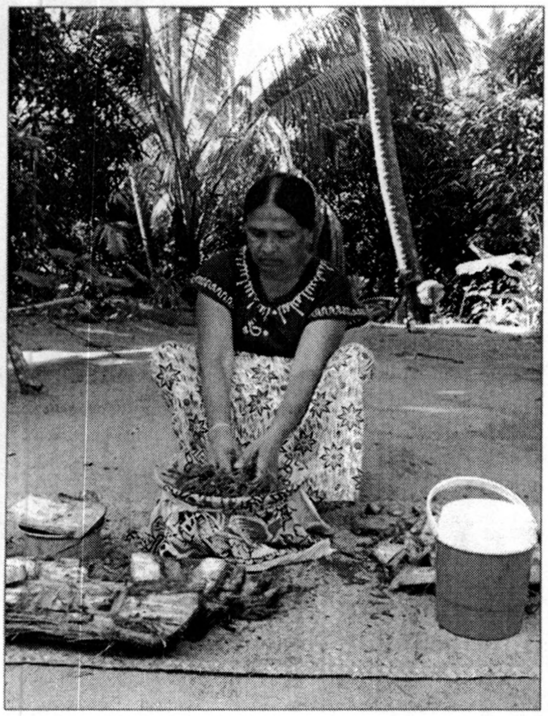

Figure 1. Squeezing the *Caryota urens* pith and fiber to obtain flour.

It is hoped to increase their usage by recommending these as alternative flour sources in place of highly refined wheat and rice flour which are commonly being used in food industry.

2 Materials and methods

2.1 Raw materials

Bulk flour samples of *C. urens* were collected from Matale and Kurunegala districts in Sri Lanka. Mature fruits of *C. circinalis* were collected from the Matale District. Fruits of *V. copallifera*, commonly known as *hal* (Sinhala), were collected from Matugama area in Kalutara District. The identity of the plants was confirmed at the National Herbarium, Royal Botanical Garden Peradeniya, Sri Lanka.

2.2 Flour preparation

C. urens (*kithul*) flour was prepared from the partially matured trunk. Pieces of matrix of the trunk were crushed with mortar and pestle, and washed with water several times as indicated in Fig. 1. Starch (Fig. 2) in the matrix was separated after decanting the water and dried under sunlight for 4–6 days and used in food preparation.

The outer cover of the *C. circinalis* seeds was removed and seeds were cut into small pieces and dried for 5–10 days in sunlight (Fig. 3). The dried grits were then soaked for 6–8 h in water and milled to obtain the flour.

The outer cover of the *V. copallifera* fruit was removed and the seeds were scraped with a peeler. Debittering was done by washing the scrapings in water for several times until the washed water was colorless. The scrapings were

Figure 2. Crude starch obtained from *Caryota urens*.

Figure 3. Dried *Cycas circinalis* seeds.

dried under sunlight prior to being used in the preparation of *pittu*.

2.3 Food preparation

The methods of food preparation were standardized, so that composition of foods prepared on different days did not vary. The ratios of food ingredients were selected according to palatability tested with an untrained panel ($n = 9$). Flour with coconut scrapings was used in the preparation of *pittu* and *roti*. Two *roti* meals were served with onion *sambol* and *pittu*, and *C. urens* porridge with gravy made from coconut milk.

2.3.1 *Caryota urens roti*

C. urens roti was prepared by mixing 75 g of *C. urens* flour, 26 g of coconut scrapings, 25 mL of water, and 6 g of salt by hand until the mixture was well combined and resulted in smooth dough. A 50 g of dough was flattened into a circle with a diameter of 10 cm and 0.8 cm thickness. The flattened dough was then roasted on a heated pan under a medium flame for 10–15 min, flipped, and cooked the other side until its surface was light brown.

2.3.2 *Caryota urens* porridge

Porridge was prepared by mixing 100 g of *C. urens* flour with 250 mL of water. The mixture was cooked for 20–30 min while stirring until the consistency of the mixture changed to a gel.

2.3.3 *Caryot aurens* muffin

Dough was prepared by mixing with 100 g of *C. urens* flour, 150 g of wheat flour, 250 g of butter, 250 g of sugar, and five eggs. The dough was poured into the baking cups and baked in an oven at 170°C for 30–45 min.

2.3.4 *Cycas circinalis roti*

Dough was prepared by mixing 37 g of *Cycas circinalis* flour, 37 g of wheat flour, and 26 g of coconut scraping mixed with 1 g of salt and 25 mL of water. Dough (50 g) was made into *roti* as mentioned above in Section 2.3.1.

2.3.5 *Cycas circinalis pittu*

C. circinalis pittu was prepared by mixing *Cycas* flour (37 g), rice flour (37 g), coconut scrapings (26 g), salt (1 g), and 40 mL of water with finger tips until flaky. The mixture was then steam cooked for 10–15 min under a medium flame after loosely packing in to the cylindrical column made with part of a air tight bamboo trunk, tightly fixed over a boiling water pan (*pittu bambuwa*).

2.3.6 *Vateria copallifera pittu*

Vateria copallifera pittu was prepared by mixing 37 g of *Vateria* scrapings, 37 g of rice flour, 26 g of coconut scrapings, 1 g of salt, and 40 mL of water until flaky. This mixture was also steam cooked as mentioned above (see Section 2.3.5).

2.4 Analysis of proximate composition of foods

Proximate compositions of the above foods were determined by using food flour obtained after drying freshly prepared edible portions at 40°C (408C, REMI™ Laboratory oven, REMI Instruments Ltd., Mumbai, India) for 4–5 days followed by milling (IKA® A11 basic, Brazil; under controlled conditions without excessive heat production). The moisture contents of fresh foods were determined by drying to a constant weight in an oven [8]. The digestible starch and the total starch contents were calculated by the method of Holm et al. [9]. Fat contents were determined according to Croon and Guchs [10], and the dietary fiber [insoluble dietary fiber (IDF) and soluble dietary fiber (SDF)] contents by the method of Asp et al. [11]. The Kjeldhal method [8] was used to estimate the crude protein contents of foods (× Nitrogen content by 6.25).

2.5 Determination of glycemic indices

The study was a randomized cross-over study. The GI of food items were determined by a standard method [12]. Normal healthy adults of both sexes ($n = 10$) and not under any medical treatment (age 20–30 years, BMI 22–23.5 kg/m^2) participated in the study. The subjects were asked to refrain from vigorous physical activities, smoking, and drinking alcohol the days prior to the test days. However, dinner meals were not controlled due to practical difficulties. After an overnight fast (8–10 h), the fasting capillary blood samples were obtained by a finger prick (softclix lancet device).

Volunteers were given the standard (Prima Crust Top™ white bread) containing 50 g of digestible carbohydrate to be consumed within 10–15 min with 250 mL of water. Further blood samples were taken at 30, 45, 60, 90, and 120 min intervals after the first bite. Blood samples (0.3–0.5 mL) were collected into clean plain Eppendorf tubes containing NaF (0.35 g/10 mL) and assayed for glucose (GOD-PAP, BIOLABOSA™, Biolabosa, France). Test foods containing 50 g of digestible carbohydrate portions were given on subsequent days at least with a 3-day interval between each food. The standard was given initially and in the middle of the study and all test foods were given to volunteers during a period of 3 months. GI was calculated as the percentage of incremental area under the curve for test food over the incremental area under the curve of standard. Glycemic load (GL) values of foods were calculated according to GL = GI × digestible starch per serving (g)/100. Ethical clearance for the human study was obtained from Ethics Committee of University of Sri Jayewardenepura (Approval no.: 376/7). Informed written consent was obtained from each individual participant prior to the study.

2.6 Amylose and amylopectin contents

Amylose, amylopectin ratio of foods was determined by the method described by Mohammadkhani et al. [13]. Flour samples (0.50 g) were digested with NaOH and ethanol. Amylose concentrations were estimated using KI/I_2 solution and the absorbance measured at 620 nm. Potato amylose (Sigma–Aldrich, Steinheim, UK) was used as the standard. Amylose contents are expressed per 100 g starch.

2.7 Microscopic studies and molecular size distribution pattern of carbohydrates

Structure of starch granules and the molecular size distribution patterns of carbohydrates of each raw flour and cooked food were examined and determined, respectively, according to the method described by Ekanayake et al. [14]. Starch in uncooked flour and processed/cooked food items were dispersed in distilled water and examined (×10 and ×100) under a light microscope (Olympus System Microscope, B-50, Olympus Systems; Tokyo, Japan).

2.8 Statistical analysis

The proximate nutrient compositions and amylose contents are expressed as mean ± SD, and the GI values as mean ± SEM. The statistical significances were calculated using SPSS version (13) at 95% confidence interval. Paired *t*-test was used to determine the significance between GI values, and the Student's *t*-test was used to decide whether significant differences existed between the nutrients provided by the meals.

3 Results and discussion

3.1 Proximate composition

Proximate composition of foods is stated in Table 1. Moisture content of foods ranged from 9.5 to 87.6 g/100 fresh weight (FW). The ranking for moisture contents was as *C. urens porridge* > *V. copallifera pittu* > *C. circinalis pittu* > *C.urens roti* > *C. circinalis roti* > *C.urens* muffin. Different moisture contents in different food items were due mainly to their methods of preparation. Excess water was added during *C. urens* porridge preparation, while *pittu* was subjected to wet heat (steam cooking). The *roti* varieties were prepared with a dough and dry heat, while water was not added when preparing *C. urens* muffin which was also baked at 105°C. The moisture contents of other *roti* preparations made with wheat, rice, *Eleusine coracana*, and whole wheat flour ranged from 17.3 to 23.7 g/100FW [15]. Comparatively, the high moisture contents of *C. urens* and

Table 1. Proximate composition of the foods (g/100 g fresh weight of edible food)

Parameter	*Caryota urens roti* (Mean ± SD)	*Caryota urens* porridge (Mean ± SD)	*Caryota urens* muffin (Mean ± SD)	*Cycas circinalis roti* (Mean ± SD)	*Cycas circinalis pittu* (Mean ± SD)	*Vateria copallifera pittu* (Mean ± SD)
Moisture[a)]	37.2 ± 1.4	87.6 ± 0.2	14.5 ± 0.6	37.6 ± 0.5	46.3 ± 0.8	52.0 ± 0.5
DC[a)]	44.0 ± 1.8	9.4 ± 3.4	39.7 ± 1.2	37.2 ± 1.0	34.4 ± 2.0	23.2 ± 1.7
Fat[a)]	7.6 ± 0.3	0.1 ± 0.0	27.5 ± 1.1	9.0 ± 0.5	6.4 ± 0.9	9.7 ± 0.3
Protein[b)]	3.1 ± 0.4	1.2 ± 0.4	7.0 ± 0.3	8.0 ± 0.5	5.2 ± 0.3	3.7 ± 0.2
SDF[a)]	1.5 ± 0.2	0.8 ± 0.2	2.1 ± 0.6	3.0 ± 0.4	2.0 ± 0.3	2.6 ± 0.7
IDF[a)]	3.1 ± 0.3	1.2 ± 0.1	1.9 ± 0.3	3.2 ± 0.8	2.5 ± ±0.3	5.7 ± 0.8
Ash[a)]	1.6 ± 0.6	1.3 ± 0.0	2.1 ± 0.1	1.6 ± 0.3	1.5 ± 0.2	1.1 ± 0.1
Amylose: Amylopectin	1.2	2.1	0.8	0.7	0.9	1.0

a) $n = 6$.
b) $n = 4$.
SDF, soluble dietary fiber; IDF, insoluble dietary fiber; SD, standard deviation; DC, digestible carbohydrates.

C. circinalis roti (37%) thus could be due to the differences in water retention capacities of these flour. The dough preparation required additional water than used by Widanagamage et al. [15] to obtain the same consistency of dough wheat and rice *roti*. A similar observation was made with *pittu* preparations of the present study when compared to *pittu* made with wheat or rice flour or *Eleusine coracana* (37.8–43.8 g/100g FW) [12, 15]. A clear decline in the moisture content was observed from boiling (*C. urens* porridge) in excess water to steam cooking (*pittu*) to dry heating (*roti*) and roasting (muffin), indicating a correlation between moisture content and the method of preparation. The moisture content of a food is critically important in determining the glycemic load and [16] also safety of a food if kept for longer periods. Incorporation of these flour in food preparations will be beneficial due to high water retention as this will decrease the intake of digestible carbohydrate and thus should be considered in the preparation of foods for diabetics.

The major nutrient of above foods was digestible carbohydrate, accounting for more than 20% of the fresh weight except in *C. urens* porridge (9.5%). Ash content of the foods ranged from 1.1 to 2.1%, with the highest ash content observed in *C. urens* muffin which could be due to addition of eggs. *C. circinalis roti* and *pittu* had high crude protein compared to foods made with other flour varieties used in the present study. The high protein in *C. urens* muffin compared to *C. urens roti* and porridge is credited to the addition of eggs and wheat flour during muffin preparation.

IDF contents of the *roti* and *pittu* ranged from 2.5 g to 5.7 g/100g FW with *V. copallifera* and *C. circinalis pittu* having the highest and the lowest IDF, respectively. The difference in IDF contents of *pittu* and *roti* prepared from *C. circinalis* flour (*pittu*: rice flour, *C. circinalis* flour, coconut: 1:1:0.7 *roti*: wheat flour, *C. circinalis* flour, coconut: 1:1:0.7) may be due to the variation in moisture due to different processing methods and different flour varieties added during the preparation. The low IDF content in *C. urens* porridge is also attributed to its constituent high moisture content. However, *C. urens roti* made by adding coconut kernel had significantly high IDF compared to porridge and muffin.

The contribution to soluble dietary fiber by these foods was low and ranged from 0.8 g to 3.0 g/100 g FW. *C. circinalis pittu* had the highest SDF content (3 g/100 g FW) due to addition of coconut kernel and wheat flour. The higher total fiber in *C. circinalis pittu* and *V. copallifera pittu* compared to rice flour *pittu* and wheat flour *pittu* may have contributed to lower GI when compared to reported data [17].

3.2 Glycemic indices

Table 2 indicates the GI values and other data corresponding to different food items. According to Brand-Miller classification [18], carbohydrate-rich foods can be categorized as high-GI ($GI \geq 70$), medium-GI ($70 > GI > 55$), and low-GI ($GI \leq 55$) (glucose as the reference). The categorization was adjusted relative to Prima Crust Top^{TM} (Ceylon Agro Industries Limited, Colombo, Sri Lanka) where foods were categorized as high (>89), medium (70–88), and low (<70) GI. According to the results obtained from this study, *C. urens roti* (57), *V. copallifera pittu* (66), and *C. circinalis roti* (67) were classified as low GI foods, whereas *C. circinalis pittu* (72) and *C. urens* muffin and *C. urens* porridge were categorized as medium- and high-GI foods, respectively. GI values of *roti* in the present study are comparable to published GI values (67–70) of *roti* made with other flour varieties [15]. However, in contrast to the GI values of rice flour and wheat flour *pittu* (103 and 101, high GI) [15], the GI values obtained for *C. circinalis* and *V. copallifera pittu* were comparatively low (medium and low GI). The low GI of *Vateria* when compared to wheat and rice flour *pittu* could be due to the high fiber [19, 20] and higher particle size of scrapings used in *pittu* preparation [21]. Thus, these endogenous flour varieties could be incorporated into when preparing *pittu* or other foods in place of wheat flour for enhanced health benefits.

The GI (92) of muffin prepared with *C. urens* flour was compatible with reported values of muffins prepared from

Table 2. The GI and other related data

Food	GI ± SEM*	Portion size (g)**	Average IAUC ± SD	Peak serum glucose concentration (mmol/L)	Glycemic load
Caryota urens roti	57 ± 4^{a}	114	101 ± 23	1.9	20
Caryota urens porridge	128 ± 11^{b}	530	157 ± 23	3.7	46
Caryota urens muffin	92 ± 9^{c}	126	227 ± 56	3.1	33
Cycas circinalis roti	$66 \pm 6^{a,c}$	135	123 ± 37	2.4	23
Cycas circinalis pittu	$72 \pm 4^{a,c}$	145	129 ± 26	2.3	25
Vateria copallifera pittu	$67 \pm 7^{a,c}$	215	94 ± 19	1.7	24

Different superscripts in a column indicate significant differences at 95% confidence interval.
*$n = 10$; SEM, standard error of mean; values expressed against bread.
**50 g digestible carbohydrate (per actual edible portion); IAUC, incremental area under curve.

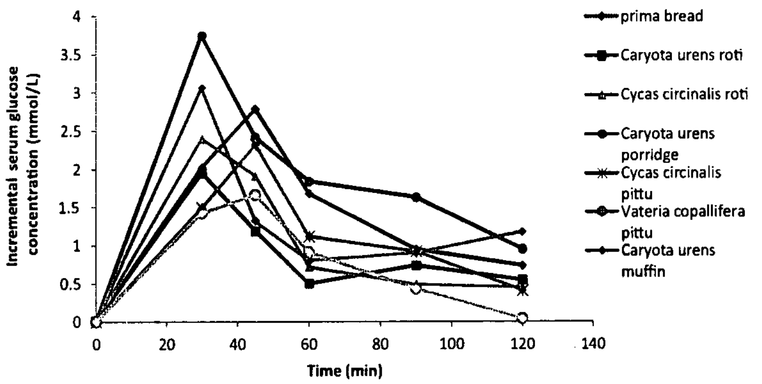

Figure 4. Glycemic responses to foods and prima bread.

carrot, low and high amylose corn starch, and other ingredients (chocolate, wheat flour, bran, etc.) and ranged from 53 to 146 [22]. This demonstrated the ability of the flour to be incorporated in to novel food preparations as well. The porridge (GI-128) prepared from *C. urens* flour had significantly high ($p < 0.05$) GI among all the foods studied and can be considered as an energy rich and an easily digestible food.

When all the studied foods are considered, no significant correlations were observed between GI and protein, total dietary fiber, IDF, SDF, or fat contents of 50 g digestible carbohydrate portions (Pearson's $\rho = 0.009, p = 0.986; \rho = 0.047, p = 0.930; \rho = -0.015, p = 0.978; \rho = 0.202, p = 0.701; \rho = 0.774, p = 0.071$), respectively. Apart from the quantity of fat and protein in a meal, the digestibility of protein also affects the expected glycemic responses [23]. However, in all these foods, the major nutrient was carbohydrate and the contribution of fat and protein may not have been adequate to make an impact on GI.

Amylose and amylopectin ratio of the foods ranged from 0.7 to 2.1. However, a correlation was not observed between the GI and the amylose content ($\rho = 0.767$, $p = 0.075$). This could be attributed to the high varietal difference in the foods studied and the contribution of preparation methods toward lowering GI, rather than the amylose and amylopectin contents.

3.3 Glycemic load and peak serum glucose levels

The volunteers considered the portions of *V. copallifera pittu* (215 g) and *C. urens* porridge (530 g) to be too large, whereas the two *roti* (135 g, 114 g) and muffin (126 g) portions were considered adequate and smaller, respectively. Only 60% of individuals were able to consume the *pittu* varieties, whereas the others considered the portions too large. The glycemic load (GL) values given in Table 2 are for 50 g digestible carbohydrate portion and do not reflect the GL of actual portion size. Thus, the GL of edible portions of the two *pittu* varieties and porridge would be lower. Thus consumption of *pittu* made with these flour could be beneficial in controlling the blood glucose concentration in both healthy individuals and type 2 diabetics.

Figure 4 indicates the peak serum glucose levels. Except *C. urens* porridge and muffin, other foods had lower peaks than prima bread. *C. circinalis pittu* and *V. copallifera pittu* had low peak serum glucose compared to other *pittu* varieties reported by Widanagamage et al. [17] (2.5–3.2 mmol/L). However, the *roti* varieties have peaks comparable with reported values [17]. The reduction of the glucose peak and the subsequent response with a plateau in *C. urens roti* and *V. copallifera pittu* in addition to their low GI would be beneficial for diabetics on dietary control.

3.4 Starch granule structural changes due to processing

The mean granular sizes (breadth and length) of starch granules of uncooked flour ranged from 11.5–10.9 and 38.7–58.8 μm. As indicated in Fig. 5, starch granules in *C. urens* porridge were highly gelatinized and disintegrated which is also reflected by the high GI. Swelling percentage of starch granules isolated from *roti* and muffin made of *C. urens* flour were 16 and 32%, respectively with a lesser degree of gelatinization which could be attributed to the low water content. This could be a reason for comparatively lower GI in muffin, even with added sugar. Breadth and length measurement of granules also revealed that the extent of gelatinization was high in *C. circinalis pittu* when compared to *roti* made with the same flour.

3.5 Carbohydrate molecular size distribution patterns

According to molecular weight distribution (Table 3 and Fig. 6) patterns, medium and low molecular weight fractions were high in all foods compared to uncooked flour. According to gel-chromatography patterns in Fig. 6, a major peak was observed in all preparations and corresponded to amylopectin [24]. The increased low molecular

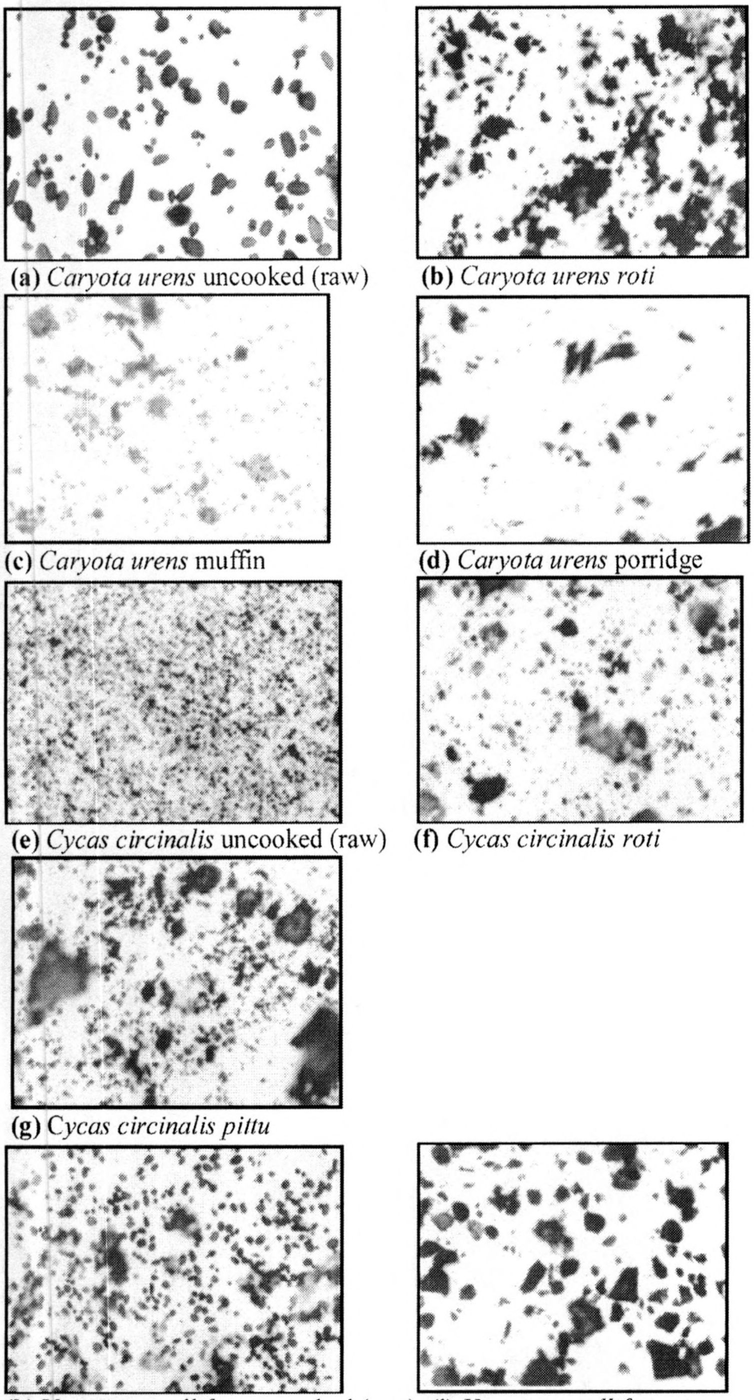

Figure 5. Light microscopic pictures of starch granules stained with iodine in KI (×10 × 100).

weight carbohydrates (10.5%) in *C. urens* muffin is attributed to the sucrose added. The reduction in high molecular weight fraction in *C. urens roti* was negligible compared to porridge (10%) and muffin (10%). Similarly *C. circinalis roti* (6%) had a lower reduction of high molecular weight fraction compared to *pittu* (9%). In the two *pittu* varieties, a 15% difference in medium molecular weight fraction was observed. However, the GI values were not significantly ($p > 0.05$) different. This also highlights that the effect of processing has contributed to the difference in GI in differently processed foods significantly than any other factor.

Table 3. Percentage molecular weight distributions and carbohydrate recovery

Uncooked and processed flour	HMWC% (Kav<0.2)	MMWC% (0.2<Kav<0.8)	LMWC% (Kav>0.8)	Recovery%
Caryota urens uncooked	87.7	12.3	–	90
Caryota urens porridge	77.7	20.6	2.4	71
Caryota urens muffin (*C. urens*: wheat; 1:1)	77.0	12.5	10.5	77
Caryota urens roti	86.3	13.4	0.3	81
Cycas circinalis uncooked	87.2	12.5	0.3	73
Cycas circinalis roti (*C. circinalis*: wheat; 1:1)	81.1	18.7	0.2	98
Cycas circinalis pittu (*C. circinalis*: rice; 1:1)	78.6	15.8	5.6	78
Vateria copallifera uncooked	72.8	23.8	3.4	78
Vateria copallifera pittu (*V. copallifera*: rice; 1:1)	65.7	31.0	3.3	83

LMWC, low molecular weight carbohydrate; MMWC, medium molecular weight carbohydrate; HMWC, high molecular weight carbohydrate.

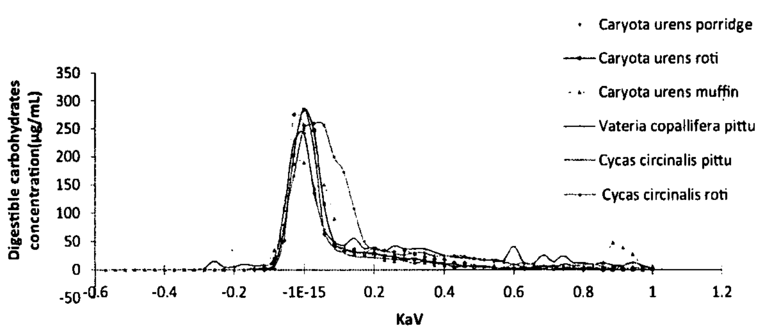

Figure 6. Digestible carbohydrate distribution patterns of starch of cooked food.

4 Conclusions

Food made with *cycas* flour and *V. copallifera* had high protein and dietary fiber, respectively. The moisture content of foods made using different flour varied based on the preparation method, with wet processed foods having higher moisture compared to dry processed foods. *Roti* made with *C. circinalis* flour, *pittu* made with *V. copallifera*, and *roti* made with *C. urens* flour were classified as low GI foods. The low GI in *Vateria pittu* compared to wheat and rice *pittu* could be due to high fiber and high particle size of *V. copallifera* scrapings. Medium and high GI values were observed with *C. circinalis pittu* and *C. urens* muffin and porridge, respectively. The molecular weight distribution patterns indicated wet processed foods had increased amount in low molecular weight carbohydrate fractions. If not counteracted by other factors, such as high fiber or protein, wet processing leads to higher glycemic responses. The above results also indicate the starch of different flour varieties have different structural characteristics and thus different susceptibility to gelatinization, depending on the botanical source of the starch. With respect to high protein, high dietary fiber contents and low GI in these food preparations, these starch sources have high potential to be incorporated or partially substituted for wheat in food industry. The positive sensory responses of the participants who consumed the foods made with traditional flour clearly indicated that all these flour varieties have high potential to be used in place of wheat or rice flour in food preparation.

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