A STUDY ON PROXIMATE COMPOSITION, FUNCTIONAL PROPERTIES AND PREBIOTIC CAPACITY OF DIETARY FIBERS ISOLATED FROM *APIUM GRAVEOLENS VAR. DULCE* POMACE

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ABSTRACT:

This study investigated the proximate composition, functional properties, and potential health benefits of total dietary fiber and its soluble and insoluble dietary fiber fractions isolated from celery pomace. The result revealed that the insoluble dietary fiber has great hydration properties with a swelling capacity of 30.41± 0.35 mL/g dry basis. The total dietary fiber is useful for reducing sugar blood ability due to its value of glucose adsorption with 2.20 ± 0.02 mg glucose/g dry basis. Notably, the soluble dietary fiber fractions demonstrated significant prebiotic activity, increasing colony-forming units and titrating acid total content by 26.86 and 3.43 times, respectively, after 48 fermentation hours. *Apium graveolens var. dulce* pomace fiber fractions show potential as functional and prebiotic ingredients for food products.

Keywords: dietary fiber, *Apium graveolens var. dulce* pomace, prebiotic capacity.

1. Introduction

Celery, scientifically known as *Apium graveolens var. dulce*, is thought to have health benefits such as lowering blood pressure, stimulating the uterus, aiding digestion, and having anti-inflammatory properties [1]. *Apium graveolens var. dulce* contains about 14.84 to 18.28% dietary fiber by dry matter weight and is a good source of antioxidant compounds with high antioxidant properties [2]. Celery in Vietnam is typically consumed raw or juiced; the leftover pulp from the juicing process, known as celery pomace, is often not used. Owing to its wide range of benefits, this by-product is being evaluated as a potential food ingredient to improve human health.

Dietary fiber is a type of carbohydrate that the human body can not digest. It is found in plant-based foods like fruits, vegetables, whole grains, and legumes. Dietary fiber has two main types: insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) [3]. Daily intake of dietary fiber has a link with decreasing the risk of cardiovascular disease, colonic health, gut motility, and colorectal carcinoma [4]. Dietary fiber acts as a prebiotic, providing nourishment for the gut microbiota. Through fermentation in the colon, dietary fiber is converted into short-chain fatty acids (SCFAs). These SCFAs have been shown to regulate various metabolic processes, including lipid, glucose, and cholesterol metabolism, contributing to overall health [4]. Based on the potential benefits of *Apium graveolens var. dulce* and dietary fiber as mentioned above, this research aims to explore the physical characteristics, functional properties, and prebiotic activity of dietary fiber extracted from *Apium graveolens var. dulce* pomace powder. Additionally, the study investigates the impact of *Apium graveolens var. dulce* fiber fractions on the human gut microbiota and their potential applications in food products.

2. Materials and methods

2.1. Materials

The raw material, celery pomace, was collected from celery juice shops in Hochiminh City and then dried at 60°C until the moisture content of the powder reached 12%, ground and sifted by 40 mesh grate, and stored in polyethylene bags in the freezer at -18°C for further experiment.

All chemicals with analytical grade were bought from Merck KGaA (Germany). Commercial enzymes were purchased from Novozymes (Denmark).

2.2. Preparation of celery dietary fibers

The three fiber fractions including total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) were extracted from the *Apium graveolens var. dulce* pomace powder following the Baenas et al (2020) [5]. The powder firstly dissolved in phosphate buffer solution (pH = 6 - 6.5) and then digested following the hydrolysis process with α-amylase heat-stable at 95°C for 30 min, with protease at 95°C for 35 minutes and with α-glucoamylase at 60°C for 35 min. When the hydrolysis process was completed, different treatments were applied to the dietary residue fiber to obtain the TDF, IDF, and SDF. For TDF extraction, 95% ethanol was added and maintained overnight to precipitate soluble components. Afterward, samples were centrifuged at 4000×g, for 20 min (Hermle Z-366K, Germany), the supernatants were discarded, and the remaining residues contained A-TDF. For IDF and SDF extraction, the treated samples were centrifuged at 4000×g for 20 min (Hermle Z-366K, Germany) and the precipitates were taken as A-IDF. The supernatants were collected and precipitated with 95% ethanol for the precipitation of SDF overnight. The samples were then centrifuged and the precipitates were taken as A-SDF. The three fractions of isolated dietary fiber (A-TDF, A-IDF, A-SDF) were dried at 60°C to reach a moisture content of 12%. The samples will be ground, sieved through 40 mesh, and stored at -4°C for further experiments.

2.3. Chemical composition

Protein, lipid, ash, total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF), were measured by AOAC 984.13, 960.39, 930.30, 996.11, 991.43, 991.42 and 993.19 methods, respectively. The carbohydrate content of a sample (per 100 grams of dry matter) is calculated by subtracting the protein, total lipid, and ash content from 100%. Neutral sugar concentrations were quantified by HPLC using an Agilent 1290 system with an RID detector, following the method of Hu et al. (2023) [6]. The total phenolic content was quantified using a spectrophotometric method based on the Folin-Ciocalteu reagent. Antioxidant capacity was evaluated by the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay and the ferric-reducing antioxidant power (FRAP) assay [7].

Water-holding capacity, oil-holding capacity, swelling capacity, water-binding capacity, and glucose absorption capacity were measured following the method reported by Wu et al (2020) [8].

2.4. In vitro fermentation of dietary fiber by human gut microbiota

To investigate the effect of fiber fractions on *Lactobacillus* growth, bacteria were cultured in an MRS medium where 50% of the glucose was replaced with one of three types of dietary fiber isolated from celery pomace. Control cultures contained either 50% or 100% glucose. Bacterial density was quantified using the colony counting method, according to the TCVN 4884-1:2015 standard. The total titrated acid amount was estimated following the reported method by Purwaningtyas et al (2024) [9].

3. Results and discussion

3.1. Nutritional composition and functional properties of Apium graveolens var. dulce pomace powder (AGPP)

Table 1 presents the nutritional contents and functional properties of the *Apium graveolens var. dulce* pomace powder

As can be seen from Table 1, the ash content of AGPP was 9.62% dry basis, higher than 10 times than that of the fresh *Apium graveolens L.*, and nearly 4 times compared to the ash content of celery roots - the part which has the highest ash value [10]. The lipid and protein contents of AGPP were 4.47%, and 13,24% dry basis, respectively, higher than every part of celery plants. On the other hand, the carbohydrate content of AGPP was 56.38% dry basis and the starch content was 6.82% dry basis. The IDF, SDF, and TDF contents of AGPP were 44.39, 5.17 and 49.56% on a dry basis, respectively significantly higher than that of broccoli and carrot pomace powder [11].

Table 1. Nutritional contents and functional properties of the *Apium graveolens var. dulce* pomace powder

	Unit	AGPP
Ash	% dry basis	9.62 ± 0.15
Lipid	% dry basis	4.47 ± 0.41
Starch	% dry basis	6.82 ± 0.12
Protein	% dry basis	13.24 ± 0.08
Carbohydrate	% dry basis	56.38 ± 0.03
Insoluble dietary fiber (IDF)	% dry basis	44.39 ± 0.22
Soluble dietary fiber (SDF)	% dry basis	5.17 ± 0.31
Total dietary fiber (TDF)	% dry basis	49.56 ± 0.36
IDF/SDF	-	8.59 ± 0.12
Total phenolic content	mg GAE/100g dry basis	794 ± 49
DPPH scavenging activity	μM TE/100g dry basis	2545 ± 104
Ferric reducing antioxidant power	μM TE/100g dry basis	1873± 78
Water holding capacity	g water/g dry basis	4.34 ± 0.48
Oil holding capacity	g oil/g dry basis	1.62 ± 0.08
Swelling capacity	mL/g dry basis	12.65 ± 0.32
Water binding capacity	g water/g dry basis	0.21 ± 0.02
Glucose adsorption capacity	mg glucose/g dry basis	3.15 ± 0.07

Every value is presented as mean ± standard deviations (n = 3) and means with different letter superscripts in every row are significantly different (p < 0.05).

Source: Analysis by authors

As shown in Table 1, the total phenolic content of AGPP was approximately 4 times higher than that of rocket salads and brussels sprouts [12]. The antioxidant activities of AGPP are 2545±104 μM TE/100g dry basis and 1873±78 μM TE/100g dry basis for DPPH and FRAP assay, respectively. The antioxidants and antioxidant activities were quite high, therefore, AGPP could be a potential ingredient for food products with strong antioxidant activity.

The water holding capacity and oil holding capacity of AGPP were 1.4 and 1.8 times lower than that of asparagus hard-stem powder, respectively [13]. AGPP had a higher swelling capacity than deoiled red raspberry pomace (6.93 mL/g dry basis). The high swelling capacity of the ingredient suggests that it could enhance satiety, reduce the risk of being overweight, and potentially be used in obesity-preventing functional foods [14]. On the other hand, the glucose adsorption capacity of AGPP was 3.15 ± 0.07 mg glucose/ g dry basis, equal to deoiled red raspberry pomace with 3.42 mg glucose/ g dry basis. Li et al (2022) found that surface area, porosity, and viscosity are factors influencing glucose adsorption capacity [14].

3.2. Chemical and functional properties of dietary fibers isolated from Apium graveolens var. dulce pomace powder

Table 2 presents the chemical and functional properties of dietary fiber isolate from Apium graveolens var. dulce pomace powder.

The results of A-TDF, A-IDF, and A-SDF show the difference in the profile of neutral sugars. The A-TDF fraction leads the trend of xylose with the amount of 32.29 µg/mg dry basis. While in glucose content, A-IDF has the highest value with 25.30 µg/mg dry basis, slightly higher than A-TDF and A-SDF with 19.79 and 22.65 µg/mg dry basis, respectively. Lastly, A-SDF leads the trend of galactose with 65.86 µg/mg dry basis, significantly higher than the A-TDF and A-IDF fractions.

As can be seen from Table 2, the total phenolic content of A-SDF was the smallest compared to the two remaining dietary fibers with 259 ± 11 mg GAE/100g dry basis. The low phenolic content of A-SDF could be explained, the soluble dietary fiber does not have cellulose for bounding polyphenols. The antioxidant activities by DPPH scavenging capacity A-TDF and A-IDF were higher by 1.8 and 2.1 times, respectively, as compared to A-SDF.

The water holding capacity and swelling capacity are related to the capacity of the water retaining of the fiber matrix, which affects the gut health system via bulking stool weight [15]. The A-IDF showed the highest capacity in the two experimental results, with 13.25 ± 1.56 g water/g dry basis and 30.41± 0.35 mL/g dry basis, respectively. On the other hand, the oil holding capacity of A-IDF was 1.33 ± 0.05 g oil/g dry basis, much higher than the value of A-SDF and A-TDF with 0.53 ± 0.02 and 1.09 ± 0.01 g oil/g dry basis, respectively. On the other hand, the water binding capacity of A-SDF shows the lowest value at 0.17 ± 0.01 g water/g dry basis.

Glucose adsorption capacity (GAC) reflects a

Table 2. Chemical and functional properties of dietary fiber isolate from *Apium graveolens var. dulce* pomace powder

	A-TDF	A-IDF	A-SDF
Xylose (µg/mg dry basis)	32.29	22.27	22.77
Glucose (µg/mg dry basis)	19.79	25.30	22.65
Galactose (µg/mg dry basis)	46.15	46.85	65.86
Total phenolic content (mg gallic acid equivalent/100 g db)	362 ± 10[b]	436 ± 54[a]	259 ± 11[c]
DPPH scavenging activity (µmol Trolox equivalent/100 g db)	1350 ± 129[b]	1527±223[a]	742 ± 93[c]
Ferric reducing antioxidant power (µmol Trolox equivalent/100 g db)	455 ± 37[b]	526±43[a]	301 ± 28[c]
Water holding capacity (g water/g dry basis)	11.89 ± 0.05[b]	13.25 ± 1.56[a]	3.87 ± 0.02[c]
Oil holding capacity g oil/g dry basis	1.09 ± 0.01[b]	1.33 ± 0.05[a]	0.53 ± 0.02[c]
Swelling capacity (mL/g dry basis)	26.28 ± 0.35[b]	30.41 ± 0.35[a]	11.76 ± 0.07[c]
Water binding capacity (g water/g dry basis)	0.56 ± 0.01[b]	0.76 ± 0.05[a]	0.17 ± 0.01[c]
Glucose adsorption capacity (mg glucose/g dry basis)	2.20 ± 0.02[a]	1.80± 0.04[b]	1.40 ± 0.01[c]

Every value is presented as mean ± standard deviations (n = 3) and means with different letter superscripts in every row are significantly different ($p < 0.05$). db: dry basis

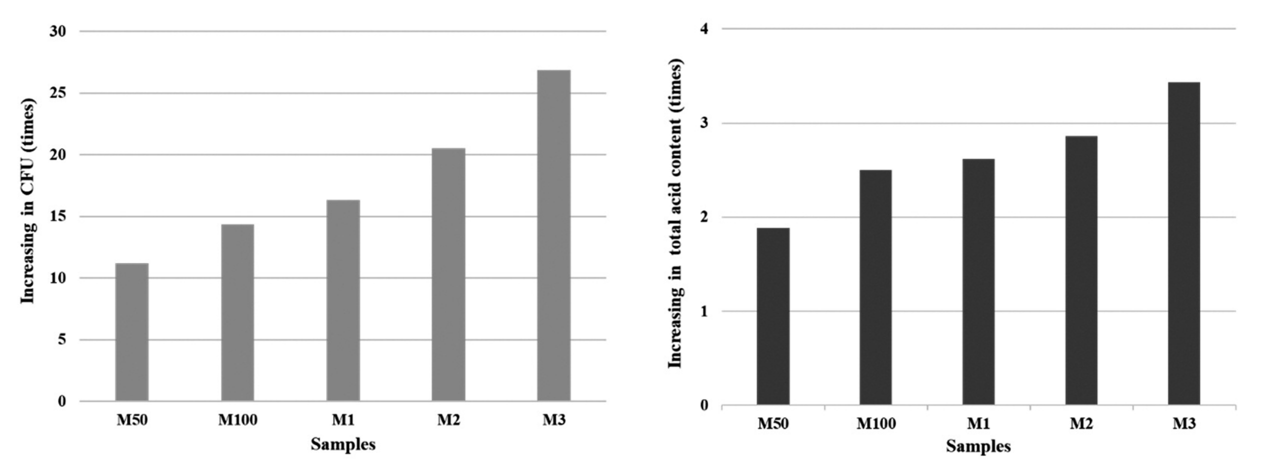
Source: Analysis by authors

material's ability to bind glucose, thereby delaying intestinal absorption and preventing postprandial hyperglycemia [16]. The experimental results showed that the A-TDF had the highest value of GAC with 2.20 ± 0.02 mg glucose/ g dry basis, higher than A-IDF (1.80 ± 0.04 mg glucose/ g dry basis) and A-SDF (1.40 ± 0.01 mg glucose/ g dry basis).

3.3. Prebiotic capacity of dietary fibers isolated from Apium graveolens var. dulce pomace powder

growth of *Lactobacillus,* a beneficial gut microbe. Following a 48-hour incubation period, a significant increase in total acid content was observed, likely due to the fermentation of fiber by Lactobacillus. The M3 media has the highest total acid content compared with the M1, M2, and control media because of the highest bacterial growth rate. This result indicated that the M3 media was the most effective environment for the dietary fiber fermentation of *Lactobacillus*.

Figure 1. The increasing of total acid and CFU after fermentation on Lactobacillus of the five environments



M50: MRS environment with 50% glucose content; M100: MRS environment with 100% glucose content; M1: MRS environment with 50%glucose content and 50% A-IDF; M2: MRS environment with 50% glucose content and 50% A-TDF; M3: MRS environment with 50% glucose content and 50% A-SDF. CFU: Colony-forming unit

Source: Analysis by authors

Figure 1 illustrates the increase in *Lactobacillus* bacteria density and total acid content following a 48-hour fermentation period in environments supplemented with A-TDF, A-IDF, A-SDF, and a controlled environment without fiber supplementation. M3 medium exhibited the highest bacterial growth rate, increasing by 26.86 times after 48 hours compared to the initial bacterial density. This can be attributed to soluble dietary fiber composition, which includes pectins and hemicelluloses - two fermentable fibers.

The graph suggests that SDF promotes the

4. Conclusion

Apium graveolens L. pomace powder is an abundant source of dietary fibers with the promising prebiotic ability of its nutritional fibers - especially the soluble fiber fraction. Coming up with the results from the nutritional and functional properties, and neutral sugars profile of three types of dietary fibers, it can be concluded that the insoluble dietary fiber is a potential ingredient for supplements that support gut intestinal health, especially the hydration properties such as water holding capacity, swelling capacity can help bulk the stool, or the glucose adsorption capacity is quite high can help reduce postprandial hypertension. The A-SDF fraction shows a great ability of prebiotics, it can be believed to be a good ingredient that supports gut microbiota which is related to human health due to the number of soluble compounds that *Lactobacillus* can ferment, especially pectin and soluble hemicellulose ■

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ĐÁNH GIÁ THÀNH PHẦN HÓA HỌC, TÍNH CHẤT CHỨC NĂNG VÀ HOẠT TÍNH PREBIOTIC CỦA CHẤT XƠ PHÂN LẬP TỪ BÃ CẦN TÂY (*APIUM GRAVEOLENS VAR. DULCE*)

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TÓM TẮT:

Nghiên cứu này đã đánh giá thành phần hóa học, tính chất vật lý, tính chất chức năng và hoạt tính prebiotic của chất xơ tổng cũng như chất xơ hòa tan và không hòa tan được phân lập từ bã cần tây. Kết quả cho thấy chất xơ không hòa tan có khả năng hydrat hóa tuyệt vời với khả năng trương nở là 30,41 ± 0,35 mL/gam chất khô. Chất xơ tổng có thể góp phần làm giảm khả năng hấp thụ glucose trong máu do giá trị hấp phụ glucose của nó là 2,20 ± 0,02 mg glucose/ gam chất khô. Đáng chú ý, thành phần chất xơ hòa tan thể hiện hoạt tính prebiotic đáng kể, sau 48h lên men bằng vi khuẩn *Lactobacillus* đã làm gia tăng mật độ vi khuẩn và hàm lượng axit tổng lần lượt là 26,86 và 3,43 so với thời điểm ban đầu. Các thành phần chất xơ trong bã *Apium graveolens var. dulce* cho thấy tiềm năng sử dụng trong các sản phẩm thực phẩm chức năng.

Từ khóa: chất xơ thưc phẩm, bã cần tây, hoạt tính prebiotic.