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Effects of several processing techniques on proximate composition, antioxidant properties of citrus fruit peel and its application in value-added food products

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Abstract
Citrus fruits (CF) are a rich source of dietary fiber, vitamins, and minerals. CF-derived various secondary metabolites include coumarins, alkaloids, limonoids, flavonoids, phenolic acids, carotenoids, and essential oils that play a vital role in the human body. However, along with CF, its by-product (peel) is also nutritious. In the current lifestyle scenario due to the increasing demand for sustainable healthy diets, CF peel is utilized and transformed as waste into a valuable, affordable, and nutritious compound to be utilized as a good source of food fibers, and low-calorie bulk ingredients in food application. This study focus on the preparation of CF (kinnow, and mosambi) peels powder by using different processing methods (blanching, boiling, and steaming), and drying (sun, and oven drying) methods as well as analysis of nutrients, physico-chemical composition, and antioxidant properties. The proximate analysis shows the presence of moisture, protein, crude fiber, fat, and carbohydrate in different concentrations. Antioxidant properties were shown that vitamin C content was higher in mosambi peel powder, and ferric reducing ions were also observed higher in steamed sundry mosambi peel powder. Then after, an attempt was made to develop fiber-rich biscuit, cake, and ice cream by supplementing both kinnow and mosambi peel powder in different concentrations of (2%, 4%, and 6%) respectively. Thus, results recommended that supplementing these fiber and antioxidant-rich peel powders in food products has the best utilization for treating various human diseases such as cancer, and cardiovascular diseases, and natural tool for obesity that kills human fats.

Keywords: citrus fruits, peel, physico-chemical**,** antioxidant, fiber

Introduction

In the modern era, the improvement of life quality directly affects the worldwide population growth rate, leading to excessive utilization of human resources, and resulting in more waste production. The term "waste" means something that is not in use or is unusable material. Hence, high waste production causes both environmental pollution as well as its inefficient waste management [1]. Traditionally, the "take-make-dispose" model aims to recover, re-use, process, and upgrade raw materials into new valuable items [2]. Similarly, this is also applicable to the food sector where it is practicable to recover, recycle, remanufacture, reuse, repair, and reduce food waste and upgrade or intensify them into novel, sustainable products [3]. Fruits and vegetables are consumed in large quantities worldwide, and a large amount of waste generated from the consumption of both as well as fruits are industrial use for the production of juices, jams, jellies, canned fruit, marmalades, dehydrated fruit, healthy drinks, and beverages [4]. Citrus fruits (CF) are the most widely consumed fruits in the world due to their aroma, flavor, and taste, and possess medicinal properties such as anti-obesity, anti-inflammatory, anti-cancer, anti-infective, anti-oxidative, and neuroprotective [5, 6, 7, 8, 9, 10] activity.

CF (Citrus L. from Rutaceae) consist of 150 genera, and 1600 species [11] have been valued as nutritious, refreshing fruits in the human diet, and also owe their popularity in terms of a variety of taste such as sweet, tangy, and sour [12]. CF-producing countries in the world are China, Brazil, Mexico, India, Iran, Spain, Italy, Nigeria, and United States [13]. CF is an excellent source of nutrients, and phytochemicals, and contained more than 80% of water. CF attributes to high nutrient content including sugar (fructose, glucose, and sucrose), dietary fibers (cellulose, and pectins), minerals (potassium, calcium, and phosphorus), and vitamins (vitamin C) [14]. The major advantage of all these nutrients helps to overcome obesity, overnutrition, and micronutrient deficiency as well as additional protection against chronic diseases. CF is also low in fat and relatively low glycaemic index which helps to maintain more stable blood glucose levels [15]. Various secondary metabolites which are present in CF are flavonoids (naringin, nobiletin, hesperidin, and tangeretin), carotenoids (α-carotene, β-carotene, antheraxanthin, and violaxanthin), limonoids (nomilin, and limonin), essential oils (limonene, α-pinene, and β-pinene), and synephrine [16]. These metabolites exhibit various protective effects against inflammatory, immune [17], cancer [18], cardiovascular, and digestive diseases [19, 20]. Generally, CF peel is considered a by-product (waste) portion of the fruit. This is a big issue, especially for the juices industry. Therefore, several alternatives are proposed for better management of CF peel to reduce environmental pollution [21, 22]. However, CF peel, is an excellent source of antioxidants, phytochemicals, nutrients, and vitamins with antimicrobial properties [23]. Previous studies show that blanching, boiling, and steaming are necessary processing techniques to be used to reduce the anti-nutritional factors in CF peel [24].

The current study aimed to give an overview of the processing technique of CF peel to prepare its powder. Furthermore, to throw light on the nutritional indices: proximate composition, physico-chemical composition, and antioxidant properties. Additionally, their functional application in the development of food products, and evaluate their acceptability.

2. Material and Methods

2.1 Collection of raw materials

The CF (kinnow and mosambi) peels powders were prepared in Banasthali Vidyapith, Tonk, Rajasthan. CF peels processing was done by different methods such as blanching, boiling, and steaming for 3-5 min after that sun drying for 4 days, and then oven drying for (50-60 ˚C) for 3 min. Then ground to make fine powder and kept in air-tight containers for further study.

2.2 Proximate composition

The crucible was sterilized, dried, and weighed accurately. Then after taking the sample in it and measuring again. Then oven drying at 110 ˚C, the crucible was further measured, and note down the readings. And repeat the process until constant weight is attained. Before the weight was taken, each time crucible was cooled down in desiccators to get the correct results. The nutrient analysis included moisture, protein, crude fiber, fat, and carbohydrate were done. Moisture content was done by using a hot air oven at 105±2 °C for 3-4 h. Weighing until a constant weight was achieved [25]. Protein content was estimated by converting nitrogen content by Kjeldahl's method [26]. Crude fiber and fat were determined by the method explained by [27]. The carbohydrate percentage was calculated by the difference method.

2.3 Physico-chemical composition

The physico-chemical composition of peel powder such as ash, acidity, and pH was determined in triplicate by using standard procedure [25].

2.4 Antioxidant properties

2.4.1 Estimation of total phenolic content

Total phenolic content was measured by the Folin-Ciocalteu method, followed by standard procedure [28]. Folin-Ciocalteu reagent and sodium carbonate were added to the peel powder and placed for 30 min in the water bath at 40 ˚C. Spectrophotometric analysis was measured at 720 nm wavelength. Total phenolic content was expressed as gallic acid equivalent (GAE)/ 100 g of peel powder.

2.4.2 Estimation of Vitamin C

Vitamin C content was estimated by a standard procedure modified by [29] using 2, 6 dichloro phenol indophenols solutions. Peels powder extract was added to 23 ml of metaphosphoric acid solution (HPO_3). 5 ml solution was added to 5 ml of trichloroacetic acid in 20% of HPO_3. The obtained solution is filtered; 2 ml of filtrate was added at pH 7.1 in 5 ml of buffer solution and 1 ml in 2, 6 dichloro phenol indophenols solutions. The absorbance was carried out at 530 nm. The content of vitamin C was measured in g/100 g of peel powder.

2.4.3 Estimation of ferric reducing antioxidant property (FRAP)

The ferric-reducing activity of the peel powder was determined by [30]. The aliquot 2.5 ml (0.5 ml peels powder extracted by 20 ml of 80% acetone) was mixed with 2.5 ml of 200 Mm sodium phosphate buffer having pH 6.6 and 2.5 ml of potassium ferricyanides, then the mixture was incubated for 20 min at 50 ˚C. After that, 2.5 ml of 10% trichloroacetic acid was added and centrifuged for 10 min at 650 rpm, 5 ml of water and supernatant was mixed and 0.1% of 1 ml ferric chloride, later absorbance was measured at 700 nm.

2.5 Food products development and sensory evaluation

Perishable and non-perishable recipes were selected such as biscuit, cake, and ice cream. One sample served as standard (S) and other test recipes (A, B, and C) were made by supplementing peels powder of kinnow and mosambi in different concentrations of (2%, 4%, and 6%) respectively. All the recipes were prepared in the food science laboratory of Banasthali Vidyapith. Then acceptability of food products was judged by semi-trained panel members by using a 9-point hedonic scale.

3. Results and Discussion

3.1 Proximate composition

Table 1 demonstrates the proximate composition of both kinnow and mosambi peel powder in different processing techniques. The result indicated that the moisture and carbohydrate content of kinnow peel powder is low as compared with mosambi peel powder. Whereas the protein, crude fiber, and fat content of kinnow are higher as compared with mosambi peel powder.

Table 1: Effect of different processing techniques on the proximate composition of kinnow and mosambi peels powder

Nutrients	Boiling	Blanching	Steaming	Boiling	Blanching	Steaming
	Kinnow peel powder			Mosambi peel powder		
	Sun drying					
Moisture content	9.8±0.81	10.0±0.98	12.3±0.99	12.8±0.89	13.1±0.04	17.5±0.98
Protein	4.5±0.18	4.6±0.12	4.5±0.22	3.4±0.04	3.0±0.57	3.2±0.06
Crude fiber	4.7±0.17	4.5±0.01	4.6±0.05	3.3±0.19	3.4±0.16	4.5±0.05
Fat	1.5±0.05	1.5±0.98	1.5±0.89	0.5±0.09	0.5±0.09	0.5±0.09
Carbohydrate	73.8±0.04	75.1±0.02	74.6±0.01	77.7±0.02	78.7±0.05	78.9±0.09
Oven drying						
Moisture content	14.7±0.98	14.6±0.77	14.7±0.98	16.5±0.85	17.0±0.43	16.6±0.60
Protein	5.7±0.06	5.6±0.10	5.4±0.12	4.5±0.19	3.7±0.16	4.4±0.10
Crude fiber	4.5±0.98	4.7±0.24	4.7±0.16	3.5±0.06	3.3±0.09	3.4±0.70
Fat	1.5±0.98	1.5±0.05	1.5±0.98	0.5±0.09	0.5±0.09	0.5±0.09
Carbohydrate	72.3±0.03	73.5±0.04	73.4±0.01	72.9±0.04	74.4±0.07	75.5±0.06

3.2 Physico-chemical composition

Table 2 demonstrates the physico-chemical composition of both kinnow and mosambi peel powder in different processing techniques. The ash composition of the mosambi peel powder was higher than the kinnow peel powder in all processing methods. The acidity of steamed oven-dry kinnow peel powder was slightly higher in comparison with the mosambi peel powder. While the pH content was the same and there is no variation in the different processing techniques.

Table 2: Effect of different processing techniques on the physico-chemical composition of kinnow and mosambi peels powder

Physico-chemical composition	Boiling	Blanching	Steaming	Boiling	Blanching	Steaming
	Kinnow peel powder			Mosambi peel powder		
	Sun drying					
Ash	1.5±0.07	1.5±0.10	1.5±0.07	1.2±0.02	1.3±0.06	5.5±0.03
Acidity	1.1±0.20	1.0±0.20	1.0±0.20	0.8±0.71	1.0±0.20	1.2±0.20
pH	5.5±0.05	5.5±0.06	5.5±0.06	5.5±0.05	5.5±0.05	5.5±0.05
Oven drying						
Ash	1.3±0.80	1.1±0.06	1.3±0.07	1.3±0.04	1.3±0.03	1.4±0.05
Acidity	1.0±0.17	1.2±0.57	1.3±0.25	0.8±0.10	0.9±0.20	1.2±0.20
pH	5.5±0.05	5.5±0.05	5.5±0.05	5.5±0.16	5.5±0.05	5.5±0.06

3.3 Antioxidant properties

Table 3 demonstrates the antioxidant properties of both kinnow and mosambi peel powder in different processing techniques. Mosambi peel powder contains slightly higher amounts of vitamin C compared with kinnow peel powder. Furthermore, the total phenolic content of steamed sundry mosambi peel powder is higher compared with kinnow peel powder.

Ferric-reducing antioxidant properties have no bigger difference by using various processing techniques.

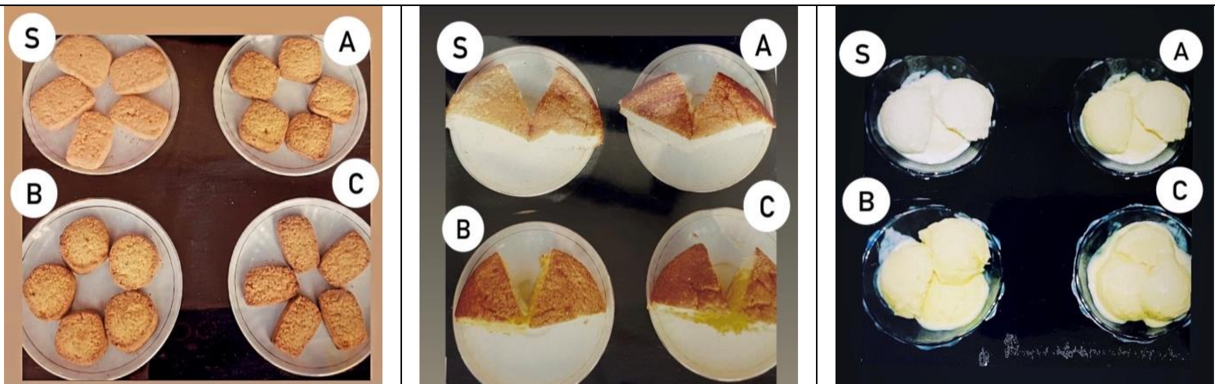
Table 3: Effect of different processing techniques on the antioxidant properties of kinnow and mosambi peels powder aqueous extract

Antioxidant properties	Boiling	Blanching	Steaming	Boiling	Blanching	Steaming
	Kinnow peel powder			Mosambi peel powder		
	Sun drying					
Vitamin C	23.5±0.50	27.6±0.98	25.9±0.78	21.3±0.01	29.5±0.10	34.0±0.47
Total phenolic content	103.6±0.06	82.1±0.72	56.7±0.30	48.1±0.06	45.1±0.06	111.4±0.48
Ferric reducing ions	0.5±0.00	0.5±0.00	0.5±0.01	0.2±0.01	0.3±0.05	0.5±0.01
Oven drying						
Vitamin C	20.0±0.42	28.0±0.38	28.0±0.38	23.5±0.02	31.0±0.44	21.4±0.05
Total phenolic content	96.1±0.54	91.5±0.06	77.5±0.48	95.6±0.16	91.3±0.69	45.6±0.27
Ferric reducing ions	0.4±0.06	0.42±0.02	0.5±0.01	0.45±0.00	0.3±0.05	0.5±0.02

3.4 Sensory evaluation of the developed food products

Sensory evaluation of the supplemented recipes biscuit, cake, and ice cream is an essential part of food product formulation as it helps to reduce product failure chances and links end-user opinion about the overall attributes of developed food products. Although, developed food products are nutritious, without taste, flavor, and appearance the product cannot reach success in the market [31]. The results of the sensory evaluation are listed in tables 4, 5, and 6. Whereas, S (standard recipe), A (2% peels powder), B (4% peels powder), and C (6% peels powder) respectively.

In the case of biscuit, it is clear from the data that, the appearance, flavor, texture, crispiness, and overall acceptability of the standard sample is more acceptable as compared to the supplemented samples. In supplemented samples, the acceptance level increased with a higher concentration of peel powder. That means C is more acceptable as compared with the A and B samples. In the case of the cake, the sensory acceptability followed the same trend as that of biscuits i.e. the standard sample was adjudged as liked extremely on the 9-point hedonic scale for appearance, flavor, texture, crumbliness, and overall acceptability than supplemented samples. In supplemented samples, the acceptance level decreased with increased concentration of the peel powder. That means A is more acceptable as compared with the B and C samples. In the case of ice cream, data revealed that the standard sample was more acceptable in case of appearance, flavor, mouth feel, and overall acceptability was rated as liked extremely as compared to supplemented samples. Supplemented samples followed the same trend as in biscuit, which means the acceptance level increased with a higher concentration of the peel powder. That means C is more acceptable than A and B samples respectively.



(a) (b) (c)

Fig 1: (a) Biscuit, (b) Cake, and (c) Ice cream supplemented with kinnow and mosambi peels powder

Table 4: Sensory evaluation of biscuit incorporated with kinnow and mosambi peels powder

Parameter	S	A (2%)	B (4%)	C (6%)
Appearance	8.5±0.63	6.1±0.51	7.4±0.73	8.1±0.27
Flavor	8.3±0.79	6.0±0.75	6.8±0.01	7.6±0.29
Texture	8.9±0.79	6.7±0.59	7.9±0.83	8.8±0.94
Crispiness	8.3±0.81	6.5±0.63	7.7±0.79	8.5±0.91
Overall acceptability	8.4±0.73	6.9±0.74	7.9±0.83	8.6±0.73

Table 5: Sensory evaluation of cake incorporated with kinnow and mosambi peels powder

Parameter	S	A (2%)	B (4%)	C (6%)
Appearance	8.6±0.73	7.2±0.86	6.1±0.70	6.1±0.91
Flavor	8.7±0.61	8.9±0.63	7.0±0.75	6.5±0.63
Texture	8.5±0.74	7.0±0.75	6.9±0.51	6.8±0.85
Crumbliness	8.3±0.97	8.9±0.79	7.5±0.74	6.1±0.72
Overall acceptability	8.7±0.61	8.0±0.75	7.7±0.70	6.7±0.80

Table 6: Sensory evaluation of ice cream incorporated with kinnow and mosambi peels powder

Parameter	S	A (2%)	B (4%)	C (6%)
Appearance	8.6±0.50	6.3±0.61	7.5±0.63	8.2±0.77
Flavor	8.0±0.70	6.6±0.82	6.3±0.59	8.0±0.65
Mouth feel	8.4±0.73	5.3±0.72	6.3±0.61	7.0±0.75
Overall acceptability	8.1±0.74	6.3±0.59	7.1±0.79	8.7±0.48

Conclusion

Today, proper management of CF peel is extremely important to strengthen the sustainability of their cultivation. Furthermore, a considerable shift in our thinking process has to happen to ensure that the individual has a healthy diet choice that is sustainable and healthy for the environment as well. CF peel is a good source of fiber as well as antioxidant properties which are helpful to prevent life-threatening diseases like cancer, cardiovascular diseases, etc. From the present study, it may be concluded that fiber and antioxidant-rich biscuit, cake, and ice cream could be developed with supplementation of kinnow, and mosambi peels powder up to 6% without compromising sensory acceptability. The developed food products can be commercialized and promoted to utilize the kinnow and mosambi peels which are going to waste. Overall, the results suggested that CF peel is a valuable, economical, sustainable, and renewable source for the food industry.

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