Functional Profiling and Structural Analysis of Dietary Fibers from Sweet Orange (*Citrus Sinensis*) Pomace

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Abstract:

Sweet orange pomace is a byproduct of juice processing industries and auspicious source of dietary fiber with potential to use in food application as a functional ingredient. The aim of this study was to analyze functional and structural characterize dietary fiber from sweet orange pomace. The dietary fibre was use for physicochemical composition, functional property evaluation and morphological analysis. The dietary fiber from sweet orange pomace revealed 58.7 % yield with 11.82 g/g water holding capacity, 2.7 g/g oil binding capacity, 24.18 ml/g swelling capacity and 1.16 g/cm^{3}particle density. SEM evaluation of dietary fiber reflect the presence of coarse, flaky, ridges, irregular cavities and fibrous thread like structure at various magnifications. Elemental profile analysis of dietary fiber using energy dispersive spectroscopy revealed a carbon and oxygen were the dominant element in composition, which is consistent with polysaccharide material.

Keywords: *Sweet orange pomace, Dietary fiber, Functional property*

Introduction

A citrus fruits, sweet orange (*Citrus sinensis*) is highly cultivated and consumed globally. India comes under the category of largest citrus fruit producing country (NHB, 2023). Considerable amount of sweet orange was processed into juices and beverages. This processing generates huge quantity of waste material like peels, seeds and pulp residue, collectively called as pomace (Sharma et al., 2020). It is figured that citrus processing industry creates 50-60% pomace as waste. This large volume of pomace often disposed as waste or used for low value application such as compost material or fertilizer and animal feed (Ajila et al., 2010). The sweet orange pomace is abundant source of dietary fiber, polyphenols, flavonoids and many other bioactive compounds (Sharma et al., 2020). That make it auspicious source for value added ingredient for food application.

The growing interest in functional food has encouraged the exploration of sustainable source of dietary fiber from fruit processing byproducts. Dietary fiber, a non-digestible carbohydrate comprises of soluble and insoluble component proven wide ranges of physiological benefits, including regulation of blood sugar level, cholesterol reduction, improvement in bowl function and modulation of gut micro flora (Elleuch et al., 2011, Anderson Et al., 2009 and Slavin 2013). Due to this physiological benefits extraction and characterization of dietary fiber for utilization in food as functional ingredient from sweet orange pomace gained attention.

The recovery of dietary fibers from sweet orange pomace not just minimized the waste of fruit processing industry but also contribute to isolation of health promoting food ingredient from this waste and used in formulation of fiber enriched food products. Besides, citrus fibers are noticed for their good water holding capacity, swelling capacity and emulsifying property, that make them suitable for value addition in bakery products, dairy products and meat analogues (Grigelmo and Martin 1999).

Several methods including alkali, acid, enzymatic and ultrasound-assisted extraction were used to extract dietary fibers with their desirable properties (Wang et, al., 2015). Characterization of dietary fiber mostly involve analysis of physicochemical composition, next to functional properties including water holding capacity, oil binding capacity, swelling capacity and bulk density (Grigelmo and Martin 1999). These properties are crucial signs of fibers behavior in food formulation as it affecting texture, stability, mouth feel and nutritional status. Examples are, high water holding capacity and swelling capacity is desirable in bakery products, where they enhance water retention and texture (Zheng et al., 2019).

Moreover, surface morphology using technique like scanning electron microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD) and Energy Dispersive Spectroscopy (EDS) provide more insight into microstructure, nature of compound and crystallinity which are important for understanding its interaction with food matrices (Wang et al., 2015). Hence, this study focuses on comprehensive characterization of dietary fibers from sweet orange pomace to analyze its physicochemical, functional and structural properties, thereby evaluating its potential for food application.

Material and Methods

Material

Sweet oranges were purchased from local market and instruments, chemicals and utensils required for completion of this study were used from department of food technology, MGM Institute of Biosciences and Technology, MGM University, Chh. Sambhajinagar, Maharashtra, India.

Chemical Composition Analysis

The dietary fiber were subjected to chemical composition analysis which include moisture, ash, fat, protein, carbohydrate and total dietary fibres. The analysis was carried with procedure prescribed by AOAC 2005.

Functional Properties Evaluation

The particle density and swelling power of the dietary fibre sample were determined using the method described by Adebowale, (2011) with slight modification, water holding capacity and oil binding capacity were analyzed by following methods of Horsfall et al. (2007).

Color Analysis

Color analysis of dietary fibre was done using Hunter color lab (Hunter Associates Laboratory Inc. USA). A glass cell containing sample placed over a light source and covered with black lid and L*, a*, b* values were noted. Where, L* represent lightness or darkness, a* represent greenness and redness and b* represent the yellowness or blueness in sample (Thao and Noomhorn 2011).

Scanning Electron Microscopy (SEM) Analysis

Dietary fibre from sweet orange pomace was analyzed using field emission electron microscopy (Nova Nano SEM 450, United State). Dietary fibres were spreader on double-sided tape mounted on field emission electron microscopy stub and at various magnifications and the micrograph was taken at an accelerating voltage of 15 KV.

Energy Dispersive Spectroscopy (EDS) Analysis

Element analysis of dietary fibre was performed using energy dispersive X-ray spectroscopy. The sample was located to adjust microscope focus. Micrograph was capture for surface view of sample. High vacuum, 20 kV accelerating voltage and secondary electron mode was the condition maintained during the analysis. Energy dispersive spectroscopy does not quantify the components like polysaccharides directly, it only identify the elements present in the sample.

Statistical Analysis

Data was analyzed using appropriate statistical method to evaluate the significances of finding. The result was presented as mean ± standard deviation at P ≤ 0.5 levels to compare between means.

Result and Discussion

Chemical Composition of Dietary Fibre from Sweet Orange Pomace

Dietary fibre used for chemical composition analysis and it revealed that, the moisture content of sample was observed to be 7.64 percent, while the ash value was found to be 4.64 percent. The protein and fat and content dietary fibres from sweet orange pomace was found to be 8.25 and 1.3 percent respectively. Total fibre content was observed to be 70.2 percent, the near to similar results of dietary fibres for chemical composition contents were obtained by Miguel and Belloso (1999), Chau and Huang (2003) and Wang et al. (2015).

Table 1. Chemical composition of dietary fibre

Parameter	Result (%)
Moisture	7.64± 0.06
Ash	4.64± 0.04
Fat	1.3± 0.14
Crude protein	8.25± 0.07
Crude Fibre	70.2± 0.14
Carbohydrate	72.03± 0.01

* Results represent the Mean ± SD of five estimations

Functional Properties of Dietary Fibres from Sweet Orange

Dietary fibres from sweet orange pomace was studied for functional property evaluation and it was found that, the water holding capacity found to be 11.86 g/g, swelling capacity 24.18 ml/g, oil binding capacity 2.17 g/g and particle density 1.16 g/cm^2. Fruit pomace powders can be used as inexpensive, non-caloric bulking agents in food for partial replacement of flour, fat or sugar, as they tend to improve the functionality of food by enhancement of water and oil retention. Good hydration properties also tend to affect the final characteristics of the products incorporated with pomace powders. The result of water holding capacity of dietary fibres is found in comparable with finding reported by Yu et al., (2024).

Table 2. Functional properties of dietary fibres

Sample	WHC (g/g)	Swelling capacity (ml/g)	OBC(g/g)	Particle Density(g/cm³)
Dietary Fibre	11.82± 0.03	24.18± 0.08	2.17± 0.03	1.16± 0.01

* Results represent the Mean ± SD of five estimations

Swelling capacity indicate how much the fibre matrix swell when water is absorbed. Swelling is diffusion phenomenon; molecule containing high swelling ability indicates high porosity of the fibres cited by larrea et al., (2005). Oil binding capacity is important for fibre incorporation into foods, where this property contributes to flavour retention. Ingredients with high oil binding capacity help in the stabilization of high fat food products and emulsions(Nassar et al., 2008). Here the oil binding capacity of the samples was around to be five to six times lower than the hydration capacity. The results of functional properties of dietary fibres were found at far with finding reported by Nassar et al., (2008).

Colour Characteristics of Dietary Fibre from Sweet Orange Pomace

The dietary fibre was used for colour determination by using Hunter colour lab and the data obtained from colour analysis is depicted in table 3, in the value of L*, a*, and b*. It was found that L*, a* and b* value of dietary fibre for colour were 63, 10.07 and 30.90 respectively. Therefore, it was concluded that dietary fibre falls under high lightness, average redness and high yellowness category. These results were similar to study conducted by Krokida et al (2001).

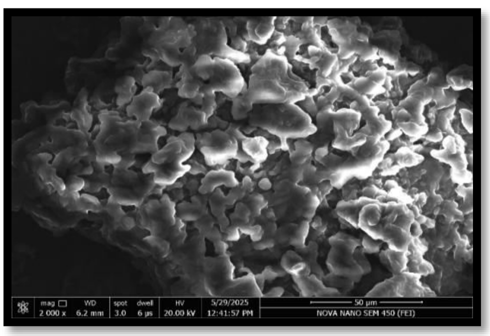
Table 3. Colour characteristics of dietary fibre from sweet orange pomace

Sr. No	Colour characteristics	Results
1	L*	63± 1.10
2	a*	10.07± 0.01
3	b*	30.90± 0.06

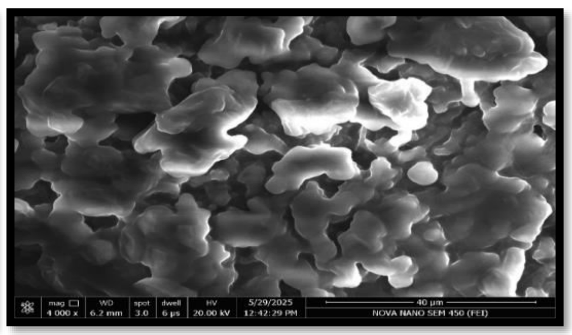
* Results represent the Mean ± SD of five estimations

Scanning Electron Microscopy (SEM) of Dietary Fibre from Sweet Orange Pomace

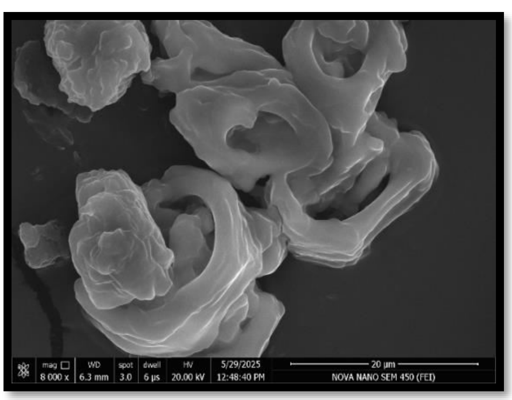
Surface morphology of dietary fibrefrom sweet orange pomace was performed using field emission scanning electron microscopy to observe the structural characteristics related to the functional properties at six different magnifications. At 2000X and 4000X magnification the dietary fibres shows dense, irregular and compact structure. Fibres also exhibit rough and uneven surface with clear clusters and aggregated particles. Dietary fibres extracted from plant based material usually have such thick and porous structures that reflect potential for good water holding and oil binding capacity due to their surface properties. At 8000X and 12000X magnification sharper structure was noticed. Here twisted sheet like formation was observed in dietary fibres indicating the presence of polysaccharides such as cellulose, hemicellulose and pectin. These structures can interact with water and oil molecules to enhance functional property like swelling capacity and emulsification (Ng et al., 2017). At high magnification 16000X and 30000X revealed fibrous and fragmented lamella structure with sharp edges indicating high surface to volume ratio and porosity.This result are in close agreement with the result of litchi pomace dietary fibre report by Yina et al., (2022).



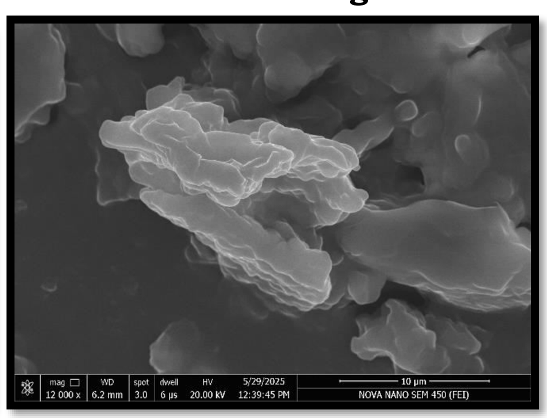
At 2000 X magnification



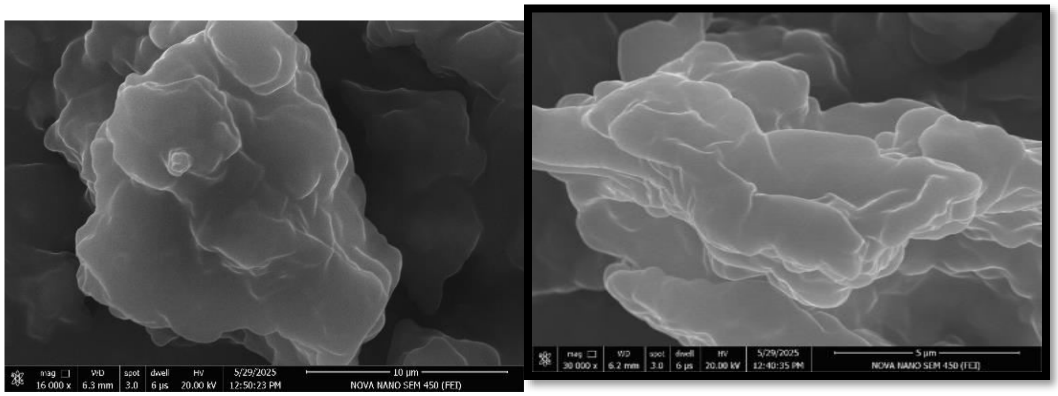
At 4000 X magnification



At 8000 X magnification



At 12000 X magnification



At 6000 X magnification At 30000 X magnification

Figure1. Scanning electron micrographs of dietary fibres from sweet orange pomace at various magnifications.

Elemental Profile Analysis of Dietary Fibres Using Energy Dispersive Spectroscopy

Energy Dispersive X-ray Spectroscopy (EDS) analysis of dietary fibres from sweet orange pomace was carried out o examine the elemental profile analysis. It was found that, carbon and oxygen were the predominant element present in dietary fibres with weight percentage of 78.28% and 21.72%, and atomic percentage 82.76% and 7.24% respectively. These elements are the fundamental components of organic matter in plat derived fibres and reflect the presence of cellulose, hemicelluloses and pectin. Similar results reported by various studies for dietary fibres extracted from fruit processing by-products. Equivalent elemental profile for mango peel dietary fibre, indicating carbon and oxygen accounted more than 95% of elemental content suggesting the presence of polysaccharides were reported by Ajila et al., (2010). Moreover, dietary fibres from tomato pomace disclosed presence of high percentage of carbon and oxygen reconfirming the composition rich in cellulose, hemicellulose and pectin was cited by Boukid et al, (2008).

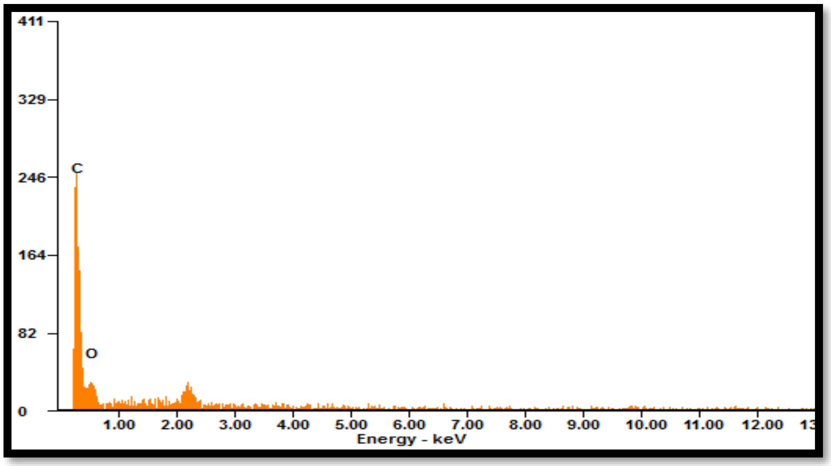


Figure 2. Energy Dispersive X-ray Spectroscopy of dietary fibre indicating intensity of the elemental spectra.

Conclusion

The present study successfully demonstrates thefunctional evaluation and characterization of dietary fibres from sweet orange pomace. The chemical composition revealed high dietary fibre, good protein and low fat and moisture content making it nutritionally strong. Dietary fibre shows excellent water holding and swelling capacity supporting its use in food formulation. SEM and EDS analysis exhibit the porous and fibrous structure, high content of carbon and oxygen, indicating presence of polysaccharides like cellulose, hemicellulose and pectin. Comprehensively, sweet orange pomace has great potential as affordable functional ingredients for value added food application comprising both nutritional enhancement and waste utilization.

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