Research Paper

Variation of Physio-chemical, Proximate Composition and Functional Properties of Flours of Some Selected Artocarpus Species for Food Application

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Abstract

Jackfruit, Chempedak, and breadfruit varieties are commonly cultivated in Sri Lanka, bearing extensively during the fruiting season. The study was conducted to generate useful information on the flour quality of selected Artocarpus species that could be used in the food industry. The physio-chemical properties such as pH, proximate compositions such as crude protein content and functional properties such as oil absorption capacity, determine the suitability of a flour to utilize as a food or a food ingredient. Five jackfruit, one Chepmedak and two breadfruit varieties were selected and flours from jackfruit flak and seed, chempedak flak and seed and flesh of breadfruit were prepared. Physio-chemical properties; pH, titratable acidity and total soluble solids, proximate compositions; moisture, crude fat, crude protein, crude fiber, ash, and carbohydrate contents and functional properties; water and oil absorption capacities, bulk density, forming capacity, swelling capacity, solubility and emulsion activity were determined in the prepared flours in 2022 and 2023. The pH (5.45-5.92), titratable acidity (0.05-0.07%) and emulsion activity (99.23-98%) were not significantly different among different flour types. The rest of the factors were significantly different (*p*=0.0001) among different sources of flour. Significant differences were observed between jackfruit and chempedak flak flour and their seed flour. All the flours are rich in crude fiber (5.52-6.86%) and in some flours' crude protein (12.45 % in 'wela' seeds) contents were high. Bulk density (0.5-0.86%), forming capacity(31.35% in 'Kothmalea' seeds), oil (250.95% in HB_2) and water (147.98% in HB_2) absorption capacities, and emulsion activity are the desirable functional properties of the tested flours that are important for dough preparations and other food formulations.

Keywords: Breadfruit, Chempedak, Flak flour, Jackfruit, Seed flour

Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.), breadfruit (*A. altilis* Parkinson), and chempedak (*A. integer*) have high productive abilities and growing potential in all parts of Sri Lanka if water is adequately available. In 2023, Sri Lanka imported 173,000 MT of wheat flour valued at more than Rs. 25 million to import (Sri Lanka Customs, 2023). To reduce the wheat flour that is being imported to Sri Lanka, suitable substitutes should be identified. Using fruits of these species to prepare flour during glut periods would minimize post-harvest losses and utilize them as an intermediate product in the processing industry.

The suitability of flour as a food or food ingredient will depend on its physio-chemical, proximate composition and functional properties. The physio-chemical properties such as titratable acidity and pH affect the solubility and the emulsion activity of flour (Nabubuya *et al*., 2012) and total soluble solids (TSS) gives the amount of water-soluble solids in the flour (Borela, 2018). The proximate compositions such as crude fiber and moisture content determine the shelf life of flour, as stated by Lin *et al*. (2010), the content of crude fat should maintain a maximum of 1.68% and flour's moisture percentage must be limited to 14% or less (Annon, 2020). Dietary fiber has beneficial effects on the human body, and attention is given to preparing fiber-enriched flour by modifying refined flour with fiber-containing flours (Zhang *et al*., 2018). Ash is the non-volatile inorganic element in flour, and its measure indicates the nutritive value of the food (Ocloo *et al*., 2010).

The functional properties of flour are influenced especially by carbohydrates, proteins, fats and oils, moisture, fiber, ash, and other ingredients in the material (Awuchi, 2019). Water absorption capacity is the amount of water absorbed by flour to achieve the desirable consistency and create appropriate organoleptic properties (Godswill, 2019) and oil absorption capacity is also an important property in food formulation as oil improves the flavor and mouth feel of a food (Ocloo *et al*., 2010). The oil absorption rate is associated with the available proteins in the flour, especially the nonpolar side chains of proteins (Godswill, 2019). Bulk density (BD) measures the heaviness of the flour and it depends on the particle size. It determines the method of handling and packaging of raw materials and wet processing in the food industry. The bulk density value is low if the starch polymer structure is loose (Reddy *et al*., 2022). The forming capacity (FC) of flour is associated with the amount of native, solubilized protein and the amount of polar and non-polar lipids in the sample (Chowdhury *et al*., 2012). Solubility is a process where flour is dissolved in a heated solution and higher solubility is linked to better baking performance (Huang *et al*., 2019). Swelling capacity measures the capacity of starch to absorb water and associative forces in the starch granules and it is an indication of α- amylose and amylopectin ratios and it increases when amounts of amylopectin increase (Godswill, 2019). A flour's emulsion activity is the protein's ability to improve solubility or the dispersive ability of immiscible solvents (Qadir and Wani ,2023).

Therefore, this study aimed to investigate the important physio-chemical and proximate and functional properties of flak and seed flour of selected Department of Agriculture (DOA) recommended jackfruit and chempedak varieties and flesh flour of breadfruit varieties. A commonly found "wela" type jackfruit (soft flak type) variety was also investigated. Therefore this study will provide useful information to the industry on alternative flour supplements to produce natural, cheap and acceptable food products.

Materials and Methods

The research was conducted at the Fruit Research and Development Institute (FRDI), Horana from harvest of two consecutive fruiting seasons (2022 and 2023). Three physiologically matured fruits from recommended jackfruit varieties, "Fatherlong", "Maharagama", "Kothmalea" and "Hirosha" and randomly selected (non-recommended) "wela" type verity (soft flack type) were harvested from the fruit orchard of Gannoruwa Fruit Research Unit. Similarly, physiologically matured fruits from "Horana Chempadak", "Horana Breadfruit 1" (HB_1) and "Horana Breadfruit 2" (HB_2) were harvested from the fruit orchard of FRDI, Horana. Approximately 2 kg of flaks (without seeds) were washed from each fruit and cut into one cm wide strips. Prepared strips were steam blanched in 1% sodium metabisulfite (SMS) solution. From each fruit, seeds were removed (approximately 1 kg) and cut into thin slices using a knife. Cut strips and slices of each variety were dried in a hot air oven for 24 hrs at 60 °C. Similarly, the flesh of breadfruits was pre-treated and dried. After drying, they were milled in a hammer mill and passed through 240 µm sieve mesh. Flours obtained from flaks and seeds were packed separately in polyethylene bags (gauge 300) and stored in a refrigerator (5-6 °C) until used for the analysis.

Proximate compositions including moisture (MO%), ash, crude fat (CF%), crude protein (CP%), crude fiber (F%), and carbohydrate (CHO%) were determined following the methods described in AOAC Official Method (1996). Physio-chemical parameters pH and total soluble solids (TSS) were determined using a digital refractometer (ATAGO-Japan) and digital pH meter (GOnDO electronics, Taipei ,Taiwan) respectively and titratable acidity (%TA) was determined using the method described by Tyl and Sadler (2017) and the percentage of lactic acid was calculated using the following formula;

$$\text{Lactic acid (\%)} = \text{Titer} \times \text{acid factor for lactic acid } (0.0038) \times 100/10\ mL^{-1} \quad \text{..........} (1)$$

The functional properties; bulk density (BD gml^{-1}), water (WAC%) and oil (OAC%) absorption capacities and emulsion activity (EA%) were determined using the methodology explained by Amandikwa *et al*. (2015), forming capacity (FC%) was measured as documented by Ocloo *et al*. (2010) and using the methodology described by Islam *et al*. (2015) swelling power (SP%) and solubility (So%) were also determined.

Treatments were assigned as a completely randomized design (CRD). All analyses were conducted in triplicate. One one-way ANOVA was conducted to determine the seasonal and varietal variation using the SAS package (9.1 Cary, NC, USA) and the least significant difference (LSD) was performed for mean separation. The correlation between chemical and functional properties was analyzed using the Pearson correlation analysis.

Results & Discussion

Physio-chemical Properties

The pH, and titratable acidity (TA) did not vary (p> 0.05) among the different flour types (Table 1) and all the tested flours were acidic (pH 5.45-5.99 and TA 0.05-0.07%). Under acidic conditions, solubility % and the emulsion activity (EA) of flour were decreased and the workability of flour becomes poor (Nabubuya *et al*., 2012). Therefore modifications are required to reduce the acid level of tested flours to improve the workability. Mukprasirt and Sajjaanantakul (2004), and Palamthodi *et al*. (2021) recorded pH of 5.35- 6.6 for jackfruit seed flour and pH of 5.6-6.5 for breadfruit flour by Akanbi *et al*. (2009) and Huang *et al*. (2019). For the TA of jackfruit seed flour, a similar value was recorded by Abraham & Jayamuthunagai (2014) (0.57%) and Ocloo *et al*. (2010) reported a higher value (1.12%) and da Silva & Narain (2021) (1.51%) also reported a higher value for breadfruit flour. Adeleke & Odedeji (2010), highlighted that acidic foods are more shelf-stable. Therefore the tested flours could be shelf-stable but need further studies to determine their shelf lives.

Maharagama flak flour and chempedak seed flour recorded higher TSS values than others (Table 1). Relatively high TSS-containing materials are used as thickening agents in the food industry (Bikila *et al*., 2022). Reddy *et al*. (2022) recorded 30.4 % TSS content in jackfruit seed flour after 180 days of storage.

Proximate Compositions

In the current analysis, moisture contents (MO) in ‘Maharagama” and “Fatrelong” falk flours had higher MO than the permissible level (14%) (Annon, 2020) and comparing flak and seed flours, comparatively less MO was available in seed flour than in falk flour (p=0.0001)(Table 1). Those flours with high MO (“Maharagama” and “Fatherlong’ flak flour) can combine with less MO seed flour (except for “chempedak” and “Maharagama” seed flour) to prepare composite flour preparations with desirable MO levels. However, studies are needed to investigate the properties of these composites. Similar to the present study, Ocloo *et al*. (2010) and Akanbi *et al*. (2009) recorded 6.09% and 10.83 % of MO in jackfruit seed flour and breadfruit flour, respectively but a higher value was recorded by Islam *et al*. (2015) in jackfruit seed flour (15.88%).

A higher crude fat (CF) was recorded in two breadfruit varieties and "Maharagama" and "Chempadak" seed flours (Table 1). Compared to flak flour (except for "Maharagama" and "Kothmalea" flaks), the seed flour (except for "Wela" seeds) recorded higher CF values than the permissible level (1.68%)(Lin *et al*., 2010). Concerning storability, flours with less CF could be recommended for long storage but fats and oils have positive organoleptic and functional properties on the baked products (Raghavendra *et al*., 2022). Therefore, flours with higher CF could be used in the bakery industry with required modifications to prevent oxidation. A CF value of 1.17% for jackfruit seed flour (Ocloo *et al*., 2010) and 0.97-2.5 % for breadfruit flour (Huang *et al*., 2019) were recorded in previous studies which were lower than those recorded in the current study.

In Hirosha flak and Chempedak seed flours higher crude fiber (F) contents were noted (Table 1). In the present study, a higher F was recorded in jackfruit seed flour than recorded by Ocloo *et al*. (2010) (3.19%). Similarly, a higher F content was recorded in tested flour sources than reported by Palamthodi *et al*. (2021), in wheat flour (0.37%). In breadfruit, a similar value (5.78%) was recorded by Adepeju *et al*. (2011).

In "Chempadak" flak and "Wela" and "Chempadak" seed flours, higher crude protein (CP) were noted than in the other flours (Tabel 1). Comparatively higher protein contents were recorded in the seed flour than in the flak flour (p=0.0001). Since form capacity (FC) is directly related to the available protein in raw material (Chowdhury *et al*., 2012) seed flour can be incorporated to improve FC of raw materials used in food applications. In the present study, CP for jackfruit seeds flour and breadfruit flour were similar to that reported by Ocloo *et al*. (2010) (13.50%) and Adepeju *et al*. (2011) (3.79%) respectively.

A higher percentage of ash was recorded in chempedak falk and Hirosha seed flours (Table 1). Though ash content indicates the nutritive value of flour, the technical quality of high-ash flour is lower because they are darker colored and has greater activity of proteolytic and amylolytic enzymes (Carson & Edwards, 2009). Compared to wheat flour (0.97%) jackfruit and breadfruit flour contain more ash (Palamthodi *et al*., 2021), therefore high ash content in current flours might affect the flour colour and its functional properties. However they can be used in preparing minerally enriched flour blends and preparing foods in which colour is not an important attribute. Similar outcomes were obtained by Ocloo *et al*. (2010) and Adepeju *et al*. (2011), for jackfruit seed flour (2.70%) and breadfruit flour (2.10%) respectively.

In the current analysis, a higher percentage of carbohydrates (CHO) was noted in "Hirosaha" flak and seed flours than in others (Table 1). The flours with high CHO are promising raw materials in the food industry and will improve food products' functional properties. All the tested flours are promising raw materials in the food industry similar to wheat flour (75-77%) (Palamthodi *et al*., 2021). Ocloo *et al*. (2010) and Adepeju *et al*. (2011) also reported similar results for CHO in jackfruit seed flour (79.34%) and in breadfruit flour (80-83%) respectively.

Table 1. Mean values of physio-chemical and proximate compositions of jackfruit, chempedak flak and seed and breadfruit flesh flour

Flour type	pH	TA(%)	TSS (%)	Moisture (%)	Crude Fat (%)	Crude Fiber(%)	Crude protein (%)	Ash (%)	Carbohydrate (%)
Wela flak	5.54 ± 0.3^{a}	0.06 ± 0.0^{a}	2.58 ± 0.4^{b}	13.62 ± 2.7^{bc}	0.21 ± 0.3^{e}	6.31 ± 0.0^{abc}	5.96 ± 0.0^{b}	3.13 ± 0.4^{a}	69.75 ± 1.5^{d}
Fatherlong flak	5.5 ± 0.19^{a}	0.06 ± 0.0^{a}	1.08 ± 0.2^{d}	14.95 ± 0.8^{b}	1.08 ± 0.3^{d}	5.49 ± 0.0^{d}	2.92 ± 0.0^{g}	2.73 ± 0.3^{bc}	72.53 ± 0.2^{bc}
Kothmalea falk	5.49 ± 0.1^{a}	0.06 ± 0.0^{a}	1.08 ± 0.2^{d}	12.08 ± 0.8^{cd}	1.79 ± 0.4^{c}	6.12 ± 0.0^{c}	3.40 ± 0.9^{de}	2.47 ± 0.2^{cd}	74.51 ± 0.7^{b}
Maharagama flak	5.88 ± 0.2^{a}	0.06 ± 0.0^{a}	3.16 ± 0.9^{a}	17.96 ± 2.2^{a}	2.13 ± 0.3^{b}	6.41 ± 0.0^{ab}	5.15 ± 1.0^{c}	2.80 ± 0.3^{b}	65.42 ± 0.2^{e}
Hirosha flak	5.56 ± 0.1^{a}	0.05 ± 0.0^{a}	2.00 ± 0.3^{c}	8.03 ± 0.3^{e}	1.08 ± 0.0^{d}	6.52 ± 0.1^{a}	2.68 ± 0.4^{g}	2.79 ± 0.3^{b}	78.60 ± 0.1^{a}
Chempedak flak	5.58 ± 0.0^{a}	0.06 ± 0.0^{a}	1.00 ± 0.3^{d}	12.20 ± 2.2^{cd}	1.50 ± 0.1^{c}	6.39 ± 0.1^{ab}	11.07 ± 0.5^{a}	3.13 ± 0.1^{a}	66.55 ± 0.4^{e}
HB 1	5.99 ± 0.1^{a}	0.05 ± 0.0^{a}	0.26 ± 0.3^{e}	13.39 ± 0.0^{bc}	3.33 ± 0.3^{a}	6.47 ± 0.0^{ab}	3.18 ± 0.0^{ef}	1.85 ± 0.3^{e}	71.82 ± 0.0^{cd}
HB 2	5.45 ± 0.1^{a}	0.06 ± 0.0^{a}	0.35 ± 0.2^{e}	10.43 ± 1.1^{d}	3.08 ± 0.0^{a}	6.21 ± 0.0^{bc}	3.85 ± 0.0^{d}	2.38 ± 0.3^{d}	74.35 ± 1.1^{b}
CV%	3.3	7.7	31.84	15.73	14.73	3.5	8.2	8.9	2.6
Wela seed	5.50 ± 0.3^{a}	0.05 ± 0.0^{a}	1.08 ± 0.2^{c}	8.92 ± 1.6^{bc}	1.33 ± 0.3^{d}	6.55 ± 0.0^{ab}	12.45 ± 0.0^{a}	2.68 ± 0.2^{b}	68.24 ± 1.2^{c}
Fatherlong seed	5.84 ± 0.1^{a}	0.06 ± 0.0^{a}	1.08 ± 0.4^{c}	6.45 ± 1.0^{d}	1.83 ± 0.3^{c}	6.39 ± 0.0^{bc}	11.25 ± 0.6^{b}	2.78 ± 0.2^{b}	71.32 ± 1.0^{b}
Kothmalea seed	5.74 ± 0.2^{a}	0.06 ± 0.0^{a}	1.08 ± 0.2^{c}	7.96 ± 1.0^{c}	2.25 ± 0.0^{ab}	5.52 ± 0.0^{d}	11.23 ± 0.0^{b}	2.54 ± 0.2^{b}	70.27 ± 0.9^{b}
Maharagama seed	5.69 ± 0.2^{a}	0.06 ± 0.0^{a}	1.41 ± 0.2^{b}	12.32 ± 2.0^{a}	2.54 ± 0.0^{a}	6.18 ± 0.0^{c}	11.56 ± 0.0^{b}	2.64 ± 0.3^{b}	64.59 ± 2.1^{d}
Hirosha seed	5.63 ± 0.2^{a}	0.07 ± 0.0^{a}	1.41 ± 0.4^{b}	6.52 ± 0.4^{d}	1.91 ± 0.4^{c}	6.15 ± 0.5^{c}	8.26 ± 0.9^{c}	3.31 ± 0.3^{a}	73.71 ± 1.2^{a}
Chempedak seed	5.92 ± 0.4^{a}	0.06 ± 0.0^{a}	2.00 ± 0.0^{a}	10.19 ± 1.0^{b}	2.41 ± 0.4^{a}	6.86 ± 0.1^{a}	12.16 ± 0.4^{a}	2.78 ± 0.1^{b}	65.60 ± 1.3^{d}
CV%	3.1	10.0	18.6	12.7	14.7	4.3	2.8	7.8	1.6

Note: The same superscripts within a column indicate no significant difference between different flour types at the 0.05 probability. % AT-titratable acidity, TSS-Total soluble solids content

Functional Properties

The water absorption capacity (WAC) of HB_2 breadfruit and Wela seed flour was higher than the current analysis's other flours (Table 2). Except for Maharagama and Wela flak flour, other flak flour absorbed more water (WAC) compared to seed flour (p=0.0001).The WAC of rice and wheat flour are 192% and 140%, respectively (Chandra & Samsher, 2013). Except for breadfruit flour, the WAC of all the flour was less than wheat flour. Therefore, their WAC could be improved by blending with wheat or rice flour and the present findings would be useful in preparing such blends. Different food formulae require different levels of hydration. Thus, there are varieties of flour, according to the requirement which a choice can be made. WAC of the present study was much lower than the findings of Reddy *et al*. (2022) (184.27%), higher than the findings of Ocloo *et al*. (2010) (25%) for jackfruit seed flour and similar to the findings of Adepeju *et al*. (2011), for breadfruit flour (154.7%). The variability between present and previous findings might be due to molecular structure, protein and carbohydrate concentrations, availability of hydrophilic groups, degree of grinding and presence of husk as explained by Reddy *et al*. (2022).

The oil absorption capacity (OAC) of "HB_2" breadfruit and Fatherlong seed flours was higher than the other flour types (Table 2). Except for "Maharagama" flak flour, other flak flours absorbed more oil (OAC) than seed flour (p=0.0001). The OAC of breadfruit flour in the current study was much higher than the OAC of rice (124%) and wheat flour (146%) (Chandra & Samsher, 2013). The OAC of jackfruit seed flour reported in the current study was similar to the findings of Reddy *et al*. (2022), (87.65%) and for breadfruit flour, Adepeju *et al*. (2011) also reported a similar value (139.9%).

According to Reddy (2022) and Godswill (2019) WAC and OAC are influenced by available CHO and P in the flour. Correlation analysis revealed weak positive correlations between CHO and WAC (r=0.4684, p=0.0001) and OAC (r=0.4107, p=0.0003) of flour and in the analysis of WAC and OAC with protein contents of flour, weak negative correlations for WAC (r=-0.38685, p=0.0008) and OAC (r=-0.39328, p=0.0006) were recorded. The negative correlation could be explained by the findings of Chandra & Samsher (2013) that water and oil absorption capacities are independent of the protein concentration but depend on the intrinsic factors of protein, like amino acid composition, protein conformation and surface polarity or hydrophobicity.

'Maharagama" falk and "Chempadak" seed flours showed higher BD than the other flours (Table 2). BD of the current study is similar to the BD of rice (0.914 gml^{-1}) and wheat flour (0.762 gml^{-1}) (Chandra & Samsher, 2013). Therefore, the handling and wet processing of flour in the current study should be similar to rice and wheat flour. BD of seed flour significantly differed in two years (p=0.0001) showing seasonal variation. Similar to the present study, Ocloo *et al*. (2010) and Reddy *et al*. (2022) reported BD of 0.73 and 0.8 gml^{-1} values respectively for jackfruit seed flour, Adepeju *et al*. (2011) reported 0.69-0.56 gml^{-1} for breadfruit flour.

Table 2. Mean values of functional properties of jackfruit, chempedak flak and seed and breadfruit flesh flour

Flour type	WAC (%)	OAC (%)	BD (gml^{-1})	FC (%)	SC	So (%)	EA (%)
Wela flak	86.49 ± 1.7^{e}	104.72 ± 0.5^{d}	0.76 ± 0.0^{c}	2.42 ± 0.4^{c}	3.43 ± 0.9^{f}	3.82 ± 1.1^{b}	99.12 ± 0.0^{a}
Fatherlong flak	111.03 ± 1.5^{c}	$108.09 \pm 5.^{cd}$	0.78 ± 0.0^{c}	2.38 ± 0.1^{c}	6.24 ± 0.6^{c}	3.89 ± 1.8^{b}	99.23 ± 1.2^{a}
Kothmalea falk	114.05 ± 1.3^{c}	117.15 ± 5.2^{c}	0.70 ± 0.0^{d}	2.65 ± 0.2^{c}	7.84 ± 0.0^{a}	3.39 ± 0.2^{c}	98.64 ± 1.7^{a}
Maharagama flak	75.73 ± 0.3^{f}	86.93 ± 0.4^{e}	0.86 ± 0.1^{a}	1.78 ± 0.8^{c}	5.14 ± 0.0^{d}	2.44 ± 1.6^{c}	98.73 ± 1.3^{a}
Hirosha flak	98.36 ± 1.4^{d}	107.83 ± 2.9^{cd}	0.81 ± 0.1^{b}	1.75 ± 0.7^{c}	4.67 ± 0.5^{e}	6.74 ± 0.6^{a}	98.14 ± 0.1^{a}
Chempedak flak	96.13 ± 5.2^{d}	115.66 ± 1.9^{c}	0.71 ± 0.01^{d}	24.19 ± 0.3^{a}	5.52 ± 0.1^{d}	0.88 ± 0.2^{d}	99.07 ± 0.7^{a}
HB 1	133.11 ± 1.0^{b}	139.38 ± 5.9^{bc}	0.65 ± 0.0^{e}	2.48 ± 0.7^{c}	6.06 ± 0.2^{d}	1.50 ± 0.7^{cd}	98.49 ± 0.1^{a}
HB 2	147.98 ± 1.3^{a}	250.95 ± 5.4^{a}	0.50 ± 0.0^{f}	4.84 ± 1.1^{b}	7.06 ± 0.3^{b}	1.83 ± 0.2^{c}	98.14 ± 0.2^{a}
CV%	4.8	7.1	2.9	32.2	5.9	27.6	0.8
Wela seed	97.40 ± 4.7^{a}	94.17 ± 4.7^{bc}	0.69 ± 0.0^{d}	23.51 ± 4.1^{bc}	6.52 ± 0.1^{b}	1.81 ± 0.6^{b}	98.69 ± 1.4^{a}
Fatherlong seed	87.87 ± 5.8^{c}	106.06 ± 5.8^{a}	0.74 ± 0.0^{bc}	25.62 ± 4.8^{b}	6.77 ± 0.3^{b}	1.97 ± 1.2^{b}	98.92 ± 0.9^{a}
Kothmalea seed	91.57 ± 5.7^{b}	88.14 ± 5.7^{cd}	0.75 ± 0.0^{b}	31.35 ± 1.8^{a}	6.02 ± 0.2^{c}	1.52 ± 1.5^{b}	98.72 ± 0.0^{a}
Maharagama seed	88.16 ± 5.6^{c}	85.97 ± 5.6^{d}	0.65 ± 0.0^{e}	26.57 ± 1.4^{b}	6.66 ± 0.1^{b}	3.77 ± 2.0^{a}	99.03 ± 0.7^{a}
Hirosha seed	85.50 ± 3.2^{d}	94.42 ± 3.2^{b}	0.72 ± 0.0^{c}	19.48 ± 3.1^{c}	7.71 ± 0.6^{a}	2.16 ± 0.1^{b}	98.00 ± 0.1^{a}
Chempedak seed	89.19 ± 0.9^{bc}	93.20 ± 0.9^{bc}	0.80 ± 0.0^{a}	10.36 ± 1.1^{d}	6.81 ± 0.1^{b}	1.74 ± 0.3^{b}	98.80 ± 1.3^{a}
CV%	1.5	5.9	2.3	16.8	4.9	42.1	0.7

Note: The same superscripts within a column indicate no significant difference between different flour types at the 0.05 probability. % WAC-water absorption capacity,% OAC-oil absorption capacity, BD-Bulk density, % FC-forming capacity, SC-swelling capacity, % So-solubility, % EA-emulsion activity.

Chempedak flak and Kothmalea seed flours reported higher values for forming capacity (FC) (Table 2). Flak flour scored much lower values for FC than seed flour (p=0.0001) except "Chempedak" falk flour. Except for "Chempedak" seed, all other seed flour exhibited higher FC than wheat flour (12.92%) and rice flour (3.52%) as reported by Chandra and Samsher (2013). In the current study, a strong positive correlation between protein content and FC (r= 81826, p≤0.0001) was identified. In contrast, a lower FC value (10.36%) was recorded in Chempedak seed flour though it contained a higher P (12.16%). Hasmadi *et al*. (2020) explained that, unlike flexible protein molecules, higher-ordered globular protein molecules do not reduce surface tension to increase FC. Accordingly, Chempedak seed might have higher-ordered globular protein molecules than flexible protein. Ocloo *et al*. (2010) reported 25.34% of FC of jackfruit seed flour but for breadfruit flour a higher value (20%) was recorded by Akubor *et al*. (2000).

"Kothmalea" flak and "Hirosha" seed had higher swelling capacity (SC) compared to the other flours (Table 2). SC of seed flour significantly differed in two years (p=0.0001) showing seasonal variation. Compared with SC of wheat (17.60) and rice flour (15.20) (Chandra & Samsher, 2013), SC of the present study was much lower. Flour with comparatively low SC indicates the presence of high amylose content or starch granules with strong bonds. Accordingly, flour extracted from jackfruit and Chempedak flakes and seeds and breadfruits might have higher amylose content than conventional flours. Mukprasirt and Sajjaanantakul (2004), reported that jackfruit seed contains 36.67% amylose. The bakery products produced with these flours will not swell well and therefore they need modification or blending with high SC flours like cassava (42-71) (Kusumayanti *et al*., 2015) to get the desired swelling. Similar to the current findings, Mukprasirt and Sajjaanantakul (2004) and Ocloo *et al*. (2010), reported SC of jackfruit seed flour 8.61 and 4.77, respectively. According to Adepeju *et al*. (2011), the SC of breadfruit flour varied 1.72-4.48 but in the present study, values were higher than the previous findings.

Higher solubility (So) was recorded in 'Hirosaha" flak and "Maharagama" seed flours than others (Table 2). Some of the So values recorded in the present study were similar to whole wheat flour (4.78%) (Dhillon *et al*., 2020) and rice flour (1.96-4.96%) (Jamal *et al*., 2016). Research conducted by Kusumayanti *et al*. (2015) revealed that swelling power decreases in contrast to its solubility in cassava and sweet potato. That might be the reason for a weak negative correlation recorded between SC and So (r=-0.34155, p=0.0033) in the present study. As recorded by Mukprasirt and Sajjaanantakul (2004) and Reddy *et al*. (2022), the So of jackfruit seed flour was 17.08 and 1.46 % respectively and in breadfruit flour, it is 7.94 % (Akanbi *et al*., 2009). In the present study, some of the jackfruit varieties gave similar results as reported by Reddy *et al*. (2022). Solubility of breadfruit flour was much lower than the previous finding.

The emulsion activity (EA) of different flour types did not differ ($p>0.05$). A research conducted by Palamthodi *et al*. (2020) revealed that adding jackfruit flour to wheat flour increases EA of wheat flour. Therefore flour of jackfruit, chempedak and breadfruit could be used in blending to enhance the functional properties of conventional flours. Akubor *et al*. (2000), discovered that EA of roasted breadfruit, wheat and rice flours were 54.4% ,43.88% and 41.84%, respectively (Chandra & Samsher, 2013). However, the findings of the present were much higher than the previous findings.

Conclusions

Flour from tested sources could be incorporated into dietary fiber-enriched flour blends for preparing fiber-rich foods. Chempedak flak and seed flour and jackfruit seed flour can be used as protein supplements in food preparations. Desirable bulk density in jackfruit flak and seed flour would be vital in food preparations as thickening agents. The high forming capacity of jackfruit seed flour can be successfully used in bakery products to enhance volume, texture and aeration. High water and oil absorption capacities of HB_2 flour can have desirable organoleptic and functional properties in dough preparations and other food formulations. Since the emulsion activity of studied flour sources is high, foods made out of them would be more digestible and therefore suitable, to use as an ingredient in infant food formulations. The outcome of this study will be vital in selecting flour for the preparation of desirable flour blends.

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