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ASSESSMENT OF BREADFRUIT (*ARTOCARPUS ALTILIS,* (PARKINSON) FOSBERG) CULTIVARS FOR RESISTANT STARCH, DIETARY FIBRE AND ENERGY DENSITY

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ABSTRACT

Breadfruit (*Artocarpus altilis*) is being promoted for increased consumption as a staple for food and nutrition security, improved livelihoods and environmental conservation, especially, in tropical regions such as the Pacific, Africa and the Caribbean where the species is well adapted. The fruit has a high starch content, however, further information is needed on nutritional properties that influence its energy density which could have implications for how it is consumed especially considering the high incidence of diet related non-communicable diseases. This study evaluated dietary fibre; total, resistant and non-resistant starch contents; total and available carbohydrate contents; and energy density of flour from 21 Caribbean and Pacific breadfruit cultivars. There were significant differences ($p<0.05$) among cultivars for all parameters measured. Depending on cultivar, the values ranged from 6.7 to 13.73 g/100 g for dietary fibre exclusive of resistant starch, from 28.16 to 50.53 g/100 g for resistant starch, from 14.87 to 34.93 g/100 g for non-resistant starch, from 63.68 to 82.57 g/100 g for total starch, from 83.54 to 93.64 g/100 g for total carbohydrate and from 25.37 to 40.61 g/100 g for available carbohydrate. Available carbohydrate content was approximately 36% of the total carbohydrate, indicating that although total carbohydrate content was high, most of it is not readily digested and absorbed in the small intestines. Based on low available carbohydrate content due to high dietary fibre content inclusive of resistant starch, the overall mean energy density was 158.14 ± 2.56 kcal/g and values ranged from 113.39 to 179.39 kcal/g, indicating that breadfruit flour can be classified as a low to medium energy density food depending on cultivar. These results showed the importance of screening to identify cultivars with unique nutritional properties related to resistant starch, dietary fibre and energy density. Additionally, the observed energy density values may support the promotion of breadfruit as a functional food with considerable potential for the dietary management of diet related non-communicable diseases such as obesity and type 2 diabetes.

Key words: available carbohydrate, non-communicable diseases, obesity, type 2 diabetes, underutilized crop

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INTRODUCTION

Breadfruit (*Artocarpus altilis*) is an underutilized, multipurpose, perennial tropical tree species, which was first domesticated and distributed in the Pacific region. It was introduced to the Caribbean in 1793 from where it was distributed to West Africa and, in the 1950's, from the Seychelles to Tanzania [1, 2]. Since 2009, through the Global Hunger Initiative mounted by the Breadfruit Institute, thousands of breadfruit plants have been distributed to alleviate hunger particularly in the Food and Agriculture Organization (FAO) list of low income, food deficit countries [3, 4]. The ability of the trees to maintain high levels of production over many years makes this species an appropriate choice for this purpose. Although time to bearing and productivity vary with cultivars, locations, production systems and levels of management, well-managed trees grown in pure stand begin bearing in two to four years and annual yield of mature trees generally exceeds 200 kg in the Caribbean [5]. Most cultivars have two bearing periods and fruits can be available for nine to ten months annually where cultivars with different or more than two bearing periods are planted [5].

Breadfruit is a good source of carbohydrate, as well as several minerals and vitamins and has a complete amino acid profile [6, 7]. It is cooked by boiling, steaming, roasting, baking or frying for a wide range of dishes including those in which it may serve as a substitute for other starchy foods such as white potato or yam [8, 9]. Studies on consumer preferences, consumer demand as well as on the physicochemical properties of the starch and other properties provide information to support the potential for increased consumption of breadfruit [8, 10, 11]. Several studies have also suggested that breadfruit is high in dietary fibre (DF) [12], however, because of varying definitions and methods of determination for DF, results among the studies also varied. In 2009, the CODEX Alimentarius Commission defined DF as "carbohydrate polymers with 10 or more monomeric units, which are not hydrolysed by endogenous enzymes in the small intestine of humans" [13]. Based on this definition, some food components not previously measured as DF, such as resistant starch (RS), are now included in the definition and method of determination [12].

There is evidence to suggest that the regular consumption of breadfruit is a healthier alternative to some popular staples and may be useful to help prevent or mitigate the effects of several diet related non-communicable diseases such as type 2 diabetes, obesity and hypertension, which are of serious public health concern worldwide [12, 14]. Diabetes is projected to become the seventh leading cause of death globally by 2030 and urgent attention is needed to help address this problem [15]. Among middle and low income developing regions, the Caribbean had the highest prevalence of diabetes in 2017 with 13.9% of the adult population being affected, while the Western Pacific had 37% of the total number of people in the world living with diabetes [16]. Even in sub-Saharan Africa, it was projected that by 2045, the 2017 figure of 15.9 million people living with diabetes will increase by 162% [16].

Although breadfruit is highly nutritious, cultivar differences have been reported based on physicochemical properties including total carbohydrate, dietary fibre, protein,

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vitamins, minerals, carotenoids and amylose and amylopectin contents [7, 11, 17, 18]. On this basis, it would be important to determine whether cultivar differences exist in those nutritional properties that are relevant to dietary issues associated with non-communicable diseases such as type 2 diabetes. Therefore, the objectives of this study were to evaluate the dietary fibre (DF), resistant starch (RS), non-resistant starch (NRS), total starch (TS), total and available carbohydrate contents as well as energy density of breadfruit flour derived from different cultivars.

MATERIALS AND METHODS

Plant Material and Fruit Collection

The fruits used in this study were from trees representing 20 known cultivars and one unidentified accession grown at the breadfruit germplasm collection of the University of the West Indies, St Augustine Campus in Trinidad and Tobago (10° 38.376'N, 061° 25.790' W). The trees represented 14 cultivars from the Pacific, that were collected from the National Tropical Botanical Garden (NTBG) in Hawaii, United States of America ('Afara', 'Fafai,' 'Huehue', 'Ma'afala', 'Meitehid', 'Momolega', 'Piipiia', 'Porohiti', 'Pu'upu'u', 'Roihaa', 'Toneno', 'UW006') and from Samoa ('Aveloloa', and 'Puou'), while seven were from the Caribbean ('Creole', 'Kashee Bread', 'Macca', 'Timor', 'White', 'Yellow', and 'Yellow Heart') [19]. At least ten fruits on each tree were tagged at the earliest stage after emerging from the terminal leaf sheath.

Flour Preparation

Mature, unripe fruits were harvested, washed, and the peduncles removed. The fruits were then inverted for approximately 1 h to allow the latex to drain out. After draining, fruits were cut into quarters, peeled, cored and the seeds of seeded cultivars removed and discarded. For each cultivar, a composite sample of pulp from three fruits was sliced into 2 mm sections using an electric slicer (Slicer Rheninghaus, Model: Argenta). The slices were dried at 60 °C for 24 h in food dehydrators (Nesco American Harvest) to achieve a moisture content of less than 10%, then milled into flour using a single-phase motor grinding mill (The Straub Company, Model: 4E).

Resistant and Non-Resistant Starch Analyses

Resistant starch was analysed in triplicate for each cultivar following the procedure described in Megazyme Resistant Starch Assay Procedure [20]. For each sample, 100 ± 5 mg of breadfruit flour was sieved using a 1.0 mm screen, placed in a screw cap glass tube and incubated in a shaking water bath (Precision Scientific, Model 66722) with pancreatic α-amylase and amyloglucosidase for 16 h at 37 °C and then treated with 4 ml of 99% (v/v) ethanol. The RS was recovered as a pellet by centrifugation for 10 min. at 3000 rpm. The pellet was washed twice with 50% ethanol by stirring on a vortex mixer and was collected by centrifugation. The RS pellet was dissolved in 2 ml of 2 M potassium hydroxide by vigorously stirring in an ice-water bath with a magnetic stirrer. Sodium acetate buffer (8 ml) and amyloglucosidase (0.1 ml) were added to the sample, followed by incubation at 50 °C for 30 min with intermittent mixing on a vortex mixer. An aliquot of 0.1 ml of the sample was collected, and 3.0 ml of glucose oxidase/peroxidase reagent was added before incubation at 50 °C for 20 min. RS was

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determined based on the sample dry weight and spectrophotometric analysis of D-glucose based on equation 1.

Equation 1 $$TS = \Delta E \; x \; F/W \; x \; FV \; x \; 90$$

Where, ΔE is the absorbance (reaction) read against the reagent blank, F is 100 (µg of D-glucose)/ absorbance for 100 µg of glucose, W is the dry weight of the sample analysed and FV is the final volume in the sample.

Non-Resistant starch (NRS) for each sample was calculated as the difference between total starch (TS) and RS.

Total Starch Analysis

Total starch was analysed in triplicate for each of the 21 cultivars following the procedure described in the Megazyme Total Starch Assay Procedure (Amyloglucosidase/α-Amylase Method) [21]. For each sample, 100 ± 5 mg of flour was sieved with a 0.5 mm screen, placed in a glass tube, moistened with 2 ml of 80% ethanol (v/v) and stirred using a vortex mixer. The sample was then dissolved in 2 ml of 2 M potassium hydroxide and vigorously stirred in an ice-water bath with a magnetic stirrer for 20 min. The sample was treated with 8 ml of 1.2 M sodium acetate buffer (pH 3.8) while being stirred on a magnetic stirrer followed by the addition of 0.1 ml thermostable α-amylase and 0.1 ml amyloglucosidase. The sample was then incubated in a 50 ^{o}C water bath for 30 min with intermittent mixing on a vortex mixer. The content of each glass tube was transferred to a 100 ml volumetric flask and the volume adjusted to 100 ml. An aliquot of 0.1 ml was collected and 3.0 ml of glucose oxidase/peroxidase reagent was added before incubation at 50 ^{o}C for 20 min. The D-glucose level was obtained by measuring the absorbance at 510 nm using a UV-Vis spectrophotometer (Shimadzu Model: UVmini-1240). The TS on a dry weight basis of the sample was then calculated using equation 2.

Equation 2 $$TS = \Delta A \; x \; F/W \; x \; FV \; x \; 0.9$$

Where, ΔA is the absorbance (reaction) read against the reagent blank, F is 100 (µg of D-glucose)/ absorbance for 100 µg of glucose, W is the dry weight of the sample analysed and FV is the final volume in the sample.

Proximate Analysis

Nutrient composition was determined by the Association of Official Agricultural Chemists (AOAC) official methods. The dry matter (DM) content was determined according to Method 934.01 [22], crude protein (CP) content (N x 6.38) by Method 920.87, crude fat (CF) content by Method 922.06, total ash (TA) content by Method 923.03 and dietary fibre (DF) content by Method 985.29. Total carbohydrate (TCHO) content was estimated by using the arithmetic difference between dry matter and the sum of crude fat, crude protein and total ash based on equation 3.

Equation 3 $$TCHO = DM - (CP + CF + TA)$$

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Available carbohydrate (ACHO) content was determined by the difference between TCHO and the sum of dietary fibre and resistance starch (RS) using equation 4.

Equation 4 $$ACHO = TCHO - (DF + RS)$$

Energy Density
Energy Density was calculated as total and available energy based on TCHO and ACHO according to the Atwater coefficients [23].

Statistical Analysis
Descriptive and inferential statistical analyses were conducted using Minitab 17 statistical software. One-way ANOVA was done at the 5% significance level to test for significant differences in DM, TS, RS, NRS, DF, TCHO, ACHO, and energy density among the breadfruit cultivars. When significant differences were detected, Tukey's studentized range test was carried out to determine which cultivars were different. Pearson's correlation coefficient was used to investigate the relationship between some of the parameters measured.

RESULTS AND DISCUSSION

Dry Matter
Dry matter percentage of flour among breadfruit cultivars was significantly different ($p<0.001$) and ranged from 92% to 95.3% (Figure 1) with an overall mean of 93.51 ± 0.14 %, which was slightly higher than the value of 89.94% reported for flour from seven Samoan breadfruit cultivars [24]. However, the results of both studies showed considerable variability among cultivars. Other factors that could contribute to slight differences between both studies include different maturities of fruits evaluated and different times and temperatures used for drying.

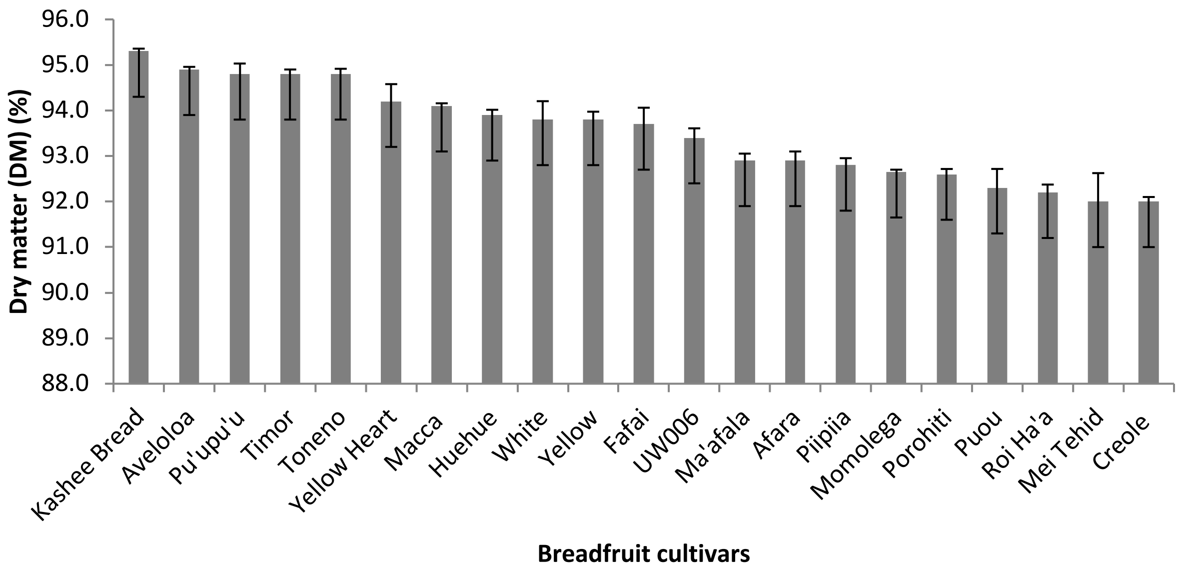

Figure 1: Dry matter content of 21 breadfruit cultivars (error bars indicate standard error of the means)

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Resistant Starch, Non-resistant Starch and Dietary Fibre

The RS content in the present study was high in all breadfruit cultivars with an overall mean of 46.03 ± 0.56 g/100 g. However, the differences in RS content among cultivars were highly significant ($p<0.001$) (Table 1). Of the cultivars examined, 'Ma'afala' contained the highest levels of RS, of 50.53 ± 0.30 g/100 g and 'UW006' had the lowest levels with 28.16 ± 0.82 g/100 g. Other cultivars with similarly high levels of RS as 'Ma'afala' included 'Fafai', 'Porohiti', 'Macca', 'Toneno', 'Piipiia', 'Aveloloa', 'Afara', 'Puou', 'Huehue', 'Pu'upu'u', and 'Yellow' (Table 1). All breadfruit cultivars in the current study had higher RS content than the mean of 14.9 g/100 g among five sweet potato (*Ipomoea batatas*) cultivars evaluated in Sri Lanka [25]. Most breadfruit cultivars in the current study also had higher RS content than the mean of 39.1 g/100 g for flour of five banana (*Musa spp.*) cultivars reported in Micronesia [26]. However, another study on banana, reported a RS content of 72.1 ± 5.7 g/100 g for raw green fruit from an unidentified cultivar [27]. The differences in RS content from the two studies on banana might be related to factors such as cultivar differences, fruit maturity and testing methods.

The non-resistant starch content of breadfruit flours was lower than the RS content among all cultivars except 'UW006'. The overall mean NRS was 25.35 ± 0.71 g/100 g and cultivar differences were highly significant ($p<0.003$) (Table 1). 'UW006' had the highest content of NRS followed by 'Roihaa' while 'Macca' had the lowest levels of NRS followed by 'Afara', and 'Momolega'. Interestingly, of the four cultivars that had NRS > 30g/100 g on a dry weight basis ('UW006', 'Roihaa', 'Aveloloa', and 'Puou'), two of these ('Aveloloa' and 'Puou') also had high levels of RS (Table 1). The relationship between RS and NRS was significant ($p<0.005$) and moderately negatively correlated ($r = -0.586$) suggesting that for most cultivars, high RS content is usually associated with low NRS or *vice versa*. However, cultivar selection is important to maximize the benefits of RS in relation to the NRS content of each cultivar. Other factors such as stage of fruit maturity and method of preparation of final products are also likely to influence the RS and NRS content [28].

The AOAC Method 985.29 for DF determination used in this study did not include RS, and it was not considered as a determination of total dietary fibre. This allowed for comparison of DF values among this study and previous studies that did not measure RS. The DF content of flour among 14 breadfruit cultivars was significantly ($p<0.001$) different and ranged from 6.70 to 13.97 g/100 g for 'Puou', and 'Yellow', respectively. Crude fibre values, based on the AOAC (1975) methods, ranged from 2.87 – 5.01% for seven Samoan breadfruit cultivars [24] and were much lower than DF values obtained in the present study. However, based on the AOAC 1990 methods, values of 43.67 ± 0.47 and 4.7 ± 0.26 for insoluble fibre (which included RS) and soluble fibre, respectively, were reported for one Venezuelan breadfruit cultivar [29]. These results for insoluble fibre are closer to those of the present study for RS only, but are less consistent when combined values for insoluble and soluble fibre are compared with combined values for DF and RS (Table 1). Another study which compared steamed pulp of 20 breadfruit cultivars, reported a total dietary fibre range of 2.13 - 7.34 g/100 g (wet weight), which

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when converted to a dry weight basis (7.72 – 21 g/100 g) is closer to the DF range (excluding RS) in the present study [30]. The differences in the results of the previous studies and the present study revealed some of the challenges when comparing results for fibre content of breadfruit because of differences in testing methods, sample preparation, cultivars and possibly, fruit maturity. However, it is clear that measurements that include RS would give much higher estimates for the fibre content of breadfruit.

The assessment of RS content has not been previously reported for breadfruit flour but the present study demonstrates how its determination affects what is measured and reported as DF, and also the estimation of energy density. The present study also showed that RS content was on average more than 400% higher than the DF content in breadfruit. With the application of the revised Codex Alimentarius definition of dietary fibre, these findings suggest that breadfruit flour DF is much higher than was estimated by the AOAC Method 985.29, and that RS is a major constituent of the DF of breadfruit.

Dietary fibre, including RS, causes an increase in the transit and digestion time of food through the digestive system because it is metabolised 5 to 7 hours after consumption compared with NRS which is digested almost immediately [31]. Additionally, the increased time required for digestion of food rich in DF and RS has the potential to increase the period of satiety, which may help to improve metabolic control associated with type 2 diabetes and aid in weight management [32]. The recommended daily allowance (RDA) for RS has not been determined but the RDA for DF is 30 – 38 g and 21- 26 g for males and females, respectively, between the ages of 14 to 50 [33]. According to one study, the consumption of 500 g of fresh breadfruit would satisfy the daily dietary requirement of 20-35 g of DF, which complies with the United States Department of Agriculture (USDA)'s RDA of 30 g [30]. Based on the findings of this study, approximately 53g of uncooked breadfruit flour, which is equivalent to 160 g of edible breadfruit pulp, would satisfy the RDA of 30 g of DF (including RS). This can be easily achieved because a study in the Caribbean showed that most consumers eat more than 216 g/meal and that breadfruit was often eaten at more than one meal per day [8]. Therefore, even smaller portions per meal may satisfy the RDA depending on the choice of cultivar.

Total Starch

The mean total starch content over all cultivars was 71.38 ± 0.64 g/100 g and cultivar differences were significant ($p<0.001$). Most cultivars (66.7%) had TS higher than 70 g/100 g. Starch is the major carbohydrate constituent (71.38% of DM and 91% of TCHO), which corroborates previous reports of high TS content in breadfruit. The TS content of flour from seven Western Samoan breadfruit cultivars ranged from 61.5 to 73.1% with an overall mean of 68.6% [24], and were lower than values obtained in the present study. For example, cultivars 'Aveloloa', 'Puou', and 'Ma'afala' had TS content of 82.57 ± 0.48 g/100g, 80.01 ± 0.76 g/100 g and 70.73 ± 0.73 g/100 g, respectively, in the present study compared with 67.7 g/100 g, 72.1 g/100 g and 66.7 g/100 g, respectively, as reported in a Samoan study for the same cultivars [24]. The differences in the values may be attributed to differences in testing methods, production conditions, and fruit maturity. Fruit maturity was also correlated with starch content [34], therefore,

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variation in maturity was highlighted as a limitation to comparing results of different studies [35]. Resistant starch was significantly ($p<0.016$) and moderately correlated with TS ($r = 0.518$), which indicates that higher TS content is expected to be associated with higher RS content among breadfruit cultivars.

Carbohydrates

The results of this study confirm that breadfruit flour is a rich source of TCHO with overall mean of 88.56 ± 0.56 g/100 g, which accounts for approximately 94% of total dry matter on average. Another study reported TCHO content ranging from 25 - 33 g/100 g, from the steamed pulp of 20 breadfruit cultivars, which is similar to the present study when values were converted on a dry matter basis (90 - 94%) [30]. Therefore, breadfruit is superior or similar in TCHO content to more popular staples such as rice (77.83 g/100 g) [36] and corn (66.12 g/100 g) [37]. The highest TCHO content was observed for cultivar 'Creole' (93.64 ± 0.63 g/100 g) while 'Toneno' (83.54 ± 0.29 g/100 g) had the lowest TCHO content (Table 1).

Although TCHO was high among all cultivars, nutritional differences between available and unavailable carbohydrates based on absorption in the small intestine influence other nutritional properties of food such as available energy and glycaemic index [36]. Available carbohydrates are readily hydrolysed into D-glucose and D-fructose and absorbed in the small intestine [38, 39]. Total carbohydrate and ACHO values based on inclusion and exclusion of the RS, respectively, have not been previously reported. High RS content resulted in marked differences between TCHO and ACHO contents of breadfruit flour for most cultivars. Based on the overall means, ACHO was approximately 36% of the TCHO, indicating that although TCHO content was high, most of it is not readily digested and absorbed in the small intestines. This is linked to the high levels of DF including RS that comprised approximately 64% of the TCHO of breadfruit flour which vastly influenced the ACHO content.

Energy Density

Differences among 14 breadfruit cultivars in energy density based on TCHO content were highly significant ($p<0.001$) and ranged from 340.53 kcal/100 g to 408.80 kcal/100 g with an overall mean of 385.98 ± 2.47 kcal/100 g (Table 2). Similarly, differences among cultivars in energy density based on ACHO content were also very highly significant ($p<0.001$) with a range from 113.39 ± 0.87 kcal/100 g to 179.39 ± 1.36 kcal/100 g for cultivars 'Toneno', and 'Creole', respectively and with an overall mean of 158.14 ± 2.56 kcal/100 g that was 59% lower than the overall mean energy density based on TCHO (Table 2). This shows that using the TCHO content of breadfruit overestimates the amount of energy that is actually available.

Based on their energy supply, foods are classified as: very low energy density (<0.6 kcal/g), low energy density (0.6 - 1.5 kcal/g), medium energy density (1.5 - 4 kcal/g) and high energy density (> 4 kcal/g) [40]. According to this ranking, the energy densities of breadfruit flour of all cultivars in this study were in the upper medium density range when calculated using TCHO, whereas when based on ACHO, no cultivar had energy density higher than 1.79 kcal/g and the mean energy density of breadfruit flour bordered

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on the low range (1.58 kcal/ g). While 'Toneno' (1.13 kcal/g), and 'Timor' (1.49 kcal/g) can be classified as low energy density cultivars, there were other cultivars such as 'Aveloloa', 'Ma'afala', 'Macca', and 'Piipiia' with energy density values that were not significantly higher. Furthermore, the use of ACHO better facilitated distinction among cultivars in energy density. 'Creole,' 'Ma'afala', and 'Macca' were not significantly different when energy content was estimated based on TCHO, whereas with the use of ACHO, 'Creole' had significantly higher energy content than 'Macca' and 'Ma'afala'. Therefore, based on these results, if selection for cultivation was based solely on low energy density, the best cultivars, in declining order, would be 'Toneno', 'Timor', 'Ma'afala', 'Piipiia', 'Macca', 'Aveloloa', and 'Yellow', while 'Yellow Heart', 'Meitehid', and 'Puou' might also be eligible. However, other important criteria, for example, desirable starch characteristics for a specific product may also influence cultivar selection [5].

Consumption of foods with very low to medium energy densities results in lower calorie intake per gram of food and is recommended for weight control and management of type 2 diabetes [41]. The low to medium energy density of breadfruit discovered in this study may be associated with the reported low to intermediate glycaemic index of cooked breadfruit reported in a previous study [14]. Therefore, the findings of this study may support recommendations for the consumption of breadfruit as a healthy option in helping to manage diet related non-communicable diseases affected by dietary choices [12, 14, 35].

CONCLUSIONS

Breadfruit is a rich source of carbohydrate with starch being the major carbohydrate component. The results indicated that breadfruit comprises high levels of RS, which increases the overall DF content and contributes to it being a low to medium energy density food depending on cultivar. Therefore, breadfruit can be considered as a healthy source of carbohydrates. This study may validate and support the promotion of increased breadfruit consumption for the dietary management of type 2 diabetes, obesity, and related non-communicable diseases, especially in tropical countries where these diseases are currently major health challenges. Additionally, deliberate selection of cultivars for these purposes is suggested.

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Table 1: Resistant starch (RS), non-resistant starch (NRS), dietary fibre (DF), total starch (TS), total carbohydrate (TCHO) and available carbohydrate (ACHO) content on a dry matter basis of flour from 21 breadfruit cultivars

Cultivar	RS (g/100 g)	NRS (g/100 g)	DF (g/100 g)	Combined DF + RS (g/100 g)	TS (g/100 g)	TCHO (g/100 g)	ACHO (g/100 g)
	Mean ± SEM	Mean ± SEM	Mean ± SEM[#]	Mean	Mean ± SEM	Mean ± SEM	Mean ± SEM
Afara	47.48 ± 0.80 abcde	17.32 ± 1.08 fg	9.11 ± 0.26 de	56.59	64.80 ± 0.79 hi	92.97 ± 0.23 a	36.38 ± 0.81 b
Aveloloa	47.64 ± 0.84 abcde	34.93 ± 1.03 a	10.29 ± 0.23 cd	57.93	82.57 ± 0.48 a	91.90 ± 0.25 ab	33.97 ± 0.67 bc
Creole	42.50 ± 0.82 f	28.97 ± 0.80 bc	10.53 ± 0.05 cd	53.03	71.48 ± 0.58 def	93.64 ± 0.63 a	40.61 ± 0.23 a
Fafai	50.06 ± 1.30 a	26.57 ± 1.41 cd	-	-	76.63 ± 0.16 bc	-	-
Huehue	47.15 ± 1.30 abcde	26.60 ± 1.58 cd	-	-	73.75 ± 0.39 cdef	-	-
Kashee Bread	44.05 ± 0.38 ef	26.43 ± 0.49 cd	13.53 ± 0.26 ab	57.58	70.49 ± 0.18 efg	90.33 ± 0.75 ab	32.75 ± 0.10 cd
Ma'afala	50.53 ± 0.30 a	20.20 ± 0.99 ef	11.40 ± 0.61 c	61.93	70.73 ± 0.73 efg	89.80 ± 0.78 abc	27.87 ± 0.23 ef
Macca	49.46 ± 0.11 abc	14.87 ± 1.01 g	8.33 ± 0.35 efg	57.79	64.34 ± 1.10 hi	84.90 ± 1.02 de	27.10 ± 0.56 f
Meitehid	46.89 ± 0.12 abcde	26.36 ± 0.12 cd	9.35 ± 0.08 de	56.24	73.25 ± 0.23 cdef	92.62 ± 0.45 a	36.38 ± 0.33 b
Momolega	45.98 ± 0.66 cdef	17.70 ± 0.50 fg	-	-	63.68 ± 1.16 hi	-	-
Piipiia	47.81 ± 0.40 abcd	19.50 ± 0.35 ef	13.73 ± 0.38 a	61.54	67.31 ± 0.48 gh	85.03 ± 1.83 de	25.37 ± 0.81 f
Porohiti	49.77 ± 0.42 ab	22.57 ± 0.16 de	-	-	72.34 ± 0.33 def	-	-
Puou	47.33 ± 0.68 abcde	32.68 ± 0.27ab	6.70 ± 0.06 g	54.03	80.01 ± 0.76 ab	88.09 ± 0.07 bcd	34.06 ± 0.67 bc
Pu'upu'u	46.99 ± 0.37 abcde	20.06 ± 0.19 ef	-	-	67.05 ± 0.30 gh	-	-
Roiha'a	42.35 ± 0.51 f	34.37 ± 0.49 a	-	-	76.72 ± 0.07 bc	-	-

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Table 1 (continued)

Cultivar	RS (g/100 g)	NRS (g/100 g)	DF (g/100 g)	Combined DF + RS (g/100 g)	TS (g/100 g)	TCHO (g/100 g)	ACHO (g/100 g)
	Mean ± SEM	Mean ± SEM	Mean ± SEM	Mean	Mean ± SEM	Mean ± SEM	Mean ± SEM
Timor	46.26 ± 0.60 bcde	26.61 ± 0.21 cd	11.77 ± 0.84 bc	58.03	72.87 ± 0.81 cdef	84.87 ± 1.54 de	26.84 ± 0.71 f
Toneno	48.78 ± 0.48 abc	22.57 ± 1.14 de	8.00 ± 0.18 efg	56.78	71.35 ± 1.34 def	83.54 ± 0.29 e	26.76 ± 0.19 f
UW006	28.16 ± 0.82 g	34.61 ± 0.85a	-	-	62.77 ± 0.25 i	-	-
White	45.47 ± 0.39 def	24.30 ± 0.48 d	7.20 ± 0.15 fg	52.67	69.73 ± 1.22 fg	85.37 ± 0.50 de	32.35 ± 0.57 cd
Yellow	46.87 ± 0.20 abcde	26.90 ± 0.52 cd	13.97 ± 0.27 a	60.84	73.77 ± 0.63 cde	91.27 ± 1.02 ab	30.43 ± 0.89 de
Yellow Heart	45.76 ± 0.53 cdef	29.25 ± 0.94 bc	8.70 ± 0.32 def	54.46	75.02 ± 0.61 cd	85.50 ± 0.36 cde	31.04 ± 0.27 d
Overall	46.03 ± 0.56	25.35 ± 0.71	10.19 ± 0.37	56.22	71.38 ± 0.64	88.56 ± 0.56	31.60 ± 0.69

*SEM; standard error of the mean
[#]Values within the same column that do not share a letter are significantly different
- Not evaluated

Table 2: Energy value of flour among 14 breadfruit cultivars

Cultivar	Energy based on TCHO (kcal/100 g)	Energy based on ACHO (kcal/100 g)
	Mean ± SEM*	**Mean ± SEM**
Afara	394.97 ± 0.85 abcd#	168.60 ± 3.45 abcd
Aveloloa	384.88 ± 0.72 bcd	153.16 ± 2.26 de
Creole	391.51 ± 2.13 bcd	179.39 ± 1.36 a
Kashee Bread	408.80 ± 2.50 a	178.45 ± 1.24 ab
Ma'afala	398.53 ± 2.67 abc	150.82 ± 1.11 e
Macca	383.00 ± 1.20 cd	151.81 ± 2.39 e
Meitehid	388.82 ± 1.59 bcd	163.86 ± 3.45 abcde
Piipiia	389.53 ± 5.98 bcd	150.87 ± 6.43 e
Puou	380.06 ± 0.39 d	163.93 ± 3.22 abcde
Timor	381.27 ± 6.40 d	149.18 ± 3.12 e
Toneno	340.53 ± 1.10 e	113.39 ± 0.87 f
White	380.87 ± 3.76 d	170.80 ± 5.43 abc
Yellow	400.90 ± 4.79 ab	157.55 ± 4.35 cde
Yellow Heart	380.03 ± 1.07 d	162.18 ± 1.80 bcde
Overall	385.98 ± 2.47	158.14 ± 2.56

*SEM; standard error of the mean
#Values within the same column that do not share a letter are significantly different

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