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Physicochemical Characterization and Functional Properties of Fruit Dietary Fibers

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Abstract

Dietary Fiber, also known as roughage, is an indigestible part of plant food that escapes digestion in the gastrointestinal tract. It plays a crucial role in stabilizing gut health by establishing a healthy gut microbiota, reducing the risk of chronic diseases. Vegetables, fruits, nuts and cereals are rich sources of dietary fiber. In the food industry, dietary fibers are being incorporated as functional foods for improving consistency, texture and sensory characteristics. Changes in physiological and functional properties of dietary fibers determine both the beneficial and adverse effects on the gut ecosystem. This study attempts to estimate the physiological and functional characteristics pertaining to dietary fibers derived from the residuals of some commonly consumed fruits like coconut, guava, jackfruit, and watermelon. Along with the proximate analysis and functional properties of these selected fruit fibers, size distribution, zeta potential, texture and SEM analysis were determined. Based on the proximate analysis, watermelon fibers were found to have high ash and protein content. Assay of zeta potential confirmed that the fibers were negatively charged. The textural studies showed that watermelon fibers were more resilient and coconut fibers exhibited hardness and adhesiveness than the other fibers. The physiological and functional studies determine the characteristic property of fruit fibers, whereas the texture and SEM analysis reveal the morphological characteristics of fruit fibers.

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Sem;
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Introduction

Fruits, particularly edible fruits, have been propagated by both humans and animals in a symbiotic relationship. Fruit consumption has considerably become an unavoidable part of the complete meal as fruits are loaded with copious proportions of

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vitamins, minerals, protein, carbohydrate and dietary fiber (DF).[1] The consumption of native seasonal fruits has a positive association, directing a practical and sustainable approach to ease malnutrition and other issues.[2] Increasingly, dietary fibers are sourced from by-products of vegetables and fruits processing.[3] Fruit fibers are rich in total and soluble fibers, hence exhibiting good water holding capacity, oil holding capacity and colonic fermentability.[4] Fruit fibers are also known to house significant amounts of antioxidants as bioactive compounds and polyphenols.[5] The short-chain fatty acids formed by the intestinal microbiota from DF play a major role in metabolism.[6] Dietary fibers also found to have a potential role in alleviating Type2 diabetes, reduced risk of cardiovascular diseases and weight regulation.[7]

India, being a tropical country, is a producer and exporter of a wide range of fruit varieties. The fruit fibers used in this study were selected based on local availability and volume. The DF sources were outer skins of guava (*Psidium guajava*), rags of jackfruit (*Atrocarpus heterophyllus*), rinds of watermelon (*Citrullus lanatus*) and coconut meat (*Cocos nucifera*). Coconuts are the most versatile and are widely used for both their culinary and non–culinary purposes. Guavas are eaten raw and are also variedly used in culinary sauces, artisan candies, dried snacks, fruit bars, desserts, etc. The "outer skin" of guavas is rough with a bitter taste to sometimes soft. The outer skin may be of any thickness varying between the varieties. Jackfruit is a multiple fruit with a sharp flavor and taste. In our study, "rags" or the inedible fibrous part of the fruit was used. These rags may be sweet or bitter depending on the variety. Watermelons are large edible fruits with a hard rind and no internal division. The "rinds" are usually green with dark green stripes housing the red, sweet juicy pulp. Watermelon rinds are also edible but are not commonly consumed because of their strong and unappealing flavor and taste because of the presence of the amino acid citrulline.8 The purpose of our research was to find out the proximate composition besides the functional characteristics of processed fruit fibers.

Materials and Methods

Sample preparation- Processing of Fruits

Our study used fruits that were bought from the local market in Vellore, India. The fruits underwent rinsing with running water to eliminate impurities on the outer surface. The coconut husks and shells were removed, and the edible part was separated. After the coconut meat was recovered, it was cut into small pieces, dried, and then finely ground using an electric mill. The rinds were removed from the fruit pulps with the help of a sharp knife. Dried watermelon rinds, guava skin, jackfruit rags and coconut meat were finely ground in an electric mill after being dried separately in a hot air oven at 60°C and sieved using a 4mm laboratory sieve. The solvent extricates were resolved using a Soxhlet apparatus with sequential treatment with ethanol and petroleum ether. Soxhlet extraction is still considered being an effective extraction procedure as it facilitates a maximum recovery of bioactive substances such as phenolic acids, flavonoids, carotenoids, anthocyanin and other substances.[9] The raw samples were processed with ethanol for 9 hours to remove phenolics and other reactive substances. The processed samples were oven dried at 60°C for 3 hours. Upon drying, the samples were treated again with petroleum ether for 6 hours to remove fatty acids and other saturated fats. After extraction, the samples were recovered from the Soxhlet and oven dried at 60°C, cooled at room temperature and stored at 4°C, labeled in screw-capped bottles until further use.

Proximate Analysis

Proximate analysis was performed on the indicated fruit fiber samples. Moisture, ash, protein, fat and fiber was deduced in concordance with AOAC (2005).[10] Moisture was determined by drying in the oven at 100C for 24 hours until a steady weight was obtained. The ash content was estimated in a muffle furnace at 600°C for 3 hours. Nitrogen content was evaluated by Kjeldahl method. Carbohydrate was calculated by difference.

Functional Characterization

Hydration Properties

The hydration properties of fruit fibers were determined according to Robertson *et al.*,[11] Water holding capacity (WHC) was estimated through treating fibers with deionized water and sodium azide (NaN3), hydrated for 18 hours. The supernatant was removed after centrifugation and the substrate was recovered, filtered and dried to constant weight at 110°C. Water holding capacity was expressed as weight of dry fiber after water absorption.

WHC (%) = Weight of hydrated fiber – weight of dry fiber X 100 / Weight of dry fiber

Water retention capacity (WRC) was determined by treating the fibers with deionized water and sodium azide (NaN3), shaken well and allowed to settle down. The supernatant was removed, filtered and centrifuged at 3000g/20min, left undisturbed at room temperature for 3 hours, dried at 105°C and the dry weight was estimated.

WRC (%) = Weight of hydrated fiber after centrifugation – weight of dry fiber X 100 / Weight of dry fiber

Absorption Capacity (ABC) was determined by mixing the sample with deionized water and 0.02% sodium azide (NaN_3), unshaken for 18 hours and bed volume recorded. Absorption capacity was measured as the final volume gained by fiber after 18 hours.

ABC (%) = Volume occupied by fiber after swelling X 100 / Initial weight of fiber

Oil Holding Capacity (OHC) was estimated through mixing fiber sample with vegetable oil and allowed to stand for 1 hour, centrifuged at 1600g/25min. The unabsorbed oil was decanted and the absorbed oil was determined by difference and expressed as volume of oil per gram of sample.

OHC (%) = Absorbed fiber weight – initial dry weight X 100 / Initial dry weight

Size Distribution and Zeta Potential

The size distribution of fruit fibers was analyzed using a Malvern Nano Zetasizer ZS 90, (Malvern Panalytical, UK) measuring nanoparticle size using dynamic light scattering technique.

Texture Analysis

The texture analysis of processed fruit fibers was carried out using a TA.HD plus C Texture analyzer [capacity750kg.f (7.5kN) speed range 0.01-20mm/s, Stable Micro Systems, UK].

SEM Analysis

The scanning electronic microscopy (SEM) analysis was performed to visualize the texture and morphology of fruit fibers. SEM images of fruit fibers were determined using a Zeiss – SEM instrument (Germany).

Table 1: Proximate Analysis of Fibers

S.No.	Parameters	Coconut Fiber (CF)	Guava Fiber (GF)	Jackfruit Fiber (JF)	Watermelon Fiber (WF)
1	Moisture content (%)	2.88 ± 0.10	9.03 ± 0.31	9.18 ± 0.57	11.97 ± 0.12
2	Ash content (%)	0.54 ± 0.03	0.94 ± 0.04	4.85 ± 0.35	7.37 ± 0.33
3	Fiber (%)	25.82 ± 1.11	25.07 ± 0.55	21.4 ± 0.28	24.55 ± 0.60
4	Fat content (%)	3.83 ± 1.52	1.86 ± 0.31	3.35 ± 1.20	1.29 ± 0.79
5	Protein content (%)	6.64 ± 0.67	4.97 ± 0.55	8.39 ± 0.52	13.72 ± 0.75
6	Carbohydrate by difference (%)	21.37 ± 0.41	42.80 ± 0.60	49.12 ± 0.53	31.20 ± 1.01
7	Energy value/100g (Kcal/kg)	510.41 ± 0.74	271.8 ± 0.76	328.06 ± 0.68	241.09±1.40

Results and Discussion

Proximate analysis was performed with different fruit fiber samples according to the standard AOAC procedure and the results are given in Table 1. From the results obtained, it was observed that moisture, ash and protein content is significantly higher in watermelon fibers than in other fibers. The fiber composition was approximately the same as all fibers. Coconut and jackfruit fibers showed an increased level of fat content than the other two fibers. Carbohydrate by difference and energy value were also observed to be higher in coconut and jackfruit fibers comparatively. Our results with fruit fibers were like the observations by Dias *et al* with different fruit peels.[12] The differences may be because of the variety of cultivars, geographical factors and varied composition of water in fruits. Ash content also differed in all the fruits, which indicate minerals that characterize the nutritive value, which is highly influenced by environmental factors.[13] The results expressed below are the mean ± standard deviation of triplicates.

The hydration properties of coconut fibers were observed to be significantly higher than that of the other fibers, followed by watermelon fibers. This may be because of the loose and sizable interstitial framework, which is the fundamental characteristic of water and oil holding capability and other absorption properties. Our results were like that of Feng *et al*.,[14] with citrus fibers which exhibited excellent physicochemical properties and it has been reported that the microstructure of fibers is correlated with the physicochemical properties. Regarding literature reports, the hydration properties of fibers were noticed to be weak with a reduction in particle size and the oil holding capacity of fibers was observed to improve with diminished particle sizes upon processing.[15] The results of hydration properties of fibers such as water holding capacity, water retention capacity, absorption capacity and oil holding capacity are given in Table 2. The hydration properties determine the fate of dietary fibers and the rate of digestion to a certain extent and account to some of the physiological effects like adding bulk to the stool, lowering the risk of diverticular diseases by easing constipation and preventing intestinal blockages.[16] The results are expressed as mean ± standard deviation of triplicates.

Table 2: Hydration Properties of Fibers

S.No.	Fiber	Water Holding Capacity(%)	Water Retention Capacity(%)	Absorption Capacity (%)	Oil Holding Capacity (%)
1.	Coconut Fiber	3.39 ± 0.04	2.76 ± 0.042	6.0 ± 0.28	3.17 ± 0.05
2.	Guava Fiber	2.23 ± 0.15	1.93 ± 0.049	2.5 ± 0.29	2.60 ± 0.03
3.	Jackfruit Fiber	2.68 ± 0.06	1.59 ± 0.042	2.8 ± 0.35	2.44 ± 0.04
4.	Watermelon Fiber	2.9 ± 0.04	2.28 ± 0.035	3.6 ± 0.21	2.08 ± 0.03

Table 3: Size Distributions by Intensity and Zeta-Potential

Fiber	Dispers -ant	Temp (°C) (kcps)	Count rate	Z -Avg (d.nm)	PdI cept	Peak inter (d.nm)	Particle size	% Inte -nsity (d.nm)	Std Dev	Zeta Potential (mV)
Coconut Fiber	Water	25	17.8	519.4	0.726	0.977	204.4	100	23.09	-18.4
Guava Fiber	Water	25	6.6	293.3	0.507	0.842	112.2	100	11.55	-14.9
Jackfruit Fiber	Water	25	2.3	440.3	0.66	0.425	214.1	76.4	51.86	-15.3
Watermelon on Fiber	Water	25	7.4	266.9	0.469	0.692	169.8	100	30.73	-16.8

The zeta analyzer was used to measure particle size, zeta potential, molecular charges and electrophoretic mobility of nano particles. Molecular size is one of the salient feature that plays a significant role in managing certain systemic functions of the gastrointestinal tract, such as passage and fermentation time, stool bulking and excretion, etc. The diversity in molecular size is a resultant from the cell wall pattern and framework and processing. The size distribution by intensity was determined based on the peak intercepts. Water was used as the dispersant and the temperature and viscosity were maintained throughout. The charges in fibers were determined by the zeta-potential of corresponding fibers and the net charge on the fibers was observed to be negative. This charge exhibited by the fiber particles plays a vital role in either attaching or repelling substances inside the gut. For instance, the common gut microbiota Lactobacilli, inorganic salts and other organic substances present in the gut adhere to the dietary fiber remnants upon ingestion and fermentation, which is solely based on the charges of the fiber particle.[17] The size distribution and zeta potential of fibers determined is given in Table 3 and the peak intercepts of size distribution by intensity are shown in Figure 1 (A-D).

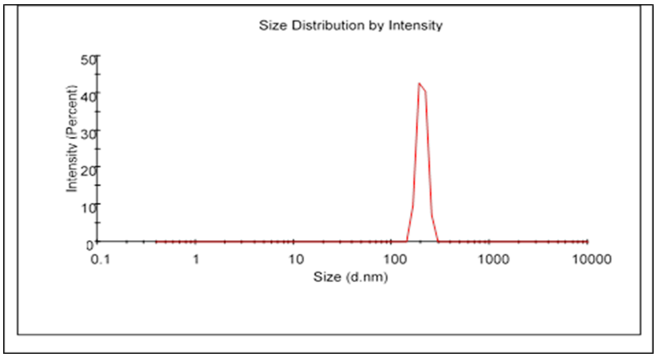

Fig. 1A: Coconut Fiber - peak intercept-204.4

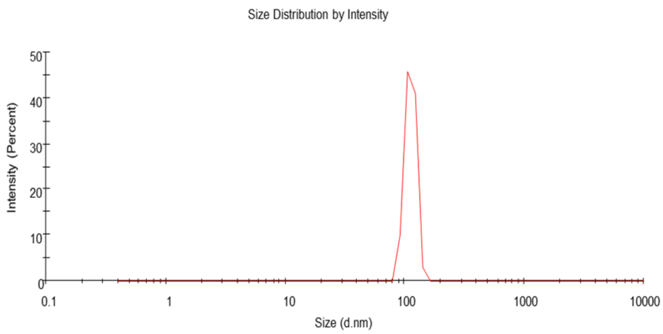

Fig. 1B: Guava Fiber –peak intercept – 112.2

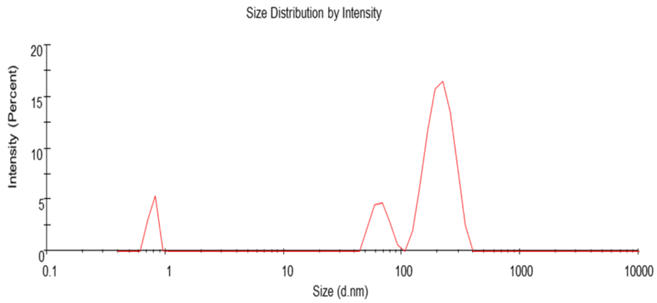

Fig. 1C: Jackfruit Fiber – peak intercept- 214.1

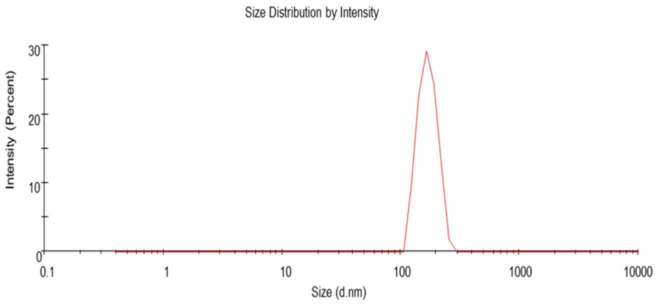

Fig. 1D: Watermelon Fiber– peak intercept- 169.8

Using a Texture Analyzer, the hardness, adhesiveness, gumminess, cohesiveness, springiness, chewiness, and resilience were measured to determine textural properties. Table 4 presents the results of the textural analysis conducted on fruit fibers. Coconut fibers were discovered to have a higher hardness, gumminess, adhesiveness, and chewiness than other fibers. Perhaps the reason for their hardness is due to coconut fibers resistance to deformation and chemical changes. Coconut fibers' inherent property causes increased gumminess, adhesiveness, and cohesiveness. The springiness of coconut fibers was also found to be higher than other fibers, and this is because of their lower water binding and water retention capacities and they are less tensile. The resilience of watermelon fibers was observed to be greater than the other fibers. This may be because of the high water binding capacity of watermelon fibers that makes them easily resilient upon water absorption. The guava fibers and jackfruit fibers were found to exhibit intermediary properties when compared to coconut and watermelon fibers.

Table 4: Texture Analysis of Fibers

S.No.	Parameters	Coconut Fiber (CF)	Guava Fiber (GF)	Jackfruit Fiber (JF)	Watermelon Fiber (WF)
1	Hardness	2702.57	1267.96	582.33	801.6
2	Adhesiveness (g.sec)	-213.07	-15.92	-7.29	-20.74
3	Springiness	0.85	0.76	0.79	0.67
4	Cohesiveness	0.45	0.36	0.37	0.35
5	Gumminess	1228.63	452.18	213.86	246.43
6	Chewiness	1065.34	346.58	172.68	165.1
7	Resilience	0.04	0.09	0.07	0.1

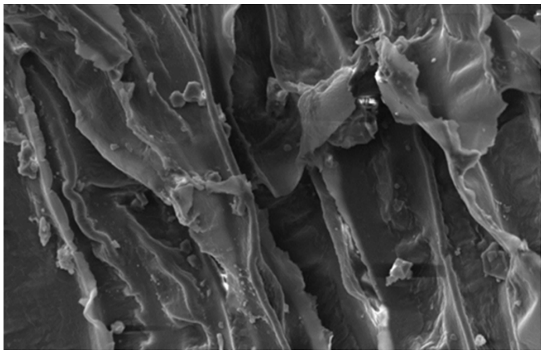

Fig. 2A: SEM image of Coconut Fiber

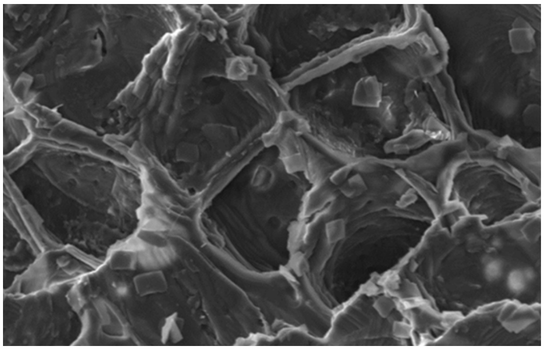

Fig. 2B: SEM image of Guava Fiber

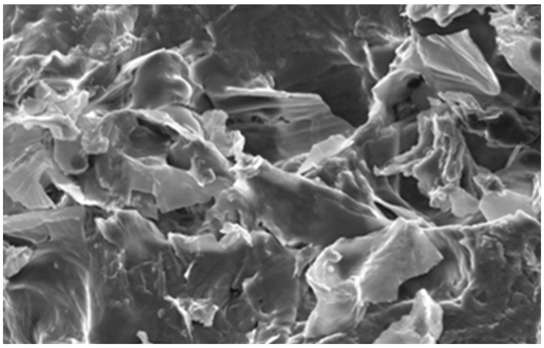

Fig. 2C: SEM image of Jackfruit Fiber

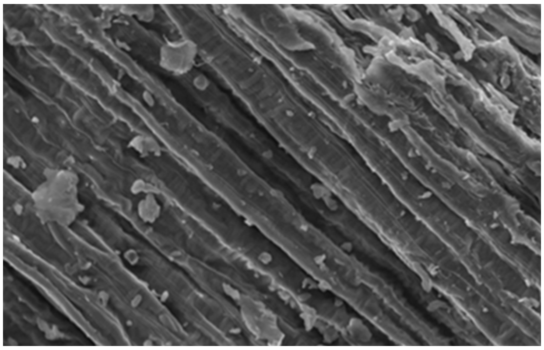

Fig. 2D: SEM image of Watermelon Fiber

For SEM analysis, the surface area of fruit fibers was measured at a resolution ranging from 10µm-20µm. The pore size and permeability affects fiber fermentation, whereas the asymmetrical arrangement of the exterior layer contributes to enhance the physiological attributes. Regarding SEM images, the porosity and surface area of dietary fibers convenient for bacteria or other molecular transcripts and enzymes highly depend on the configuration and framework of fiber and that is directly correlated to the species and its processing history and the extent of fermentation.[18] The SEM images of fibers obtained are given Figure 2 (A-D).

Conclusion

The results and findings of this research work bring out the physiological and functional properties of fruit fibers in relation to their suitability as prebiotic. Dietary fiber is a composite assortment of chemical structures and its constitution in diverse sources has never been uniform or constant. This miscellaneous diversity illustrates the intricacy of innate features associated to dietary fibers. The physiological characteristics of dietary fibers are contingent on its physicochemical properties. Besides these attributes, the plant cellular framework influences the storage stability and sensory characteristics of dietary fibers. In case of any technological processing, the physiological characteristics of dietary fibers may be surpassed and consequently, the physiological and functional effects may be significantly altered.

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Conflict of interest

The authors have no conflict of interest pertaining to this study.

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