doi: https://doi.org/10.37833/cord.v38i.443
Coconut Research & Development, 2022, 38: 43-50

Evaluation of Staple Foods Supplemented with Defatted Coconut Testa Flour

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Abstract

Coconut testa is an important byproduct of coconut processing. This study investigated the acceptability of staple foods incorporated with defatted coconut testa flour (CTF). Food supplemented with CTF will be ideal as a functional food for diabetes. Formulations of string hoppers incorporated with CTF were done by mixing white rice flour (WRF) with CTF in four different ratios; F_1 (WRF:CTF=70:30), F_2 (WRF:CTF=75:25), F_3 (WRF:CTF=80:20) and F_4 (WRF:CTF=85:15). Likewise, formulation of flat-bread *rotti* were prepared by mixing wheat flour (WF) with CTF in four different ratios; P_1 (WF:CTF=60:40), P_2 (WF:CTF=70:30), P_3 (WF:CTF=80:20) and P_4 (WF:CTF=90:10). Acceptability of the formulations was determined by preference ranking test and the data were analyzed using Friedman test and Mann-Whitney test. According to sensory evaluation, the highest score of overall acceptability and other sensory attributes were observed for composite flour mixtures incorporated with 25% of CTF in rice flour for string hoppers (*idiyappa*) and 20% of CTF in wheat flour for flat-bread (*rotti*). The proximate analysis of the finished products namely, string hopper (*idiyappa*) and flat-bread (*rotti*) showed better nutritional properties with regard to protein, dietary fiber, fat and mineral content than the respective composite flour mixtures used in their preparation. Furthermore, string hopper (*idiyappa*) flour mixture [IF, (WRF:CTF=75:25)] and string hopper (*idiyappa*) samples showed increased nutritional compositions in terms of dietary fiber, mineral content when compared to RF [RF, (WF:CTF=80:20)] and flat-bread *rotti* samples. In conclusion, the two-formulated products' quality attributes and dietary fiber content indicated their potential use as anti-diabetic foods.

Keywords: Coconut testa four, coconut dietary fiber, sensory analysis, anti-diabetic foods

Introduction

Coconut plays an important role in the plantation sector of Sri Lanka. It accounts for 12% of Sri Lanka's total agricultural production. Coconut fruit is considered a valuable part of the coconut tree due to its food and nutritional values and a host of medicinal properties (Deen et al., 2021). The most economically valuable part of the coconut fruit is its kernel, which is covered by a brown layer known as coconut testa (CT) (Ojha et al., 2019). Production of desiccated coconut, coconut milk powder and virgin coconut oil usually require removal of CT from the fresh kernel as a byproduct since it imparts undesirable color to oil and dull appearance to other products (Appaiah et al., 2014). According to some previous estimates, approximately 18 % of the total kernel (w/w, wet basis) is said to be lost during the removal of testa (Gunarathna et al., 2022). Based on the fruit component study by Perera et al (2014), about 6,500 kg of wet CT is generated out of 100,000 nuts of Sri Lankan tall variety. Although CT is an edible bio-waste, it is not yet fully exploited in Sri Lanka as an ingredient for staple food production. At present, it is only used for low-grade oil extraction and the residues are being used for animal feed (Marasinghe et al., 2019). The transformation of agro-byproducts into value-added products has become a global trend these days, which has paved the way for sustainable agriculture (Lucarini et al., 2021). Converting any bio-waste into productive uses is generally in alignment with the United Nations' goals of sustainable development. It exerts a direct and implicit impact on the environment and the economic spheres by minimizing the disposal cost and controlling the escalating value of the finished products (Marikkar et al., 2020). Hence, it is timely to undertake a study on the utilization of CT as a source of food ingredient.

The rising trend in diabetes worldwide has created a new demand for functional foods that would help maintain uncontrolled blood glucose among those with chronic diabetic conditions (Tanko et al., 2021). Apart from the adoption of recommended medications, dietary modification has been recognized as one of the most effective and viable ways to address this health issue (Tanko et al., 2017). Early studies have affirmed that coconut flour made out of defatted coconut kernel residue is a rich source of protein, fat, minerals, dietary fiber and can be a potential raw material for functional food. Hewapathirana et al. (2020) previously found that partially-defatted coconut flour might significantly reduce the glycemic index (GI) of processed food products that help to manage diabetes mellitus. Coconut testa flour (CTF) may also be used similarly for such dietary intervention for diabetes as it is a potential source of antioxidants due to the presence of polyphenols (Arivalagan et al., 2018; Adekola et al., 2017).

Foods with high dietary fiber content have been affirmed to significantly reduce the glycemic index (GI) of processed products (Hewapathirana et al., 2020). Previous studies reported from other parts of the world have indicated that CT generated as a byproduct of coconut would possess antidiabetic properties (Adekola et al., 2022). After subjecting CT to oil extraction, the leftover defatted residue can be crushed into fiber-rich flour, which showed good functional attributes (Marasinghe et al. 2021). According to a nutritional comparison of locally grown coconut cultivars, CTF is rich in protein which is twice the protein content of commercial wheat flour (Marasinghe et al., 2019). A follow-up study indicated that CTF is possessed with anti-hyperglycemic effect in vitro, and thus it is qualified to be called a functional food (Gunarathne et al. 2022). However, a study on the distribution of soluble and non-soluble dietary fiber in CTF obtained from locally grown coconut cultivars is yet to be reported. A recent study showed that defatted CTF can be used as a partial base for wheat flour in producing nutritious cookies (Marikkar et al., 2020). However, CTF from Sri Lankan commercial variety as a partial substitute in major staple foods has not been previously reported. Although wheat flour supplemented with barely flour (Mansoor et al., 2019), soy flour (Khan et al., 2005) and rice bran flour (Saeed et al., 2009) have been already reported from various sources, wheat flour supplemented with CTF in formulating staple foods has been rarely reported previously. Hence, this study aimed to evaluate the acceptability of two staple foods formulated by incorporating CTF into wheat and rice flours. Development and evaluation of staple foods out of these combinations is expected to provide means of maintaining uncontrolled blood glucose among those with chronic diabetes. As such the preliminary findings could be useful as a basis for further study to affirm the effectiveness of the developed products in controlling high blood glucose among those suffering from chronic diabetes through a study in vivo. Furthermore, the proximate analysis data of the novel foods supplemented with CTF could be useful for nutritionists, technologists and future entrepreneurs to explore feasibility of commercialization.

Materials and Methods

Materials and Sampling: Samples of CTF were produced according to the procedure described by Marasinghe et al. (2019) using a commercial hybrid variety of Sri Lanka. In brief, disintegrated fresh testa (moisture content of 42 to 45%) were oven-dried at 70°C using a cabinet-type dryer (Wessberg, Martin, Germany) for 8 h to reduce to 3 to 5% moisture. Low-temperature drying was adopted to minimize severe burning or thermal degradation. Two kilograms of dried testa (medium size particles) were then taken out and subjected to cold press oil extraction using a micro oil expeller (Komet DD85 machine, Germany). The residues left after oil extraction were ground into fine coconut testa flour (CTF) using a commercial grinder (Panasonic, Model:MK-MG 1000). Wheat flour, white rice flour and salt were purchased from the popular commercial enterprises in Sri Lanka.

Methods

Preparation of string hoppers (Idiyappa): Preparation of string hoppers was carried out according to the method described by Malkanthi & Hiremath (2020) with slight modifications. The maximum level of incorporation of CTF into WRF was selected based on the dough consistency and the string hopper brittleness. Hence, the maximum level of CTF that could be incorporated into WRF was identified as 30 %. As the level of incorporation of CTF increased the dough became hard and the resultant string hoppers became brittle. By considering maximum level of incorporation of CTF into WRF, string hoppers were prepared by mixing WRF with CTF in four different ratios; F_1 (WRF:CTF=70:30), F_2 (WRF:CTF=75:25), F_3 (WRF:CTF 80:20) and F_4 (WRF:CTF=85:15) (Table 1). The four flour mixtures were added with warm water to reach proper consistency. After feeding the dough into the string hopper presser, it was squeezed out in a circular pattern onto a steamer mat followed by steaming for 15 minutes.

Preparation of Flat-bread rotti: Preparation of flat-bread *rotti* was carried out as described by Saeed et al. (2009) with

Table 1. Recipe for String hoppers (*Idiyappa*) preparation

Ingredients	Treatments			
	F_1	F_2	F_3	F_4
CTF (g)	210	175	140	105
Rice flour (g)	490	525	560	595
Salt (g)	12	12	12	12
Water (mL)	220	220	220	220

minor modifications. The optimum level of incorporation of CTF into WF was decided considering the dough consistency and the brittleness of the flat-bread *rotti*. The maximum level of CTF that could be incorporated into WF was identified as 40 %. As the level of incorporation of CTF exceeded 40 %, the dough became hard and the resultant flat-bread *rotti* became brittle. Therefore, four different formulations of flat-bread *rotti* were prepared by mixing WF with CTF in different ratios; P_1 (WF:CTF=60:40), P_2 (WF:CTF=70:30), P_3 (WF:CTF=80:20) and P_4 (WF:CTF=90:10), considering maximum level of incorporation of CTF into WF (Table 2). The four flour mixtures were added with 25 % of freshly shredded coconut and 10 g of salt. After adding water to form a sticky dough, kneading was continued until form a soft dough. The resulting dough was cut shape into circles of 0.5 cm thickness on a flat surface followed by baking on a hot pan for 3-4 minutes on each side.

Table 2. Recipe for Flat-bread *rotti* preparation

Ingredients	Treatments			
	P_1	P_2	P_3	P_4
CTF (g)	200	150	100	50
Wheat flour (g)	300	350	400	450
Shredded Coconut (g)	125	125	125	125
Salt (g)	10	10	10	10
Water (mL)	180	180	180	180

Proximate compositional analysis: For proximate analysis, formulated food samples were oven-dried and ground into powders using mortar and pestle. Moisture content was determined using the oven (Gallenkamp, SANYO Gallenkamp PLC, U.K.) method by drying at 105°C for 4 hrs until constant weight is reached (AOAC Official Method 934.06); oil content was determined by soxhlet extraction using petroleum ether (40-60ºC) as solvent (AOAC Official Method 948.22); ash content determination was by dry ashing method (AOAC Official Method 942.05); crude protein content determination by micro Kjeldahl method (AOAC Official Method 970.02). Carbohydrate content was calculated according to the following equation:Total Carbohydrate content (%) = 100 – % (Moisture + ash + protein + fat).

Determination of dietary fiber content: Total, soluble and insoluble dietary fiber contents were determined according to method 991.43 of the AOAC (2019) manual.

Sensory evaluation: The sensory evaluation of the novel products was performed under the previously validated method described by Mansoor et al. (2019). A preference ranking test was performed using a group of thirty semi-trained panelists to select the most preferred formulation out of the four formulations of CTF in terms of preference for sensory attributes namely appearance, color, aroma, taste, texture and overall acceptability. The best formulation selected through the preference ranking test was used for further analysis.

Serving the sample: The samples were coded with three digits random numbers and served to the panelists in random order. The samples were heated at 50°C before the time of serving and the panelists were asked to rinse their mouths after tasting each sample.

Testing criteria: The panelists were asked to assign ranks according to the given scale:1:extremely preferred sample; 2:Moderately preferred sample; 3:slightly preferred sample; 4:least preferred sample based on each sensory attribute for four samples provided and no ties were allowed.

Statistical analysis: The data obtained from the sensory evaluation was statistically analyzed using Minitab 17.1 software package. Friedman test was performed to determine if there is a significant difference ($p<0.05$) among median values obtained for each sensory attribute of four formulations. When a significant difference ($p<0.05$) was identified in Friedman test, the Mann-Whitney test was performed to identify the significant difference ($p<0.05$) between all possible combinations of formulations based on each sensory attribute.

Results and Discussions

Selection of the best flour mixture for string hoppers

The results of the Friedman test performed on sensory attributes of different string hopper formulations are shown in Table 3. There were no significant ($p>0.05$) differences

Table 3. Results of Friedman test along with the rank median of sensory attributes of different treatments

Percentage of CTF	Appearance	Color	Aroma	Texture	Taste	Overall acceptability
F_1	3.44^{c}	2.75^{a}	2.75^{a}	3.88^{b}	3.25^{b}	$2.81^{b,c}$
F_2	1.81^{a}	1.75^{a}	1.75^{a}	2.53^{a}	2.00^{a}	$2.06^{a,b}$
F_3	$2.19^{a,b}$	2.25^{a}	2.25^{a}	1.88^{a}	2.00^{a}	2.06^{a}
F_4	$2.81^{b,c}$	3.25^{a}	3.25^{a}	1.73^{a}	$2.75^{a,b}$	3.31^{c}
CL	*	NS	NS	*	*	*

Rank median bearing different superscriptions are significantly different from each other at a 95% confidence interval level (α=0.05). Abbreviations:CL, confidence level; NS, not significant; *($p<0.05$); F_1, string hopper formulation by rice flour mixed with 30% CTF; F_2, string hopper formulation by rice flour mixed with 25% CTF, F_3, string hopper formulation by rice flour mixed with 20% CTF; F_4, string hopper formulation by rice flour mixed with 15% CTF.

among the formulations with regard to color and aroma, but significant differences ($p<0.05$) were observed between the formulations with regard to appearance, taste, texture, and overall acceptability.

According to Table 3, F_2 (25% CTF) formulation had the highest preference (lowest median) for appearance, color, aroma, taste, and overall acceptability except for texture. For texture, F_4 (15% CTF) formulation scored the highest preference level (lowest median). However, there was no significant ($p>0.05$) difference among F_2, F_3, and F_4 formulations concerning texture attributes. Hence, F_2 (25% CTF) formulation was selected as the most preferred formulation among them. Furthermore, data showed that the preference of the panelists regarding texture attribute seems to be declining with the increasing level of CTF incorporation. This could be due to the grainy texture of CTF which could be improved by further reducing the particle size. For overall acceptability, color and aroma, there were no significant ($p>0.05$) differences between F_1 (30% CTF) and F_2 (25% CTF) formulations. However, significant differences ($p<0.05$) among them were noticed concerning appearance, texture and taste. Furthermore, there was no significant ($p>0.05$) difference between F_2 (25% CTF) and F_3 (20% CTF) for the overall acceptability, color, aroma, taste, and texture. However, a significant ($p<0.05$) difference was noticed between them in appearance. Hence, F_2 (25% CTF) formulation was selected as the most preferred formulation.

Results of the sensory evaluation of the four formulations using the preference ranking test by radar graph is shown in Figure 1. In the ranking test, the lowest median is an indicator of the highest level of preference and as such the lines appearing near to zero in the radar chart indicate the highest preference levels and the preference level gradually declines when the lines move outwards from zero. According to the radar chart in Figure 1, lines representing the medians of all sensory attributes of F_2 (25% CTF) formulation were confined to the area near to zero in the radar chart except for the texture attribute. The median of texture attribute for F_4 (15% CTF) formulation occupied the area near zero on the radar chart. Nevertheless, medians of all other attributes of F_4 (15% CTF) formulation had moved far outwards from zero in the radar chart. Hence, F_2 (25% CTF) formulation was selected as the most preferred formulation for string hopper (*idiyappa*) preparation.

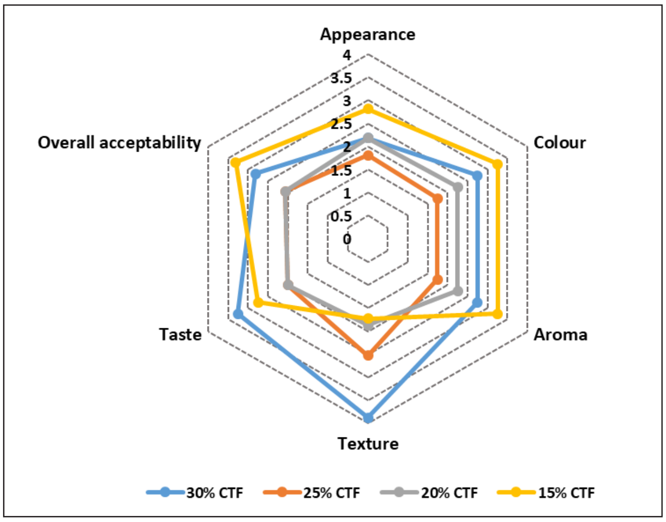

Figure 1. Radar graph for sensory analysis median score values for string hoppers with different proportions of CTF

Selection of the best flour mixture for Flat-bread rotti

The results of the Friedman test performed for sensory evaluation of different flat-bread *rotti* formulations are shown in Table 4. According to Table 4, a significant ($p<0.05$) difference was observed between the formulations regarding color. For texture and taste, highly significant differences ($p<0.001$) were observed between the formulations. Concerning appearance, aroma and overall acceptability, the formulations showed very strong significant ($p<0.0001$) differences.

According to Table 4, P_3 (20% CTF) formulation was found to have the highest preference (lowest median) with regard to color, aroma and overall acceptability. When compared to other formulations, P_4 (15% CTF) showed a significantly ($p<0.05$) higher preference for appearance and taste attributes. However, no significant ($p>0.05$) difference was noticed between P_3 and P_4 formulations with regard to appearance and taste attributes. For texture, P_2 (30% CTF) formulation showed the highest preference

Table 4. Results of Friedman test along with the rank median of sensory attributes of different treatments

Percentage of CTF	Appearance	Color	Aroma	Texture	Taste	Overall acceptability
P_1	3.44^{b}	3.38^{b}	2.75^{b}	3.56^{b}	3.13^{b}	3.38^{b}
P_2	2.81^{b}	2.75^{b}	3.50^{c}	1.94^{a}	$2.50^{a,b}$	2.25^{a}
P_3	1.94^{a}	1.63^{a}	1.50^{a}	2.25^{a}	2.25^{a}	1.63^{a}
P_4	1.56^{a}	2.25^{b}	2.25^{b}	2.25^{a}	2.13^{a}	2.75^{b}
CL	***	*	***	**	**	***

Rank median bearing different superscriptions are significantly different from each other at 95% confidence interval level (α=0.05). Abbreviations:CL, confidence level; *($p<0.05$), **($p<0.001$), ***($p<0.0001$), T_1, flat-bread *rotti* formulation by wheat flour mixed with 40% CTF; T_2, flat-bread *rotti* formulation by wheat flour mixed with 30% CTF; T_3, flat-bread *rotti* formulation by wheat flour mixed with 20% CTF; T_4, flat-bread *rotti* formulation by wheat flour mixed with 10% CTF.

(lowest median), but no significant (p>0.05) difference was noticed among P_2, P_3, and P_4 formulations with regard to texture attribute. Hence, P_3 (20% CTF) formulation was selected as the most preferred formulation among them. The evaluation of the four formulations using the preference ranking test by radar graph is shown in Figure 2. Here too, the lowest median is considered an indicator of the highest level of preference in the ranking test. As such, the lines appearing near zero in the radar graphs indicate the highest preference and the preference level gradually declines when the lines move outwards from zero. According to Figure 2, data lines representing medians of all sensory characteristics of P_3 (20% CTF) formulation were confined to the area near to zero of the radar chart except for appearance and texture attributes. The median of texture attribute for P_2 (30% CTF) formulation and the median for appearance attribute for P_4 (10% CTF) formulation occupied the area near zero of the radar chart. However, medians of all other attributes such as taste, color, aroma, and overall acceptability for P_2 (30% CTF) and P_4 (10% CTF) formulations had moved far outwards from zero in the radar chart. Owing to these reasons, P_3 (20% CTF) formulation was selected as the most preferred formulation for flat-bread *rotti* preparation.

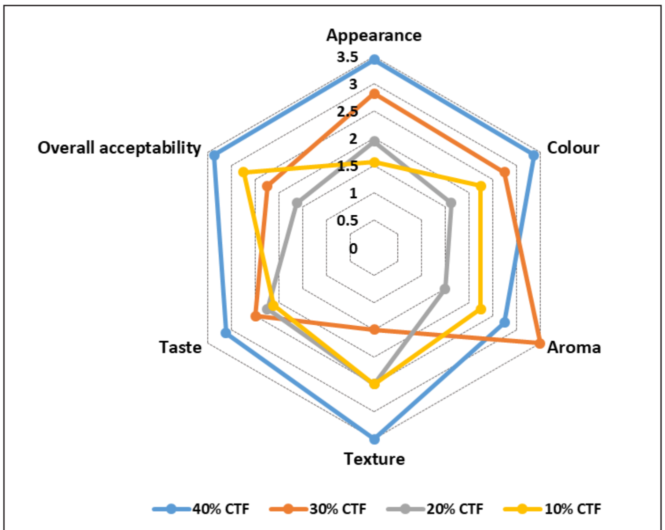

Figure 2. Radar graph for sensory analysis median score values for flat-bread *rotti* with different proportions of CTF

Proximate composition of products

The proximate compositional data of the staple foods supplemented with CTF could be useful for nutritionists, technologists, and future entrepreneurs to explore the feasibility of commercialization. As shown in Table 5, proximate compositions of the best-selected string hopper and flat-bread *rotti* were compared with composite flour mixtures (IF and RF respectively) used in their preparations. In Sri Lanka, string hopper and flat-bread *rotti* are usually prepared with rice flour and wheat flour, which are low in protein and dietary fiber content. The potential benefits of CTF supplementation in staple food production had been realized due to some important nutritional attributes of CTF reported recently (Marasinghe et al., 2019). The data presented in Table 5 shows the improvements brought by CTF supplementation in string hopper and flat-bread *rotti*. The moisture content of composite flour mixtures namely, IF (8.64 %) and RF (11.01 %) were lower than those of the finished products such as string hopper (26.00 %) and flat-bread *rotti* (28.29 %). The increase in moisture contents of the finished products, as noticed from the data would adversely affect the shelf-life stability of crude protein and crude fat. Based on the data, CTF having the least moisture content (6.06 %) would be advantageous for its longer shelf life.

Ash content is a measure of the mineral quantity of samples. Calcium, phosphorous, potassium, magnesium, zinc, copper, and iron are some of the minerals in flour (Czaja et al., 2020). According to Table 5, CTF having the highest mineral content (5.75 %) would contribute to increased nutritional properties. The ash contents of the composite flour mixtures, namely IF (1.91 %) and RF (2.01 %) were lower than those of their respective final products such as string hopper (2.11 %) and flat-bread *rotti* (2.54 %). Thus, it was apparent that cooking increased the ash content of the food products. Among the samples, CTF was found to possess the highest protein content (20.75 %) while the protein contents of composite flour mixtures namely IF (10.47 %) and RF (11.89 %) were slightly higher than their respective finished products, namely string hopper (9.94 %) and flat-bread *rotti* (10.36 %). According to the fat analysis, CTF had a fat content of 9.03 % and fat contents of composite flour mixture IF (2.16%) were slightly higher than that of string hopper (1.09%). However, the fat

Table 5. Proximate composition of flour mixtures and products (g/ 100g; wet basis)

Samples	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (by difference)
String hopper	$26.00^{d}\pm0.01$	$2.11^{c}\pm0.01$	$1.09^{a}\pm0.05$	$9.94^{a}\pm0.04$	$60.86^{b}\pm0.02$
Flat-bread *rotti*	$28.29^{e}\pm0.01$	$2.54^{d}\pm0.00$	$3.09^{d}\pm0.09$	$10.36^{b}\pm0.01$	$55.72^{a}\pm0.04$
IF	$8.64^{b}\pm0.00$	$1.91^{a}\pm0.01$	$2.16^{b}\pm0.04$	$10.46^{c}\pm0.02$	$76.83^{e}\pm0.03$
RF	$11.01^{c}\pm0.00$	$2.01^{b}\pm0.01$	$2.75^{c}\pm0.01$	$11.89^{d}\pm0.11$	$72.34^{d}\pm0.03$
CTF	$6.06^{a}\pm0.00$	$5.75^{e}\pm0.03$	$9.03^{e}\pm0.00$	$20.75^{e}\pm0.06$	$58.41^{c}\pm0.05$
CL	***	***	***	***	***

Each data in the table represents mean of triplicate analysis. Means in the same column bearing different superscript are significantly different (p<0.05) from each other. Abbreviations:***(p<0.0001); IF, String hopper (*Idiyappa*) flour mixture formulation by mixing rice flour with 25% of CTF; RF, Flat-bread *rotti* flour mixture formulation by mixing wheatflour with 20% of CTF; CTF, Coconut testa flour.

content of RF (2.16 %) flour mixture was slightly lower than that of flat-bread *rotti* (3.09%). This could be partly due to the incorporation of shredded coconut in the case of flat-bread *rotti* preparation. Furthermore, the carbohydrate content of composite flour mixtures namely, IF (76.82 %) and RF (72.34 %) were greater than their respective finished products such as string hopper (61.16 %) and flat-bread *rotti* (55.72 %). Based on the data, strong significant (p<0.001) differences were observed among all samples with respect to each of the proximate parameter. Compared to the composite flour mixtures used in their preparation, the finished products, namely, string hopper (idiyappa) and flat-bread (*rotti*), showed some enhanced nutritional properties regarding fat and mineral contents.

Dietary fiber contents of products

Results in Table 6 compare the total, soluble and insoluble dietary fiber content of samples. The dietary fiber component is essentially a part of the carbohydrate that shows resistance toward adsorption and digestion in the small intestine, but it undergoes either partial or complete fermentation in the large intestine (Ranaet al., 2011). Both the soluble and insoluble dietary fibers have been reported to have numerous health benefits (Lattimer and Haub 2010; Ranaet al., 2011). According to data in Table 6, among the samples, the total, soluble and insoluble dietary fiber contents of CTF were 65.05 %, 19.02 %, and 46.04 %, respectively. The total and soluble dietary fiber contents of composite flour mixtures of IF (string hopper flour mixture) and RF (flat-bread *rotti* flour mixture) were significantly (p<0.001) higher than those of their respective finished products namely, string hopper (*idiyappa*) and flat-bread (*rotti*) samples.

It is clear from Table 6, a greater portion of the total dietary fiber of the samples is constituted with insoluble dietary fiber. Moreover, its content in string hopper (14.08 %) and flat-bread *rotti* (12.03 %) were significantly (p<0.05) greater than their respective composite flour mixtures IF (13.13 %) and RF (10.26 %). According to some previous research studies, an increased amount of insoluble dietary fiber content in the human diet would undoubtedly reduce appetite, constipation and risk of type 2 diabetes (Stewart 2014). Consumption of insoluble dietary fiber-enriched diets may help in the control of hemorrhoids and constipation while eliminating extra bile acids and toxins. It would also provide other health benefits including protection against some colon-related cancer (Nur Ain Najwa et al. 2021; Anderson et al., 2009).

The techno-economic feasibility is a critical aspect of the commercialization of CTF-related products. The technology for the production of CTF in this study is exactly similar to the production of defatted coconut flour through the mini-cold pressed oil extraction technology previously described. Nevertheless, machineries are needed to convert the defatted residue into flour after separating testa oil from CT. First of all, a medium-sized grinding machine is required to crush the defatted testa residues into powder form. A sieve shaker is inevitably required to separate the finer flour particles from the bulk crushed residues. This is required because the presence of bigger fibrous matter might affect the palatability of the flour and the finished products. It is this fibrous matter which prevents the direct use of whole CTF in products, but instead, if it can be blended with wheat flour the palatability can be improved. The microbiological stability of the blended flour (CTF: WF) should be undertaken to determine the stability of the flour in an extended period of storage under ambient temperature conditions.

In this study, the novel formulations developed were evaluated by a group of trained panelists, but it may be worthwhile to cross-check the validity of the findings by a group of professional chefs and food consultants. Despite the consumer acceptability of the novel product formulations, they should be subjected to cost-benefit analysis and feedback through cross-sectional surveys. For instance, seeking the opinion of the consumer public and the stakeholders of the coconut industry could be highly useful for commercialization. Without seeking feedback or opinion through an *ad hoc*-selected manner, a cross-sectional survey should be administered through a structured questionnaire and the opinions of the stakeholders of the coconut industry can be obtained separately. For cost-benefit analysis, the calculations for an eight-hour day shift in a small-scale operation should be done using proper agricultural economics procedure.

Table 6. Total, soluble and insoluble dietary fiber contents of flour mixtures and products (g/ 100g wet matter basis)

Samples	Total Dietary Fiber (%)	Insoluble Dietary Fiber (%)	Soluble Dietary Fiber (by difference) (%)
String hopper	14.23b±0.19	14.08d±0.15	0.14a±0.04
Flat-bread rotti	12.26a±0.28	12.03b±0.05	0.22b±0.23
IF	16.56d±0.06	13.13c±0.04	3.43c±0.01
RF	15.15c±0.06	10.26a±0.02	4.94d±0.05
CTF	65.06e±0.21	46.04e±0.07	19.02e±0.14
CL	***	***	***

Each data in the table represents mean of triplicate analysis. Means in the same column bearing different superscripts are significantly different (p<0.05) from each other. Abbreviations:IF; String hopper (*Idiyappa*) flour mixture formulation by mixing rice flour with 25% of CTF, RF; Flat-bread *rotti* flour mixture formulation by mixing wheat flour with 20% of CTF, CTF; Coconut testa flour

Conclusions

This study demonstrated that string hoppers (*idiyappa*) and flatbread (*rotti*) of acceptable quality could be prepared using composite flour mixtures of 25% of CTF in rice flour and 20% of CTF in wheat flour, respectively. This was based on the highest overall acceptability and other sensory attributes observed from a sensory evaluation. The proximate analysis of the finished products such as string hopper (*idiyappa*) and flat-bread (*rotti*) showed improvements in nutritional properties with regard to protein, dietary fiber, fat, and mineral contents when compared to respective composite flour mixtures used in their preparation. in terms of dietary fiber and mineral contents string hopper (*idiyappa*) sample's nutritional composition was better than that of flat-bread *rotti* samples. As all samples were reported to have a higher percentage of insoluble dietary fiber than soluble dietary fiber, these products would exert tremendous prebiotic health benefits.

Acknowledgements

The authors gratefully acknowledge the financial support from the Inter-Institutional Multidisciplinary Research Grant (Gr No. IIMD/2021/CRI/01) Scheme awarded by the Sri Lanka Council of Agricultural Research Policy. This study was partly funded by the National Institute of Fundamental Studies, Hanthana Road, Kandy, Sri Lanka.

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