Kithul Flour (*Caryota urens*) as a Potential Flour Source for Food Industry

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Abstract   This study search for underutilized flour source, obtained from Kithul (*Caryota urens*) trees in Sri Lanka which is potentially valuable as food ingredient for the industry. The aim of this paper is to discuss the Physico-chemical and functional properties of Kithul flour. The protein content of the flour was 1.0% while the total fat content was 0.33%. It contained considerable amount of Calcium, Potassium, Magnesium and Iron content as 70.1, 59.5, 66.6 and 14.0 mg/100g respectively. Total starch content was 66.82%. In the case of Amylose content, Kithul flour contained 28.42% while amylopectin presented 71.32%. The high moisture sorption value has presented by Kithul flour samples as 29.47%. And also being high density flour (as 0.69g/cm^3) this will be better thickener as well as a stabilizer in baking powders and as an emulsifier in the food industry. The measurement of gelatinization temperature which was obtained by Differential scanning colorimetric method was 76.74 °C, while enthalpy for gelatinization of Kithul flour was 11.12 J/g. The least gelation concentration (LGC) was 6. Length of the granules ranged from 26.5 to 64.7 μm and width of granules ranged from 7.0 to 56.9 μm. Three types of granular shapes as oval, spherical and irregular globular shape were exhibited. By considering all above Physico-chemical properties there is high possibility to use Kithul flour for empower the food industry, simultaneously strengthening the Kithul Industry with rural economy in Sri Lanka.

Keywords: Kithul flour, Caryota urens, Physico-chemical composition, mineral content, DSC, FT-IR

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1. Introduction

Flour from many sources provides a better raw material for the production of starch and different sweeteners [1,2]. Starch has broad capability to move about wide variety of uses [3]. Due to functional properties affects the physical characteristics of many foods, starch is used to apportion those properties for processed food, in food industries. Starch is mainly applied as taste enhancer, thickener, binder, and filler [1,2,3,4] as well as stabilizer, edible film former in food industry [5], but also in non-food industries such as pharmaceutical, textile [6], Cosmetics, plastics, adhesives and paper industries [7] used to produce adhesive, agro-chemicals, cosmetics and toiletries, detergent, paper making additives, pharmaceuticals, paints, textiles, water purification agents, and biodegradable plastics [2,8].

Palms are proper source for starch production which belongs to oldest families of plants on earth [9]. Contemporary researchers pay their keen attention to discover novel sources of starch, which exist in the wild. Kithul (*Caryota urens*) is a better response for this requirement, which is still keep as semi-wild species [10]. This palm is native for India, Malaysia and Sri Lanka [11]. The bark yields around 100 kg -150 kg of pith per palm which used to preparation of flour [11]. The main usage of Kithul in current society is production of sap for toddy and jiggery [12]. So then common names for Kithul are Toddy palm and Jaggery palm [13]. The starch stored in trunk of the Kithul tree is the main edible food product of this palm. According to the reported values, palm generates 24 tons/hectare per year compared to rice which produce 6 tons / hectare per year while 5.5 tons/ hectare from corn and 2.5 tons/ hectare from potato [14]. According to the Rajalakshmi (2004) quality of flour from *Caryota urens* to be equal to the best sago of commerce extracted from *Metroxylon sagu rottb* [10].

The national survey conducted in 2009, has reported that the total number of Kithul trees found in the island amounts to 2,977,261 (vastly spread in Sabaragamuwa, Central and Uva provinces) [15]. Although matured or 'peedunu' trees was being 574,259, which sap was extracted amounts to only 89,855 (15.64%). Further evaluation proves that among the opportunities to develop Kithul industry there are 84% of the matured trees to be tapped [15]. This is the main point to deviate another expansion of Kithul industry as Kithul flour because non-tapping trees are more suitable for collecting. According to this statistic data 2,403,002 of new trees are available for maturation in 2014 with expanding the both tapping and flour industries [15].

Because of the high necessity due to number of industrial applications, a huge demand on few well-known starch sources. Therefore it is creating requirement on new sources for the continuous supply as commercially viable starch. The aim of the work reported herein was to undertake a comprehensive investigation on the physicochemical and functional properties of the flour obtained from Kithul (*Caryota urens)* tree.

2. Materials and Methods

2.1. Sample Collection

Five hundred grams of Kithul (*Caryota urens*) were purchased at random from both households and commercial market in Sri Lanka All chemical used was analytical grade.

2.2. Sample Preparation and Storage

Samples were sifted through a 355μm sieve and packed in air-tight containers, then stored in refrigerator (5°C) until further analysis.

2.3. Solubility Test

A 1g of Kithul flour was weighed and poured into a beaker containing 1ml, 2ml, 10ml, 1L and 10L distilled water at 30°C and was stirred, and the solubility was observed. Same procedure was repeated using 65% alcohol as a solvent. The procedures were repeated for all six samples [16].

2.4. Iodine Test

Using Musa et al, 2011 [16] starch identification test, 1g of flour was boiled with 15ml of water and allowed to cool. A few drops of 0.1N Iodine solution were added to 1ml of the mucilage and the colour changes recorded.

2.5. Moisture Content

One gram of each flour sample was weighted in a dish and reading was taken by placing in the Infra-red moisture content testing machine (ULTRA X) [6].

2.6. Proximate Analysis

Total fat, protein (N x 6.25), ash and crude fiber content were determined according to AOAC (1990) [17] methods. Carbohydrate contents were determined by difference sum of above categories. Mineral content was determined by dry ashing technique as described AOAC 999.11 [17]. The ash was dissolved in conc. HCl, filtered and dilute with distilled water. Prepared samples were analyzed with a standard series of solutions by Atomic Absorption Spectrophotometer (Thermo Scientific ICE3000 series).

2.7. Amylose and Amylopectin Determination

Amylose content of Kithul flour was determined in three steps using simple iodine colorimetric method as described by B.O. Juliano (1971) with slight modifications [18]. Amount of amylopectin was calculated by subtracting the amylose content from the starch content and expressed as g/100g of dry weight [19].

2.8. Total Starch Determination

Starch content was determined by the complete acid hydrolysis method. Flour sample of 2.5g was suspended in a mixture of 200 ml of water and 20ml of HCl acid (specific gravity 1.125).The mixture was heated in a flask provided with a reflux condenser for 2.5 hours. Contents were cooled, and neutralized with NaOH (5N).Volume was made to 250ml and sugar formed was determined as dextrose by Lane and Eynon reducing sugar estimation method. The dextrose multiplied by 0.9 was taken a starch [20].

2.9. Determination of Moisture Sorption Capacity

Moisture sorption capacity was determined by method described by shiihii et al (2011) [6]. Each dried flour samples were spread evenly in Petri dishes; the Petri dish was placed in a desiccator with 98% relative humidity at room temperature. The samples were periodically weighed until a constant weight was attained. The percentage increase in weight as calculated and taken as the moisture sorption capacity. The above experiments were repeated thrice and the mean of the readings was recorded.

2.10. Determination of Flour Density

Bulk density: Bulk density of the flour was determined according to the method of Musa et al.(2011) [16] with slight modifications**.**20g each, of individual flour respectively were poured through a short-stemmed glass funnel into a 250ml graduated glass cylinder and the volume occupied by the flour was read and the bulk density calculated in triplicate.

Tapped density: Graduated cylinder containing 20g of flour was dropped on a bench 50 times from a height of about 20mm and the respective volumes recorded. Same was done for all samples and the tapped densities were then calculated in g/ml [16].

Carr's Index: The difference between the tapped and bulk density divided by the tapped density was calculated and ratio expressed as a percentage [16].

Hausner ratio: Hausner ratio was calculated by taking the ratio of tapped density to bulk density for all the samples [16].

2.11. Comparison of Colour Variations of the Flour by Using Chromometer Minolta (CR 400) Colorimeter

The instrumental measurement of Kithul flour color was carried out with a Colorimeter Minolta CR-400 (Minolta, Spectrophotometer, Japan) and the results were expressed in accordance with the CIELAB system. It is based on the color perception of 92% of the population which has a good vision [20, a]. The samples were placed directly on the glass (6.4 mm diameter diaphragm with an optical glass), with the surface of the sample was manually made a flat. The color attributes were determined by colour coordinates of $L*$ ($L* = 0$ [black] and $L* = 100$ [white]), $a*$ ($-a* =$ greenness and $+a* =$ redness), and $b*$ ($-b* =$ blueness and $+b* =$ yellowness) [48].

2.12. Differential Scanning Calorimetry (DSC)

Thermograms for Kithul flour was taken by DSC (Model DSC TA instrument Q 200, USA).Flour was weighed on to the aluminum DSC pan and distilled water was added with micro syringe for 50% (w/w) mixture. Pan was sealed and allowed to stand for 1hr at room temperature. The scanning temperature range and heating rate were 30-140°C and 5°C/min, respectively, using empty pan as reference [20]. The onset temperature (To), peak temperature (Tp), conclusion temperature (Tc), and gelatinization enthalpy (ΔHG) were recorded.

2.13. FT – IR Spectroscopy

The transmission spectra were obtained between 4000 and 500 cm^{-1}, with 4 cm^{-1} resolution and 128 scans using Nicolet 6700, USA Fourier Transform Infrared Spectroscopy (FT-IR). Sample pellets were prepared for FT-IR by mixing vacuum dried 10 mg of samples with fused-110 mg of KBr. Spectral analyses were performed using OMNIC (version 8.0) software tools (Nicolet 6700, USA). [23].

2.14. Gelation Studies

Flour dispersions (2-18%w/v) were prepared in test tubes with distilled water (5ml). The flour suspensions were thoroughly mixed for 5 min. the test tubes were heated for 30min at 80°C in a water bath, followed by rapid cooling under running cold tap water for 2hr. Least gelation concentration was determined as lowest concentration when the sample from the inverted test tube did not fall down or slip [23].

2.15. Granular Morphological Variations of the Starch by Light Microscope (LM)

Morphology of Kithul starch granules was observed according to the method described by Jayakody et al, 2007 [24] with slight modifications. Starch solution was prepared by mixing with 1:1(w/v) mixture of distilled water to glycerin (1:1,v/v).The starch solution was stained with 0.05% iodine solution and a thin smear was prepared on a glass slide with a cover slip. Microscopic measurement of Kithul starch granules was done using light microscope (HITACHI SU 6600, Japan) under the magnification power of 400 x with Magnus live USB 2.0 viewer and UTHSCSA Image tool for windows software (Developed by University of Texas, 1995-2002).The length and diameter of the granules from each starch sample obtained from five different districts were measured and the shape of granules was observed.

2.16. Morphological Characteristics by Scanning Electron Microscope (SEM)

Morphology of native Kithul flour was studied by using scanning electron microscope (JSM 6380A, Jeol Japan). Flour samples placed in aluminum specimen holder were coated with gold and examined under different magnifications [20].

2.17. Statistical Analysis

Results were analyzed using one-way analysis of variance (ANOVA) at 0.05 probability level with MINITAB software package (version 17 for Windows).

3. Results and Discussion

3.1. Identification and Chemical Parameters

The Kithul flour treatments collected as per 2.1 were odourless. And these were insoluble in water and 65% ethanol with positive respond for Iodine test and acidity test (Table 1). Generally starch granules are insoluble in cold water. They undergo a reversible reaction in cold water, swelling slightly and becoming hydrated. Kithul flour was answered positively for Iodine test according to the Muazu,J *et al* the starches were all positive for this test [16].

Table 1. Results of identification and Chemical composition test of Kithul flour collected from different growing areas in Sri Lanka

Identification Test	Result
Odour	Odourless
Solubility Test	Insoluble
Iodine Test	Positive
Chemical composition Test	**Value**
Moisture Content %*	10.1± 2.1
Crude Protein (g/100g db)*	1.0 ± 0.2
Total Fat (g/100g db)*	0.33± 0.08
Crude Fiber (g/100g db)*	1.0± 0.5
Ash Content (g/100g db)*	0.8± 0.6
Carbohydrate (By Difference)*	87.5± 2.2
Calcium (mg/100g db)*	70.1 ± 26.9
Potassium (mg/100g db)*	59.5 ± 22.8
Sodium (mg/100g db)*	56.7 ± 35.5
Iron (mg/100g db)*	14.0 ± 4.9
Zinc (mg/100g db)*	3.3 ± 1.9
Magnesium (mg/100g db)*	66.6 ± 27.0
Values were recorded in replicate of all six flour treatments.	

According to the results moisture content ranged 8.0% to 12.2%, while protein content ranged from 0.8 to 1.2 g/100g (dry basis). Literature reveals that the crude protein content of *Caryota urens* flour has been reported as 1.13 [25].

According to the comparison with available data on economically important tuber and pith starch sources which are currently use as rich in starch, Kithul flour exhibited higher protein content (1.0%) than sweet potato (0.17%) [26] and sago pith flour was exhibited 0.1% [27] while potato (*Solanum tuberosum) starch* contained higher protein value than Kithul as 2.5 to 3.2% according to the Abbas *et al* [28]. Although mean value of the total fat content of Kithul flour (0.33± 0.08g/100g (dry basis) was presented little bit higher than reported value from Indian Scientist as 0.2 [25], it was comparably slightly lower than cassava starch (0.74 -1.49 g/100g) [29] as well as Sweet potatoes (1.1-1.7g/100g) [20]. This minimal amount of fat and protein of Kithul flour could be expected to have because of this palm is non-leguminous plant [30].

Reported crude fiber content of collected Kithul flour samples was ranged from 0.5 to 1.5% with aligned to literature, where the crude fiber content of Kithul flour has been reported as 0.2 to 3.5% [31]. The fiber content can be

different due to flour extraction method. Literature provides facts as in dry method removed portions of pith were dried, pounded and sieved through the household strainer, so it contains higher fiber content than wet method where pieces of pith were removed and pounded, mixed with water and sieved from a piece of cloth [12]. Crude fiber content showed comparable values with cassava root starch (1.4 to 3.2 g/100g) [30]. Depending on the extraction procedure ash content also can vary, by addition of sand particles could present by passing through the strainer or cloth. As per the results of this study total ash content of the flour samples were ranged of 0.2% to 1.4% while literature shows in Sri Lanka it was 0.65 % [24] and in Indian researchers have reported as the ash content is range to 1.5-2.5 % [31]. Carbohydrate content was calculated by difference of sum of above five components. Because of the moisture content of flour directly effect on this calculation there was slight variations of the carbohydrate content. Therefore total starch determination is the better way to identify the starch component in the flour.

Studied Kithul flour had a considerable amount of nutritionally important trace elements Iron (Fe) and Zinc (Zn), with mean values of 14.0 and 3.3 mg/100g (dry basis), respectively (Table 1). Mean concentrations of macro minerals, namely Sodium (Na), Potassium (K), Calcium (Ca), and Magnesium (Mg), were as 56.7, 59.5, 70.1, 66.6 mg/100g respectively. However Calcium content (70.1 mg/100g) of the Kithul flour was higher than corn starch18.6 mg/100g [32], while Iron content of Kithul flour (14.0 mg/100g) was exhibited same behaviour with corn (15.2 mg/100g) [32].

Usually, the functional properties are regulated by amylose and amylopectin content of the starch [33].As well as these parameters are key quality points of starches, which could impact characteristics of baked foods, and greatly influence important functional attributes like pasting and gelling properties [34]. During swelling amylose behaves as a restraint to gelatinization by distributing out of the granules. So it makes up the continuous phase by reticulating in outside the granules [35]. According to the reported previous data, waxy starches (High Amylose pectin) usually swell to a greater extent than non-waxy (High amylose) starches [36].

Based on the Rice classification of Lawal *et al* [37] Kithul flour was belonged to high amylose (25-33 %) category due to it has contained 28.42% Amylose content (Table 2). So it shows a non-waxy flour type as most native flours contain 20-30 % of amylose [31].

Table 2. Variations on Amylose, Amylopectin and total starch of native Kithul flour in Sri Lanka

Sample Name	Values
Amylose**	28.42±0.04
Amylopectin **	71.32±0.40
Total Starch	66.82±0.25

db = Dry basis.
* Data are the average of three repetitions ±standard deviation. The values in a column followed by the same letter are not
In base of 100% of starch.

Due to high amylose content water absorption index tend to be relatively low due to amylose is hardly converted into amorphous state compared to amylopectin [38]. Tester & Morrison, [39,40] reported a very similar ideas as amylopectin is efficient to swell due to the frailty of the intra- and inter-molecular bonds, while amylose inhibit the swelling of starch, [39,40].

Total starch content was determined using two steps as acid hydrolysis and determined the reducing sugar content. The Lane-Eynon method was used for determining the concentration of reducing sugars in the samples. A burette was used to add the flour solution being analyzed to a flask containing a known amount of boiling copper sulfate solution and a methylene blue indicator. The main disadvantage of this method is the results depend on the precise reaction times; temperatures and reagent concentrations used [41]. There for personnel errors must be carefully controlled. Kithul flour contained 66.82% of mean total starch content (Table 2) which slightly higher than value reported by Thanuja.P, [25] as 64% from India.

3.2. Functional Properties

Variation of the Moisture sorption value of native Kithul flour with the time is shown in the Figure 1 based on the data in Table 3. This behaving pattern is a reflection of the looseness between granules of Kithul flour and it confirms that the granules are not tightly associated together [27]. According to the literature, it is assumed that hydration of flour represents the water absorbed by the particles or particle surface [42].So high water sorption capacity means smaller particle size.
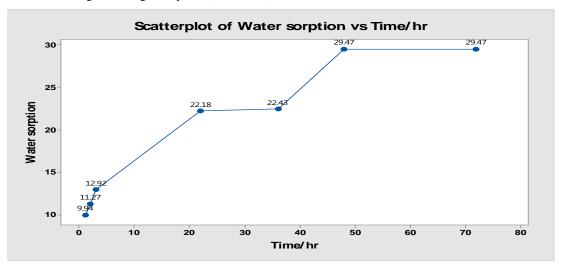

Figure 1. Scatterplot of water sorption behaviour of Native Kithul flour with the time

Table 3. Variations on water sorption value of Kithul flour with the time

Sample	1hr	2hr	3hr	22hr	36hrs	48hr	72hr
Raw Kithul Flour	9.94±1.05	11.27±0.64	12.92±1.06	22.18±0.52	22.43±0.46	29.47±0.4	29.47±0.4

Each value represents the means of three estimations of three samples of raw Kithul flour.

Bulk density is a measure of heaviness of a flour sample which is depended upon the particle size of the samples. It is important parameter for concluding industrial requirements as packaging, material handling and utilization in wet processes in the food industry [42]. Due to flours with high bulk densities are used as thickeners in food industry, Kithul flour could be used as a thickener [43], which has presented 0.69 of bulk density while bulk density of corn flour showed 0.51 [44]. The parameters called Carr's index and Hausner ratio predict the flow and compressibility of powders [42], which used in pharmaceutical industry. Based on the bulk and tapped densities, Kithul flour sample was obtained Carr's index as 22.58 (Table 4).

Table 4. Functional properties of native Kithul flour in Sri Lanka

Density	Value
Bulk Density	0.69±0.01
Tapped Density	0.89±0.005
Carrs Index= (tapped-bulk)*100/tapped	22.58±1.50
Hausner ratio=tapped/bulk	1.29±0.025
Colour attributes	
L* Mean	68.47±2.47
a* Mean	5.05±0.38
b* Mean	15.86±1.47
DSC Data	
Onset Temperature(°C)	72.02±1.08
Peak Temperature(°C)	76.74±0.81
Conclusion Temperature(°C)	87.46±0.54
Gelatinizing Enthalpy(J/g)	11.12±0.46

db = Dry basis.
Above all Data are the average of three repetitions ±standard deviation.

Hausner ratio values obtained in this study for Kithul flour samples were 1.29. As per the literature, Hausner ratio above 1.2 and Carr's index above 23% do not indicate good flow or good compressibility [26]. Kithul flour samples were indicated less suitable values as good flow and good compressibility as per the Muazu *et al* (2011) [42]. Starch modification would be answered easily for this situation. Colour analysis showed L*(lightness) values in the range of 60 to 70.94, a*(redness) values 4.67 to 5.43 and b* (yellowness) raked 14.39 to 17.33 (Table 4). The positive a* value for Kithul flour samples showed its propensity towards pinkish colour as positive a* values represent the redness of samples [22]. The colour of flour is depended on the presence of polyphenolic compounds, ascorbic acid and carotene has impact on its quality[45]. The crude Kithul flour contains a considerable amount of phenols, as 52.0 %, when compared to white coloured corn flour, which has no phenols [25]. However pigmentation in the flour is carried up to the final product. So it reduces the quality, as well as consumer's acceptability of starch product.

In the sense of food processing, the functionality of flour is mainly linked to its gelatinization and pasting characteristics [44]. In the presence of excess water, heating of starch cause to a phase transition from array to disarray known as gelatinization over a temperature range characteristic of the starch source. The Differential Scanning Calorimetry (DSC) provides an accurate and comprehensive method for monitoring the gelatinization characteristics of Kithul flour. One endothermic transition was raised during gelatinization of the flour (Figure 2). The data obtained for the DSC thermo grams for Kithul flour are given in Table 4. It can be seen that the, onset temperature, peak temperature and conclusion temperature values as 72.02°C, 76.74°C and 87.46 °C respectively, since gelatinization temperatures reflect the degree of orderliness of the molecules in the granules. Kithul flour has a comparatively slight lower gelatinization temperature than Corn starch (80°C) [35]. This is probably due to its higher amylose content. High amylose content has been found to influence gelatinization temperature [46]. FT-IR is one of the imperative instruments used to analyze food quality parameters [47]. Spatial distribution of starch, protein and lipid in flour-based products can be determined by FT-IR spectroscopy [48]. Figure 3 shows very strong absorption band around 3370-3340 cm^{-1} may be due to the presence of bonded N-H, C-H, O-H stretching in amines and amides [49].
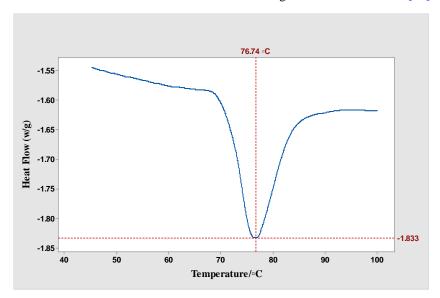

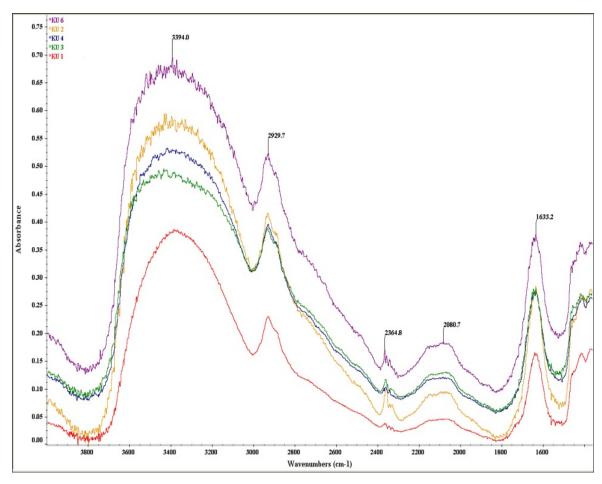**Figure 2.** DSC thermo grams for Kithul flour

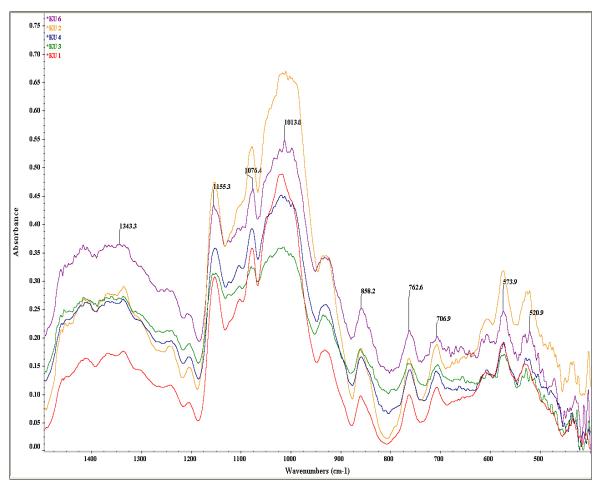**Figure 3.** Transmission spectra obtained between 4000 and 1500 cm-1

Figure 4. Transmission spectra obtained between 1500 and 4000 cm-1

The very strong absorption at 3394 cm^{-1} shows the presence of amino acids and the absorption band appearing the region 2932 cm^{-1} is as a result of N-H stretching [49]. In addition, a symmetrical stretching of NO$_2$ group results in strong absorption in the region 1660-1625 cm^{-1}. The observed absorption band at 1633 cm^{-1} indicates the presence of amines [49]. Figure 4 demonstrates the peak at around 1343 cm^{-1} as the C-H bending mode of CH$_2$ [49]. Absorption peak at 1155 cm^{-1} can be assign into C-O stretching or OH bending while CH bending can be assign to the peak at 1076 cm^{-1} [50]. The peak around 1013 cm^{-1} shows the C-O or C-C stretching modes [50]. Further, COH bending vibration is appeared at 855 cm^{-1} [50]. Peaks appeared at 573, 706 and 763 cm^{-1} can be assigned into the CH out-of-plane bending vibrations. The peak at around 520 cm^{-1} can be assign into the torsion and ring of phenyl [49].

3.3. Gelation Studies

In Table 5, gelation properties of native Kithul flour samples are presented. The least gelation concentration (LGC) was 6.This value is important for food processing activities which are based with the flour, to determine the correct water: flour ratio for desirable texture.
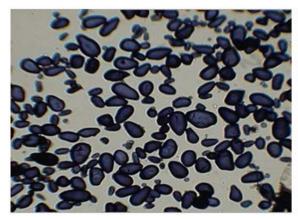
Values were recorded in replicate of all six flour treatments.

Table 5. Gelation properties of native

Concentration (% w/v)	Status
2	Viscous Liquid
4	Soft Gel
6	Soft gel+ Firm gel
8	Firm gel
10	Very firm gel
Least Gelation Concentration	6

3.4. Morphological Properties

Morphological properties of native Kithul flour were studied using both LM (Light Microscope) and SEM (Scanning Electron Microscope) at different magnifications ranging from 100x to 400x for LM (Figure 5) and 100x to 500x for SEM (Figure 6). Approximate size and shape of flour are presented in Table 6.
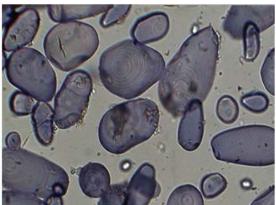

Figure 5. Light micrograph of Native Kithul (*Caryota urens*) flour under two magnifications (X100 and x400)
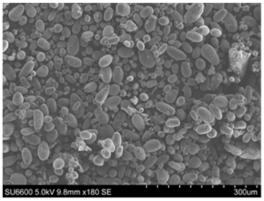

Figure 6. Scanning Electron Micrograph (SEM) of Native Kithul (*Caryota urens*) flour under two magnifications (300µm and 100 µm)

Table 6. Variations in Granular size and Granular shapes of Kithul flour collected from main growing areas in Sri Lanka (Based on LM and SME results)

Indices	Value
Length of the granule / µm	45.6 ± 19.1
Width of the granule / µm	26.4 ± 9.9
Spherical shape %	35.1 ± 17.3
Oval shape %	51.4 ± 14.6
Irregular globular shape %	13.5 ± 10.8
Values were recorded in means of three replicate of all flour treatments.	

Length of the granules ranged from 26.5 to 64.7 µm though mean value was 45.6 µm, which is compatible with previously reported value (44 µm) of *Caryota urens* pith flour [51], while the width of granules ranged from 7.0 to 56.9 µm with a mean value of 26.4 µm (Table 6). Three types of granular shapes as oval, spherical and irregular globular shape were exhibited. Mostly common in oval shape and with the walls that are generally smooth without edges, which represented 51.4 ± 14.6 % of granules. Spherical shape got the second representative

percentage contributing 35.1 ± 17.3% of granular while irregular globular had lowest value as 13.5 ± 10.8 %.

4. Conclusion

Kithul flour has huge potentials of being used to food industry in order to provide better gelling property with other functional needs. Based on this study Kithul flour can be promoted because of its positive nutritional and Physico-chemical properties for the enhancement of different food products. However, the results from this study can be used by food technology researchers, agro-processors and investors as an input for their work. More specifically, the results can contribute to those who are interested in the production of starch based product developments which could be helped to empower the Kithul industry.

Acknowledgement

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