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The Effects of Preprocessing and Drying Methods on the Quality of a Nutritious Dried Soup Product Derived from Purple Sweet Potatoes and Chinese Kale Leaves

SUWANNA PICHAIYONGVONGDEE[1]*, BOONYAKRIT RATTANAPUN[2], WACHIRA SINGKONG[2], TEERANUCH CHYSIRICHOTE[3], NUJIRA RASAMIPAIBOON[4] and JIRAPORN PHONGSOPA[5]

[1]Department of Innovation Technology for Food Entrepreneur, School of Culinary,
Suan Dusit University, Bangkok, Thailand.
[2]Faculty of Science and Technology, Kamphaeng Phet Rajabhat
University, Kamphaeng Phet, Thailand.
[3]Department of Culinary Technology and Service Program, School of Culinary,
Suan Dusit University, Bangkok, Thailand.
[4]Department of Home Economics, School of Culinary,
Suan Dusit University, Bangkok, Thailand.
[5]Department of General Science Program, Faculty of Science and Technology,
Suan Dusit University, Bangkok, Thailand.

Abstract

In general, most traditional cream soups are high in carbohydrates and low in calcium, fiber, and phytochemicals, which reduces their nutritional value. Therefore, the development of purple sweet potato soup fortified with Chinese kale was important to enhance its nutritional value and address malnutrition. This innovative product combines the health benefits of purple sweet potato due to its antioxidant properties, while Chinese kale was a rich source of calcium and dietary fiber, making it a more nutritious and health-promoting food. This research investigated the effects of different pre-processing and drying methods on the physicochemical and cooking properties of freeze-dried soup products made from purple sweet potato (PP) and Chinese kale (CK). CK was blanched in 1% NaCl and 1% NaHCO3 solutions and then tray-drying and freeze-drying techniques were used. It was found that CK branched in 1% NaCl solution and freeze-dried retained significant levels of chlorophyll, calcium, fiber, and antioxidants.

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CONTACT Suwanna Pichaiyongvongdee ✉ suwanna_pic@dusit.ac.th Department of Innovation Technology for Food Entrepreneur, School of Culinary, Suan Dusit University, Bangkok, Thailand.

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Steaming PP before drying increased the anthocyanin content more than boiling. Freeze-dried PP had a higher fiber content than tray-dried PP. Therefore, a soup using freeze-dried CK and PP was developed to develop a healthy purple sweet potato powder soup with three levels of CK supplemented (5, 10, and 15%). All formulas were sensory evaluated by quantitative descriptive analysis (QDA) by 10 food experts. It was found that the appropriate amount of additional freeze-dried CK of 10% could be determined. The ratio of PP-CK soup to hot water is 1:5 to achieve the most suitable taste, viscosity, mouthfeel, and overall acceptability. The soup is nutritionally rich, high in calcium, dietary fiber and antioxidants, making it an excellent choice for a healthy breakfast.

Introduction

Soup is a traditional food that is considered an appetizer. It is usually made by combining green vegetable leaves, such as fruits, tubers, and legumes. Their popularity, particularly in powder form, is due to their cost-effectiveness, ease of preservation, and straightforward preparation, which align perfectly with modern, fast-paced lifestyles. Kalsoom *et al*[1] investigated innovative combinations in Tateishi Kazu soup, incorporating underutilized leafy greens with ingredients such as burdock root, shiitake mushroom, and termite flour. Mon*dal et al*[2] developed soup mixtures using lesser-known vegetables from North-East India, including *Ipomoea* aquatica Forssk, Lagenaria siceraria, and Basella alba.

Green leafy vegetables are celebrated for their nutritional richness, packed with many essential nutrients. These vegetables boast high dietary fiber, chlorophyll, carotenoids, vitamins C, and calcium. Spinach and Chinese kale are particularly notable for their nutritional profiles, making them popular choices in soup recipes. Chinese kale has emerged as a significant ingredient in soup formulations due to its high calcium content, which is crucial for bone and dental health. Chinese kale provides a more bioavailable source of calcium, thus presenting an opportunity to develop high-calcium functional foods. Pichaiyongvongdee *et al*[3] conducted a detailed analysis of Chinese kale's nutritional profile, uncovering remarkable findings: 246.15 mg of calcium per 100 g, 84.81 mg of total chlorophyll per 100 g, and 176.82 mg eqGA of total polyphenol content per 100 g. These results highlight the significant nutritional value of Chinese kale, particularly its substantial calcium content. The bioavailability of calcium from plant sources has been extensively studied, emphasizing the superior absorption rates of vegetables compared to traditional dairy sources. Kamchan *et al*[4] used Miller's method in an in vitro study to examine calcium absorption from various vegetables, finding that all tested types—kale, celery, pak-chee-lao, Chinese cabbage, and soybean sprouts—had higher calcium absorption rates than powdered milk. These vegetables were low oxalate and rich in phytate dietary fiber, enhancing calcium absorption. Satheesh and Fanta[5] corroborated these results, specifically praising kale for its high fiber and mineral content and noting that its calcium is more bioavailable than milk, underscoring its viability as a source of calcium in functional foods. While kale contains anti-nutritional factors like oxalates and tannins, Noonan[6] reported that these can be significantly reduced through processing methods such as soaking and heat treatment, thereby mitigating their effects.

In addition, purple sweet potatoes (*Ipomoea batatas* L. Lam), a carbohydrate source, are an interesting addition to green leafy vegetables, offering substantial nutritional benefits among the various ingredients used in soup formulations. Panda and Sonkamble[7] emphasized their rich content of carotenoids and antioxidants. Among the myriads of ingredients utilized in soup formulations. Soison *et al*[8] conducted a comparative study on the anthocyanin content in different sweet potato varieties, finding that the Torperk (purple) variety contained 8.81 mg C-3-G/100 g of anthocyanins, markedly higher than other varieties such as Kaset (yellow), Maejo (white-cream), and Khai (yellow-orange), which showed negligible anthocyanin levels. Moreover, Torperk displayed the highest antioxidant activity (DPPH) at 108.7 mg GAE, significantly outperforming the others. Thus, purple sweet potatoes are not only nutritious but also have health benefits. They are suitable for processing various food products, such as breakfast, baby food, and snacks, and they tend to develop healthy foods, especially in soup recipes.

Pre-treatment methods, particularly blanching, play multiple roles: They fix the color in green vegetables, deactivate enzymes that cause browning, and reduce surface microbial loads. The choice of drying method is equally crucial as it influences product quality, shelf life, and economic viability. Studies such as those by Zhang *et al*[9] and Korus[10] have shown that blanching before drying can retain vitamins in kale during storage and enhance the preservation of B-group vitamins and tocopherols. Similarly, Raja[11] found that blanching and oven-drying improved physical properties and phenolic compounds in papaya leaf powder, while freeze-drying preserved more vitamin C. Marzuki *et al*[12] observed that blanching and microwave-vacuum drying maintained the quality of dried, purple-fleshed sweet potatoes by preserving color, antioxidant properties, and phenolic compounds, and reducing drying time. Charoenphun and Meemuk[13] noted that blanching inhibited enzyme activity in sweet orange potatoes, with microwave processing being the fastest, and boiling water and steam improving appearance. These findings emphasize the importance of customizing pre-treatment and drying methods to fit specific ingredients and desired product characteristics, significantly affecting nutritional content, color, and overall quality.

From the above data, it can be concluded that combining purple sweet potato and kale in a soup recipe develops healthy food with added nutritional value such as antioxidants, fiber, and calcium. This new approach responds to consumer demand for healthy and convenient food while supporting Thai agriculture using locally sourced ingredients. This study aims to assess the effects of various preliminary processing and drying methods on purple sweet potatoes and Chinese kale, focusing on the physicochemical and cooking properties of the resultant dried soup product. By integrating purple sweet potatoes as the primary starch source and Chinese kale, whey protein, and inulin, this research endeavors to develop a convenient, nutritious soup that effectively balances essential food ingredients and appeals to a broad consumer base.

Materials and Methods

Raw Materials, Ingredients, and Chemicals

Chinese kale were harvested from Supanburi province, Thailand, their nutritional content with 357.99 mg of calcium, 2.65 g of total dietary fiber, 41.64 mg of phosphorus per 100 g, along with chlorophyll-A at 22.45 mg/g, chlorophyll-B at 11.65 mg/g, and 159.53 mg of total polyphenols (as gallic acid equivalents) per 100 g. Purple sweet potatoes (*Ipomoea* batatatas (L.) Lam.) were harvested from Simummuang Market, Thailand, their were analyzed and found to contain 2.65 g of tot *Ipomoea* al dietary fiber and 66.91 mg of anthocyanins (as cyanidin-3-glucoside) per 100 g. The formulation also included whey protein from Maxwell Global Co., Ltd. Thailand, inulin from 4Care Co., Ltd., Thailand, and coconut cream powder from Natural EX Co., Ltd. Thailand, along with sugar and salt purchased from local markets. All chemicals employed in the study were of analytical reagent grade, ensuring high precision in the measurement and analysis of these components.

Sample Preparation

Pre-Treatment Preparation for Dried Chinese Kale (CK)

Chinese kale leaves were prepared by cleaning, washing with tap water, and slicing into 5 cm thick pieces. The study explored three pre-treatment conditions for drying: T1 involved blanching in hot water, T2 in a 1% sodium chloride (NaCl) solution, and T3 in a 1% sodium bicarbonate ($NaHCO_3$) solution, with the leaves immersed in boiling water at a 1:10 ratio of leaves to water (W/V). The leaves that retained their green color after these pre-treatments were then subjected to 2 drying methods. The first method was freeze-drying using a GFD-10EC from Grisrianthong, Thailand, and the second was tray drying using a Memmert dryer from Germany at 50 °C for 15 - 20 h or until the moisture content was below 10 %, in line with the findings of Agama-Acevedo[14] noted that temperatures between 40 and 50 °C are sufficient to reduce moisture content to below 10%. Following drying, the leaves were finely ground using a multi-function high-speed disintegrator (rotation rate between 25,000 and 28,000 RPM for 5 min, made in Taiwan) into particles that passed through 80-mesh sieves. The ground mixture was then vacuum-packed in aluminum packets and stored at 4±2 °C until analysis.

Pre-Gelatinize Preparation for Dried Purple Sweet Potatoes (PP)

The purple sweet potatoes were washed and cleaned to remove the adhering soil and peeled before undergoing two pre-gelatinization treatments aimed at enhancing texture and digestibility. The first method involved steaming 1 cm thick crosswise slices, The first method was steaming blanching: Boil clean water in a steamer. Blanch the PP (1 cm thick crosswise slices) in 100 °C steam for 10 minutes. After that, immerse the samples in cold water (4°C) for 90 seconds. Remove the pieces from the water and place them on paper towels to absorb any surface moisture. The second method was boiling: PP (1 cm thick crosswise slices) was blanched in boiling water (10:1 w/v) at 100°C for 10 minutes. Then, the samples were immersed in cold water (4°C) for 90 seconds. Finally, the pieces were removed from the water and placed on paper towels to absorb any surface moisture. After pre-treatment, the PP were subjected to two drying methods: freeze-drying and tray drying in an oven at 50 °C for 15-20 h, or until the moisture content was reduced to below 10%.[15] The dried samples were then finely ground into particles that passed through 80-mesh sieves. This ground mixture was subsequently vacuum-packed in aluminum packets and stored at a controlled temperature of 4±2 °C until further analysis.

Properties of Dried Chinese Kale (CK) and Dried Purple Sweet Potatoes (PP)

Chemical Properties and Color

Chemical composition analysis adhered to the AOAC 2023[16] methods, specifically total dietary fiber, calcium, and phosphorus. Chlorophyll-A and chlorophyll-B were quantified following the method described by Rajput and Patil.[17] Color parameters (L*=black to white; a*=green to red; b*=blue to yellow) were measured using a Hunter colorimeter (Minolta Camera Co., Osaka, Japan).

Antioxidant Capacity

An extraction method from Bridgers *et al*18 involved mixing 10 grams of each sample with 25 ml of 80% methanol. After a 2-hour incubation at 80 °C and centrifugation, extracts were filtered for analysis. Total phenolic content (TPC) was evaluated using the Folin-Ciocalteu method as described by Katsuke *et al*[19] and DPPH free radical scavenging activity was measured by mixing extracts with DPPH solution, then calculating trolox equivalents. ABTS assay used method from Arnao *et al,*[20] and total anthocyanin content (TAC) was determined using a method from Finocchiaro *et al*.[21]

Functional Properties

The water solubility index (WSI) and water absorption index (WAI) were analyzed according to the method described by Cortes-Rojas.[22]

Microstructures

Microstructural analysis was conducted using a scanning electron microscope (SEM) (JSM-6610LV, JEOL Ltd., Tokyo, Japan). The samples were fixed to the SEM frame using carbon tape and were coated with a thin layer of gold (Balzer, Germany). Images were recorded at an accelerating potential of 10 kV.

Preparation of Vegetable Soup

Purple sweet potato soup supplemented with Chinese kale was formulated with careful consideration of nutritional balance and functional properties. Starch source: processed purple sweet potato powder 55%; mineral and antioxidant source: Chinese kale powder: three variations (5, 10 and 15%); additional ingredients (modified from Soison *et al*[8] and Saed *et al*[23]: fiber source: Chinese kale powder and inulin (10%); protein source: whey protein (20%); fat source: coconut cream powder (8%); and seasonings: sugar (5%) and salt (2%). The resulting formulation was analyzed physiochemically and sensory analysis.

Properties of Vegetable Soup

Physical Properties

Color parameters were measured using a Hunter Colorimeter. Viscosity properties (apparent viscosity) were evaluated using a Brookfield viscometer (DV-III and DV-II+, Brookfield Engineering Laboratory, Inc., USA). The soup was mixed with boiling water to form a 200-mL solution. A No. 2 spindle was used for measurement. The solution was placed in a 250-mL beaker. The viscosity was measured at 100 rpm. The soup temperature was maintained at 25 °C (room temperature).

Chemical Properties

Chemical property analysis was performed according to the AOAC 2023 method,[16] including total fat, protein, total carbohydrate (calculated), total dietary fiber, sodium, vitamin B1, vitamin B2, calcium, iron, ash, moisture, and vitamin a (modified from Kangsdalampai and Sungpuang.[24]

Antioxidant Capacity

Total polyphenol content, DPPH, FRAP, ABTS, and total anthocyanin content were described in the dried CK, and dried PP.

Sensory Evaluation

For the sensory evaluation of the soup, 2 distinct methods were employed. The first was a quantitative descriptive analysis (QDA) conducted by 10 experts. The second was a consumer preference test conducted by 50 consumers using a 9-point hedonic scale. The appearance, color (darkness), flavors of purple sweet potato and Chinese kale, viscosity, mouthfeel, and overall acceptance. This study involved human participants in a sensory test, which received approval from the Ethical Review Subcommittee for Human Research at the Research and Development Institute of Suan Dusit University (COA.NO: SDU-RDI-HS 2024-003), ensuring adherence to established ethical standards.

Statistical Analysis

This experiment was designed in CRD (Complete Randomized Design) in factorial design and was performed in triplicates. The statistical analysis of the data was conducted using SPSS Statistics Version 20.0. The analytical approach included a One-way Analysis of Variance (ANOVA), Duncan's Multiple Range test was used for comparisons to identify specific differences between means. All statistical tests were performed at a significance level of $p \leq 0.05$ to ensure the reliability of the results by confirming that the observed differences were statistically significant.

Table 1: Effect of pre-treatment on color, pH, and appearance of Chinese kale leaves

	L	a*	b*	pH	Appearance
 Fresh	30.57±0.22^{d}	−3.80±0.13^{a}	27.91±0.10^{a}	6.74±0.02^{d}	The leaves have a glossy texture and are light green with a crisp texture.
 Hot water	41.30±0.12^{a}	−1.11±0.04^{c}	13.26±0.27^{b}	7.34±0.01^{c}	The leaves are bright green in color, with a soft, tender texture.
 1%NaCl	39.72±0.12^{b}	−1.77±0.06^{b}	11.58±0.18c	7.57±0.02^{b}	The leaves feature a soft, tender, and slightly wilted texture with a relatively dark greenish-yellow color.
 1%$NaHCO_3$	38.61±0.3^{c}	−0.66±0.04^{d}	10.28±0.2^{d}	8.61±0.35^{d}	The leaves are dark greenish brown with a soft, smooth, and tender surface.

Note: Values with different letters denote significant (p ± 0.05) differences among treatment in columns

Results

Pre-Treatment Preparation Properties of Chinese Kale (CK)

Before drying, pre-treatment of Chinese kale leaves involved three distinct methods: blanching in hot water, blanching 1% NaCl solution, and blanching 1% $NaHCO_3$ solution, each heated at 100°C for 3 min. Effect of pre-treatment on color, pH, and appearance of Chinese kale leaves as shown in Table 1. Fresh Chinese kale leaves exhibited the highest a* (-3.80) and b* (27.91), exhibiting a greenish and yellowish tone, and the lowest brightness (L=30.57), suggesting a darker appearance. Chinese kale leaves blanching in hot water produced less vivid green and yellow tones by dramatically increasing lightness (L=41.30) while decreasing a*(-1.11) and b* (13.26). Chinese kale leaves blanched in 1% NaCl exhibited a tendency comparable to that of hot water, but with significantly less lightness (L=39.72) and yellow tones (b*=11.58). While, blanching Chinese kale leaves with 1% $NaHCO_3$ produced the least yellow b* (10.28) and the green color (a* -0.66) decreased more than any other blanching method

The pH of Chinese kale leaves was the lowest (6.74), indicating that the kale leaves were almost neutrally acidic. The Chinese leaves blanched in hot water and 1% NaCl had slightly higher pH values of 7.34 and 7.57, respectively, indicating slightly alkaline. The increased pH value of 8.61 was caused by branching with 1%$NaHCO_3$.

Table 2: Physico-chemical properties of dried Chinese kale

Properties				
	TD-NB	**FD-NB**	**TD-B**	**FD-B**
	Physical properties			
L	51.88±0.05^{c}	54.56±0.32^{b}	48.82±0.12^{d}	55.39±0.41^{a}
a*	−0.33±0.02^{b}	−1.07±0.02^{d}	2.14±0.04^{a}	−1.54±0.02^{c}
b*	14.26±0.05^{c}	15.06±0.01^{b}	10.46±0.26^{d}	15.60±0.10^{a}
	Functional properties			
(WAI) (g/g)	8.03±0.11^{c}	8.24±0.02^{c}	9.18±0.27^{b}	9.69±0.04^{a}
(WSI) (%)	3.42±0.19^{d}	4.71±0.24^{c}	8.72±0.34^{b}	13.10±0.36^{a}
	Chemical composition			
Total dietary fiber (g/100 g)	25.57±0.03^{b}	29.73± 0.04^{c}	34.78±0.04^{b}	37.46±0.06^{a}
Calcium (mg/100 g)	2,835±3.35^{b}	3,119±2.52^{a}	1,462±3.07^{d}	1,805±3.59^{c}
Phosphorus (mg/100 g)	601±0.58^{b}	620±0.17^{a}	411±0.23^{d}	599±0.18^{c}
Total Chlorophyll (mg/kg)	6,433	6,657	5,258	6,723
Chlorophyll A (mg/kg)	3,951±3.80^{c}	3,798±2.33^{d}	3,936±4.67^{c}	4,029±4.26^{a}
Chlorophyll B (mg/kg)	2,482±4.89^{c}	2,863±3.00^{a}	1,321±5.73^{d}	2,694±5.35^{b}
Moisture (g/100 g)	6.32±0.05^{a}	4.65±0.26^{d}	6.02±0.07^{b}	5.43±0.13^{c}
Aw	0.43±0.01^{b}	0.30±0.01^{d}	0.46±0.01^{a}	0.39±0.01^{c}
	Antioxidant capacity			
TPC (mg gallic/100 g)	615±1.73^{b}	693±2.10^{a}	504±3.00^{d}	578±3.47^{c}
DPPH (mg/100 g)	14.48±0.21^{b}	15.31±0.21^{a}	12.57±0.30^{d}	13.63±0.20^{c}
ABTS (mg/100 g)	12.29±0.26^{c}	14.82±0.45^{a}	10.58±0.34^{d}	13.52±0.20^{b}

Note: Values with different letters denote significant ($p \leq 0.05$) differences among treatment in rows
Type of product; TD-NB tray dried from non-blanched Chinese kale; FD-NB freeze dried from non- blanched Chinese kale; TD-B tray dried from blanched 1% NaCl Chinese kale; FD-B freeze dried from blanched 1% NaCL Chinese kale

Properties of Dried Chinese Kale (CK)

The present study examined the effects of various pre-treatments and drying methods on Chinese kale's color parameters and total chlorophyll content. The color parameters L, a*, and b* and total chlorophyll content were analyzed across different treatments found that the L* values ranged from 48.82 to 55.39, a* values from -1.54 to 2.14, and b* values from 10.46 to 15.60. Total chlorophyll content varied between 5,258 and 6,723 mg/kg (dry basis). The brightness (L*value) of freeze-dried, blanched FD-B exhibited significantly higher brightness ($p \leq 0.05$) than untreated FD-NB. (Table 2)

The effects of blanching and drying methods on Chinese kale leaves' total dietary fiber (TDF) content. The findings reveal significant variations in TDF content across different treatments. It was reported that blanched and dried samples TD-B and FD-B exhibited the highest TDF content in FD-B (37.46 g/100 g), and TD-B (34.76 g/100 g). Non-blanched samples showed lower TDF content in TD-NB (25.57g/100 g), and FD-NB (29.73 g/100g).

FD-NB contains the highest calcium (3,119 mg/100 g), followed by TD-ND (2,835 mg/100 g), FD-B (1,805 mg/100 g,) and TD-B (1,462 mg/100 g). In terms of phosphorus, FD-NB (620 mg/100 g) and TD-ND (601 mg/100 g) were similar, whereas, TD-B has the lowest (411 mg/100 g), respectively. FD-NB had the highest total phenolic content (693 mg gallic/100 g) followed by TD-ND (615 mg gallic/100 g) and FD-B (578 mg gallic/100 g), respectively. In addition, the DPPH and ABTS results confirmed the antioxidant activity of the FD-NB with the highest DPPH and ABTS values (15.31 mg gallic/100 g and 14.82 mg gallic/100 g), respectively.

Functional Properties

The water absorption index (WAI) and water solubility index (WSI) were critical indicators of processed vegetables' functional properties. FD-B sample had the highest WAI (9.69 g/g), followed by TD-B (9.18 g/g) and FD-NB (8.24 g/g), respectively. In terms of WSI, TD-NB had the lowest solubility (3.42 %), while FD-B had the highest solubility (13.10%), indicating its higher dispersion in aqueous solution.

Pre-Gelatinizes Preparation Properties of Purple Sweet Potatoes (Pp)

This study investigated the impact of various pre-treatment methods on PP's color characteristics and anthocyanin content. Table 3 presents the effects of pre-gelatinization on color for steaming, values were L=39.70, a*=18.63, b*= −6.53, while for boiling, values were L=35.42, a*=13.36, b*=-2.75. Anthocyanin content was 190.59 mg cyaniding-3 glucoside/100 g for steaming and 152.24 mg cyaniding-3 glucoside/100 g for boiling.

Table 3: Color and antioxidant activity of pre-gelatinize in purple sweet potatoes

	Untreated	Boiling	Steaming
			
L	44.72±0.44^{a}	35.42±0.46^{c}	39.70±0.18^{b}
a*	24.52±0.21^{a}	13.36±0.37^{c}	18.63±0.09^{b}
b*	8.45±0.21^{a}	−2.75±0.03^{c}	−6.53±0.27^{b}
Anthocyanin (mg cyaniding -3 glucoside/100 g)	66.91±1.68^{c}	152.24±2.00^{b}	190.59±1.35^{a}

Note: Values with different letters denote significant ($p \leq 0.05$) differences among treatment in rows

Properties of Dried Purple Sweet Potatoes (PP)

This study examined the impact of pre-gelatinization and drying methods on the color attributes of dried purple sweet potatoes (PP). Table 4 shows that pre-gelatinized and dried PP samples displayed increase redness (a*), reduced yellowness (b*), and lower lightness (L*) in comparison to untreated samples. A comparison of drying methods between TD-S and FD-S revealed the highest redness, with a* values of 11.47 and 9.54, respectively, and the most significant blueness, with b* values of -0.84 and -0.27, respectively. In terms of correlation with anthocyanin formation, the increase in a* values after thermal pre-gelatinization were linked to the production of polymeric anthocyanins. The results of anthocyanin measurement in all samples were as follows: FD-S had the highest anthocyanin content (602.94 mg cyaniding-3 glucoside/100 g), followed by TD-S (115.22 mg cyaniding-3 glucoside/100 g), FD-ND (75.92 mg cyaniding-3 glucoside/100 g), and TD-NS (68.46 mg cyaniding-3 glucoside/100 g), respectively. The results of dietary fiber measurement found that FD-S had the highest anthocyanin content (10.95 mg/100 g), followed by FD-NS (9.83 mg/100 g), TD-S (9.76 mg/100 g), and TD-NS (8.11 mg/100 g), respectively. In the results on the antioxidant capacity in PP, revealing significant variations across different processing conditions. It found that pre-gelatinized and dried PP (TD-S and FD-S) exhibited the highest antioxidant activity compared to untreated samples ($p \leq 0.05$).

Table 4: Physico-chemical properties of dried purple sweet potatoes

Properties				
	TD-NS	**FD-NS**	**TD-S**	**FD-S**
Physical properties				
L	56.58±0.2^{b}	59.20±0.10^{a}	50.46±0.08^{d}	53.73±0.13^{c}
a*	8.81±0.08^{c}	7.93±0.01^{d}	11.47±0.04^{a}	9.54±0.05^{b}
b*	7.74±0.17^{a}	7.18±0.07^{b}	−0.84±0.04^{c}	−0.27±0.02^{d}
Functional properties				
(WAI) (g/g)				
(WSI) (%)	2.19 ±0.12^{c}	2.30±0.11^{c}	3.19±0.12^{b}	3.52±0.23^{a}
	14.57±0.50^{d}	17.51±0.42 ^{c}	19.41±0.31^{b}	23.94±0.3^{a}
Chemical composition				
Total dietary fiber (g/100 g)	8.11±0.03^{d}	9.83±0.03^{b}	9.76±0.01^{c}	10.95±0.01^{a}
Moisture (g/100g)	5.23±0.03^{a}	2.35±0.16^{d}	5.08±0.05^{b}	3.69±0.01^{c}
Aw	0.36±0.01^{a}	0.22±0.01^{d}	0.32±±0.02^{b}	0.25±0.01^{c}
Antioxidant capacity				
TPC (mg gallic/100 g)	22.86±0.69^{d}	25.74±0.10^{c}	68.69±0.57^{b}	110.91±0.35^{a}
DPPH (mg/100 g)	21.15±0.56^{c}	21.75±0.14^{c}	22.17±0.28^{b}	40.78±0.28^{a}
ABTS (mg/100 g)	4.43±0.20^{d}	4.86±0.26^{c}	8.26±0.24^{b}	12.65±0.32^{a}
Anthocyanin (mg cyaniding-3 glucoside/100 g)	68.46±1.67^{d}	75.92±1.55^{c}	115.22±1.67^{b}	602.94±3.18^{a}

Note: Values with different letters denote significant ($p \leq 0.05$) differences among treatment in rows

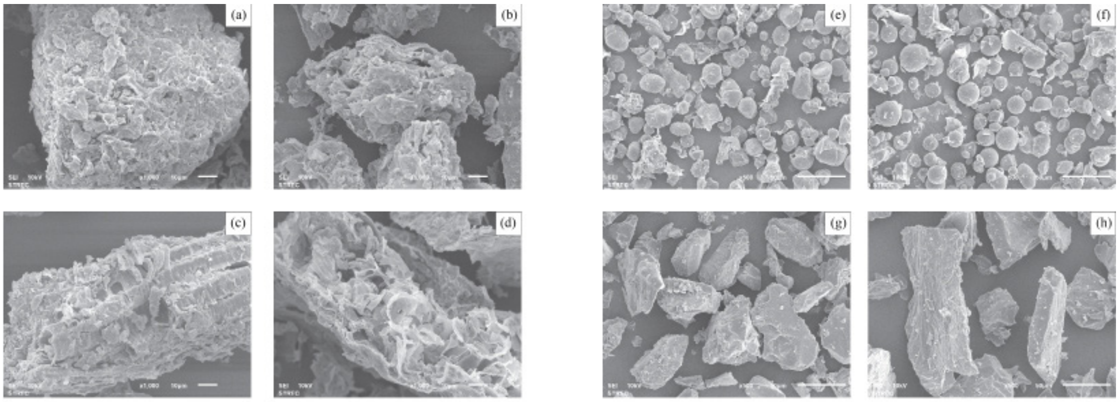
Type of product; TD-NS tray dried from non-steamed purple sweet potatoes; FD-NS freeze dried from non- steamed purple sweet potatoes; TD-S tray dried from steamed purple sweet potatoes ; FD-S freeze dried from steamed purple sweet potatoes

Functional Properties

The effects of gelatinization and drying methods on the WAI and WSI of dried PP were presented in Table 4. The pretreatment method significantly influenced the WAI and WSI of all the samples. The results of the water absorption index (WAI) of all samples found that FD-S had the highest WAI (3.52 g/g), followed by TD-S (3.19 g/g), FD-NS (2.30 g/g), and TD-NS (2.19 g/g), respectively. In terms of WSI, FD-S had the highest solubility (23.94%), followed by TD-S (19.41%), FD-NB (17.51%), and TD-NS (14.57%), respectively.

The Microstructure characteristics of Dried CK and Dried PP

This study investigated the microstructural characteristics of dried CK and PP after various pretreatments and drying methods, as illustrated in Figure 1. For dried Chinese kale : untreated dried samples TD-NB (a) had a nearly circular shape with a smooth surface and fewer pores, while FD-NB (b) was more porous. Samples blanched in 1% NaCl solution were TD-B (c) and FD-B (d), which showed a more fibrous structure.



Dried Chinese kale (CK)

Dried purple sweet potato (PP)

Fig. 1: Microstructure of dried Chinese kale (×1000) with different pretreatment and drying methods: (a) TD-NB: tray dried from non-blanched Chinese kale; (b) FD-NB: freeze dried from non-blanched Chinese kale; (c) TD-B: tray dried from blanched 1% NaCl Chinese kale; (d) FD B: freeze dried from blanched 1% NaCl Chinese kale

Microstructure of dried purple sweet potato (×500) with different pre-gelatinization and drying methods: (e) TD-NS: tray dried from non-steamed purple sweet potatoes; (f) FD-NS: freeze dried from non- steamed purple sweet potatoes; (g) TD-S: tray dried from steamed purple sweet potatoes; (h) FD-S: freeze dried from steamed purple sweet potatoes

For dried purple sweet potatoes, untreated dried samples TD-NS (e) and FD-NS (f) maintained similar microstructures and particle sizes, with FD-NS (f) having more round shapes. Pregelatinized samples TD-S (g) and FD-S (h) showed swollen, irregular granules with rough surfaces, with FD-S (h) appearing more swollen and elongated than TD-S (g).

Sensory characteristics of Purple Sweet Potato And Chinese Kale (PP-CK) Soup, different Levels of Dried Chinese Kale

The results of the organoleptic evaluation of all the prepared purple sweet potato soup supplemented with Chinese kale (PP-CK soup) by 10 experts were presented in Figure 2. The PP-CK soup sample containing 10% FD-B (freeze-dried from blanched 1% NaCl Chinese kale) had the highest score of all the organoleptic parameters: color (darkness), flavors of purple sweet potato, flavors of Chinese kale, viscosity, mouthfeel, and overall acceptance: 7.53, 7.99, 6.23, 8.27, 7.89, and 8.09, respectively, compared to the control sample: 7.76, 8.78, 0.79, 3.84, 9.01, and 8.8, respectively. Increasing the amount of FD-B increased the viscosity. It was found that the soup with 15% FD-B (CKLP 15%) had the highest viscosity (1216 cp), followed by CKLP 10% (1017.33 cp) and CKLP 5% (569.67 cp), respectively. Considering the color value of the soup. It was found that increasing the amount of kale powder resulted in a decrease in the brightness value (L). It was found that the soup containing 15% FD-B (CKLP 15%) had the lowest L value (26.56), followed by CKLP 10% (28.17) and CKLP 5% (30.27), respectively. The green color value (-a*) of the soup was found that the soup containing 15% FD-B had the highest -a* value (-5.20), followed by CKLP 10% (-3.11) and CKLP 5% (0.86), respectively.

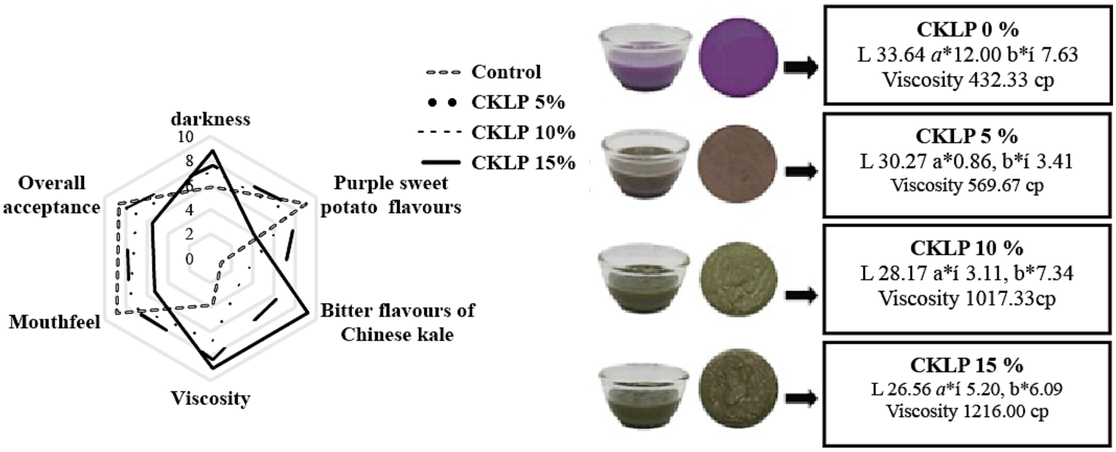


Fig. 2: Sensory Characteristics of PP-CK soup Note: CKLP; Chinese kale leaves powder

Different rRatios of PP-CK Soup to Hot Water

Sensory evaluation results of PP-CK soup with different hot water ratios, soup powder to hot water ratios of 1:5 and 1:6 (w/v), were obtained from a 50-consumer preference test using a 9-point hedonic scale. The appearance, color, flavors of purple sweet potato, flavors of Chinese kale, overall flavors, viscosity, mouthfeel, and overall acceptance were presented in Table 5. The PP-CK soup samples with a ratio of 1:5 received the highest scores: 6.10, 7.16, 7.02, 5.90, 6.28, 7.12, 6.98, and 6.65, respectively.

Table 5: Sensory characteristics of PP-CK soup at different hot water ratios

Attributes	1:5	1:6
Appetence^{ns}	6.10±0.93	6.06±0.71
Colorns	7.16±1.04	7.00±0.93
Purple sweet potato flavors	7.02±0.98^{a}	6.30±1.03^{b}
Chinese Kale Leaves flavors^{ns}	5.90±0.83	5.60±0.97
Overall flavors^{ns}	6.28±1.01	6.02±0.87
Viscosity	7.12±0.80^{a}	5.96±0.83b^{b}
Mouthfeel	6.98±1.20^{a}	5.82±1.06^{b}
Overall acceptance	6.65±0.50^{a}	6.11±0.48^{b}

Note: Values with different letters denote significant ($p \le 0.05$) differences among treatment in rows

Nutritional characteristics of dried PP-CK Soup

This analysis comprehensively evaluates the nutritional profile of Purple Sweet Potato and Chinese Kale (PP-CK) soup based on 40 g serving size (Table 6). The composition of ingredients of the purple sweet potato and Chinese kale (PP-CK) soup powder was as follows: 50% purple sweet potato powder, 9.09% Chinese kale powder, 9.09% inulin, 18.18% whey protein, 7.27% coconut cream powder, 4.55% sugar, and 1.82% salt. The findings emphasize the soup's significant nutritional benefits, including a moisture content of 3.20 g/100g. Key nutritional components include a protein content of 20.10 g/100g, total dietary fiber of 12.45 g/100g, and substantial amounts of beta-carotene (2,052.00 µg/100g) and calcium (251.81 mg/100g). Notably, the soup contains no cholesterol and features total polyphenol compounds at 64.59 mg gallic acid per 100 g.

Table 6: Nutritional characteristics of the dried PP-CK soup (Serving size: 40 g)

Properties	PP soup (Control) 100 g	PP-CK soup 100 g	Nutrition Information of PP-CK soup (Serving size: 1 box (40g)	Percent Thai RDI*
Energy (Kcal)	413.74	410.35	160	-
Energy from fat (Kcal/100 g)	73.98	72.99	30	-
Total fat (g/100 g)	8.22	8.11	3	5 %
Saturated fat (g/100 g)	7.20	6.70	2.5	12 %
Cholesterol (mg/100 g)	2.32	Not Detected	0	0
Protein (g/100 g)	20.51	20.10	8	-
Total carbohydrate (g/100 g)	64.43	64.24	26	9 %
Total dietary fiber (g/100 g)	7.65	12.45	5	20 %
Sugar (g/100 g)	23.21	19.42	8	-
Sodium (mg/100 g)	652.70	767.45	310	16 %
Vitamin A (µg/100 g)	Not Detected	342.00	137	15 %
Beta-carotene (µg/100 g)	Not Detected	2,052.00	820	-
Vitamin B1 (mg/100 g)	Not Detected	0.040	0.02	0 %
Vitamin B2 (mg/100 g)	Less than 0.030	Not Detected	-	0 %
Calcium (mg/100 g)	147.33	251.81	-	10 %
Iron (Fe) (mg/100 g)	1.19	2.05	-	6 %
Ash (g/100 g)	3.83	4.33	-	-
Moisture (g/100 g)	3.01	3.20	-	-
Total polyphenol content (mg gallic/100 g)	66.84	64.59	-	-
DPPH Assay (mg/100 g)	18.60	17.17	-	-
ABTS Assay (mg/100 g)	15.33	11.18	-	-
Anthocyanin (mg cyaniding-3-glucoside/100 g)	227.11	172.37	-	-

Note *Percentage of Thai Recommended Daily intakes for the population over 6 years of age are based on 2,000 kcal diet

The number in parenthesis of vitamins and minerals does not show on the label

Discussion

Pre-Treatment Preparation Properties of Chinese Kale (CK)

This blanching process served dual purposes: expelling air trapped between leaves cells and enhancing the visibility of chlorophyll-induced green coloration. The impact of these treatments on the leaves' green value was significant. Fresh Chinese kale leaves maintained superior greenness compared to those blanched with boiling water or treated with 1% $NaHCO_3$, as shown in Table 1. The color of the post-treatment water, used as a proxy for luminance value, displayed a pronounced yellow hue with minimal red value, indicating that adding of 1% NaCl during blanching yielded vivid, visually appealing reproductions. However, yellow and red tones in the water suggested chloroplast cell disruption and subsequent chlorophyll dispersion. Koca *et al*[25] noted that green color loss and chlorophyll degradation rates decreased with increasing pH, favoring color retention at a pH of 7.5 in blanched green peas. In contrast, this study found that blanching Chinese kale leaves in a highly alkaline 1% $NaHCO_3$ solution (pH of CK leaves : 8.61, pH of solution : 9.56) induced a shift in chlorophyll coloration to a yellowish-green or darker green hue, potentially signaling reduced freshness. This alkalinity also stimulated chlorophyllase activity, accelerating chlorophyll degradation and pheophytin formation. Thus, blanching with 1% NaCl solution emerged as the optimal pre-treatment for preserving color and efficacy in the subsequent drying process for soup vegetable production

Properties of Dried Chinese Kale (CK)

Color and Total Chlorophyll

The physico-chemical characteristics of dried Chinese kale for four different samples (TD-ND, FD-NB, TD-B, and FD-B) are shown in table 2. Tray-dried samples (TD-NB and TD-B) showed lower brightness than freeze-dried ones. Tray-dried samples (TD-NB and TD-B) displayed a lighter green color than freeze-dried samples (FD-NB and FD-B). Blanching significantly affected the b* parameter across drying methods. The results of total chlorophyll content found that untreated samples (TD-NB and FD-NB) exhibited lower total chlorophyll content compared to blanched FD-B. The effect of blanching proved to preserve the green color and total chlorophyll content, particularly in freeze-dried samples (FD-B).

Total Dietary Fiber

These results demonstrate that blanching in 1% NaCl solution before drying significantly increased the TDF content compared to non-blanched samples, regardless of the drying method employed. The mechanism of TDF increase could be explained by the increase in TDF after blanching, which is consistent with the results of previous studies. Several mechanisms may contribute to this phenomenon, such as cell wall disruption; blanching can disrupt cell walls, releasing TDF compounds such as heat treatments may promote β-eliminative degradation of pectic polysaccharides, solubilizing previously insoluble dietary fiber (IDF) and high-temperature processing can convert structural pectin (protopectin) into soluble pectin through hydrolysis. The findings are consistent with previous research, Chantaro *et al*[26] reported a 49 % increase in TDF after a 1-minute boiling water treatment. Tejada-Ortigoza *et al*[27] observed a 24 % TDF increase in sour orange pomace after 90 °C, 1-minute blanching. Marin *et al*[28] noted a 6 % TDF increase in lemon pulp pomace under similar conditions. Saengthongpinit *et al*[29] reported a 15.72 % TDF increase in Water Meal (Wolffia globosa) after blanching, attributing it to cell wall damage and loss of mineral salts, ash, and protein.

Calcium and Phosphorus

The drying of FD-NB showed the highest calcium and phosphorus content. Blanching led to reduced mineral content due to the leaching of water-soluble components into the blanching water, corroborating findings by Korus.10 Drying method comparison found that freeze-drying from non-blanched preserved had minerals (calcium 3,119 mg/100 g and phosphorus 620 mg/100 g) better than tray drying (calcium 2,835 mg/100 g, phosphorus 601 mg/100 g), particularly in unblanched samples. This preservation was attributed to the absence of high heat exposure during freeze-drying. The effect of drying process concentrated minerals, resulting in higher calcium and phosphorus content than fresh leaves. Blanching led to a reduction in mineral content due to the leaching of water-soluble components into the blanching water, corroborating findings by Korus.10 Drying Method Comparison found that freeze-drying preserved minerals was better than tray drying, particularly in unblanched samples. This preservation is attributed to the absence of high heat exposure during freeze-drying.

Antioxidant Capacity

In addition, it was found that the FD-NB of Chinese kale had the highest antioxidant activity (693 mg GAE/100 g total phenolics, 15.31 mg/100g DPPH, and 14.82 mg/100 g ABTS) followed by TD-NB. and had higher antioxidant activity than blanched Chinese kale (TD-B and FD-NB). The reduction in antioxidant activity in blanched samples aligns with findings by Abu-Ghannam and Jaiswal[30] and Hossain *et al,*[31] which observed that higher blanched temperatures accelerate the breakdown of heat-sensitive bioactive compounds. Saengthongpinit[29] reported similar findings in watermeal (Wolffia globosa), attributing the loss to heat-induced cell wall damage and increased exposure of phenolic compounds to heat and oxygen. Sarkar *et al*[32] demonstrated that polyphenol content and DPPH scavenging activity losses are more pronounced with blanching and high-temperature treatments. Gonçalves *et al*[33] found that non-blanched dried cabbage had a higher total phenolic content than cabbage blanched at 80 °C. Interestingly, using a blanching temperature of 100 °C for 3 min, the current study showed lower total phenolic content in blanched-dried samples compared to non-blanched-dried samples. This study underscores the complex interplay between processing methods and antioxidant retention in vegetable products. While blanching may reduce antioxidant activity, it offers benefits such as enzyme inactivation and improved rehydration properties, which are crucial for developing ready-to-use powders.

Functional Properties

WAI quantifies a sample's volume after swelling in excess water while maintaining structural integrity, whereas WSI measures the amount of water absorbed.[34] Table 2 posits a positive correlation between polysaccharide concentration and water absorption, suggesting higher polysaccharide content yields elevated WAI values. This Table elucidates the impact of various pretreatment and drying methods on the WAI and WSI of dried Chinese kale. The data reveal significant variations across processing conditions. Blanched and dried samples found that FD-B had the highest WAI (9.69 g/g) and WSI (13.10 %), followed by TD-B, FD-NB, and TD-NB, respectively. These results demonstrate markedly higher WAI and WSI values in blanched Chinese kale samples compared to their non-blanched counterparts. As previously discussed, this enhancement is attributed to the blanching process, which increases dietary fiber content. Comparing drying methods, freeze-drying emerged superior in preserving WAI and WSI properties relative to hot air tray drying. This superiority stems from the minimal structural damage incurred during freeze-drying, contrasting with the potential degradation caused by heat exposure in tray drying. Compared to traditional fixation methods, the phenomenon is analogous to the preservation of cellular structures in cryogenic electron microscopy. Using a 1% NaCl solution in blanching further improved WAI and WSI properties compared to non-blanched Chinese kale. This finding raises intriguing questions about the role of salt in modifying plant tissue hydration characteristics, possibly through osmotic effects or alterations in cell wall structure.

Pre-Gelatinizes Preparation Properties of Purple Sweet Potatoes (PP)

Color and Anthocyanin

Steamed purple sweet potatoes exhibited higher lightness, redness, and blue hues than boiled samples. Both pre-treatments resulted in a darker orange color of the pulp, with increased blanching time leading to lighter but increasingly dark flesh. Anthocyanin content was 190.59 mg cyaniding-3-glucoside/100 g for steaming and 152.24 mg cyaniding-3-glucoside/100 g for boiling. Steaming demonstrated superior anthocyanin retention compared to boiling. The color changes observed during processing can be attributed to the chemical reactions of anthocyanins under different conditions. In boiling, anthocyanins react with heat and the alkaline environment of the cooking water, shifting the color toward bluish-purple or grayish blue. Conversely, steaming better preserves the bright purple color due to minimal leashing and a less alkaline environment. These findings align with Curayag and Dizon's35 study, which reported a 28.56% increase in antioxidant activity after steaming, along with high phenol, flavonoid, and anthocyanidin contents. Similarly, Phomkaivon *et al*[15] and Mulyawanti *et al*[36] observed increased anthocyanin content following steaming procedures in purple sweet potato processing.

Properties of Dried Purple Sweet Potatoes (PP)

Color

The color changes observed in pre-gelatinized and dried PP indicate significant alterations in the pigment profile, particularly in anthocyanin compounds. The increase in redness (a*) coupled with a decrease in yellowness (b*) and lightness (L*) suggests the concentration and transformation of anthocyanins during processing. The formation of polymeric anthocyanins during thermal pre-gelatinization is a crucial finding, as it may enhance color stability in the final product. This phenomenon is analogous to the color stabilization observed in wine aging, where anthocyanin polymerization leads to more stable color compounds. FD-S, produced through pre-gelatinization and freeze-drying, emerges as a promising source for flour with a heat-stable purple color. This stability is particularly valuable for applications in the food industry, where color retention during further processing is crucial.

Dietary Fiber

Pre-gelatinized and freeze-dried PP had the highest dietary fiber content at 10.95 g/100g, while pre-gelatinized and tray-dried PP exhibited lower fiber content. Furthermore, untreated freeze-dried PP retained more dietary fiber than both pregelatinized and tray-dried samples. The analysis suggests that the superior dietary fiber retention in pre-gelatinized, freeze-dried PP can be linked to several factors. The pre-gelatinization method involves steaming, which does not add extra water and may help preserve fiber by causing partial evaporation of water from the PP while breaking down cell walls, thereby potentially increasing fiber accessibility and digestibility. The gentle processing conditions of freeze-drying, which involve low temperatures and the absence of liquid water, seem to preserve fiber content more effectively than tray drying, akin to how volatile compounds are retained in freeze-dried products in the fragrance industry. Conversely, the lower fiber content in tray-dried samples could be due to prolonged exposure to high temperatures, which might degrade or break down fiber structures, as the loss of heat-sensitive nutrients observed during conventional cooking methods.

Antioxidant Capacity

Furthermore, FD-S, which underwent steaming and freeze-drying, showed superior retention of bioactive compounds: total phenolic content at 110.91 mg gallic acid/100 g, DPPH antioxidant activity at 40.78 mg/100 g, ABTS antioxidant activity at 12.65 mg/100 g, and anthocyanin content at 602.94 mg cyanidin-3-glucoside/100 g. The enhanced retention of bioactive compounds in FD-S can be attributed to several factors. The pre-gelatinization effect, where steaming disrupts cellular structures, improving the extractability of phenolics and anthocyanins, similar to the increased bioavailability of lycopene in cooked tomatoes; the advantage of freeze-drying, which employs low-temperature, low-pressure conditions to minimize thermal degradation and oxidation of sensitive compounds, akin to the preservation of volatile flavors in freeze-dried coffee; and the synergistic processing effects of combining steaming with freeze-drying, creating optimal conditions for preserving and potentially enhancing the bioactive compound profile of PP. These findings are supported by previous research where Marzuki[12] reported improvements in color, antioxidant activity, and total phenolic content with microwave-vacuum drying, Belkacemi[37] noted higher polyphenol and tannin content in unpeeled and blanched sweet potato samples, and Vi*dal et al*[38] emphasized the importance of lower drying temperatures in preserving phenolic compounds.

Functional Properties

Drying methods had significant impacts on the WAI and WSI of dried products. Freeze drying produced samples with higher WAI and WSI than hot drying. The water absorption of starch was governed by its molecular structure, including its crystalline structure and chemical composition. Gelatinization during thermal pretreatment and drying may have led to structural modifications that affected the water-binding capacity of the starch.[39] Various changes, such as swelling of granules, water absorption, loss of crystallinity, and amylose leaching, were observed during starch gelatinization.[40] The lower WAI and WSI of tray-dried PP compared to freeze-dried PP could be due to the samples' drying time and high temperatures. The results suggested that pretreatment rather than drying methods mainly influenced WSI. The increase in WSI and WAI during drying could stem from the disruption of starch granules and the exposure of hydrophilic groups.[41] Pregelatinized starch, defined as starch subjected to heat to enhance solubility, facilitates the production of starch with enhanced thickening properties. Consequently, applying pre-gelatinization treatment in conjunction with suitable drying can improve potato products' functionality, quality, and shelf life. Therefore, FD-S was more appropriate for various food applications.

The Microstructure characteristics of Dried CK and Dried PP

The analysis sheds light on how these processing methods induce structural changes and their impact on functional properties. Untreated dried samples TD-NB (a) displayed an almost circular shape for dried Chinese kale with a smoother outer surface and fewer pores, while FD-NB (b) showed a more porous structure. Blanched in 1% NaCl solution, TD-B (c) and FD-B (d) exhibited a more fibrous structure, enhancing dietary fiber content (Table 2). FD-B (d) was more porous than TD-B (c) due to freeze-drying, which helps preserve the structure. The blanching of CK led to a fibrous structure (TD-B and FD-B), consistent with the increased dietary fiber reported, akin to fibrillar network formation in heat-treated plant tissues like nata de coco. The superior porosity of freeze-dried FD-B (d) compared to tray-dried TD-B (c) correlates with better Water Absorption Index (WAI) and Water Solubility Index (WSI) values (Table 2), the same as the preservation seen in freeze-dried fruits used in breakfast cereals.

For dried purple sweet potatoes, untreated dried samples TD-NS (e) and FD-NS (f) maintained similar microstructures and particle sizes, with FD-NS (f) having more round shapes. Pregelatinized samples TD-S (g) and FD-S (h) showed swollen, irregular granules with rough surfaces, with FD-S

(h) appearing more swollen and elongated than TD-S (g). The extensive gelatinization observed in pregelatinized PP samples resembles structural changes in rice grains during parboiling, where granules starch swell and deform. SEM images confirm these structural transformations, linking starch gelatinization during steaming to the functional properties such as WAI and WSI in both dried and untreated PP (Table 4), thus highlighting the crucial structure-function relationship in processed food materials.

Sensory characteristics of Purple Sweet Potato and Chinese Kale (PP-CK) Soup,

This study evaluated the sensory characteristics of purple sweet potato soup supplemented with different concentrations of FD-B (5, 10 and 15%) by food experts. It was found that increasing the concentration of FD-B resulted in a darker color of the soup, with 15% FD-B resulting in an overly dark color of the soup. This observation was supported by Hunter Lab values, which showed decreased brightness (L), increased greenness (−a*), and decreased redness (b*). The relationship between the amount of FD-B and purple sweet potato was found that higher FD-B concentrations very bitter the Chinese kale flavor but resulted in a concurrent decrease in the purple sweet potato (FD-S) flavor perception. The viscosity increased with dried Chinese kale added to the soup. (Figure 2).

Additionally, the initial ratio of PP-CK soup to hot water (1:4) resulted in excessive viscosity. Expert advice suggests that an optimum FD-B concentration of 10% has been identified in all aspects, including color, flavors of purple sweet potato and Chinese kale, viscosity, mouthfeel, and overall acceptance. However, experts recommend increasing hot water availability to alleviate viscosity problems. These findings and recommendations are detailed in Figure 2, emphasizing the nuanced adjustments needed to optimize sensory attributes in soup formulations.

Characteristics of PP-CK Soup at different Hot Water Ratios

Following consumer preference test evaluation, this study optimized the purple sweet potato and Chinese kale soup formulation by adjusting the hydration ratio. The final recipe, containing 10% dried CK (FD-B), was tested with 1:5 and 1:6 soup powder-to-water ratios. Sensory evaluation with fifty testers indicated that the 1:5 ratio achieved the highest scores, including 7.16 for color and 7.12 for viscosity, leading to an overall acceptability score of 6.65. The results highlight a successful balance of flavors, particularly between purple sweet potato and Chinese kale, emphasizing the significance of hydration ratio adjustments in enhancing sensory attributes.

Nutritional characteristics of Dried PP-CK Soup

The prepared purple sweet potato soup supplemented with 10% Chinese kale powder was added as the most accepted soup formula. Thus, the soup formula contains 50% purple sweet potato powder, 9.09% kale powder, 9.09% inulin, 18.18% whey protein, 7.27% coconut milk powder, 4.55% sugar, and 1.82% salt. The nutritional profile of the resulting PP-CK soup exhibited high levels of calcium, dietary fiber, vitamin A, iron, and antioxidants. With protein levels comparable to legume-based soups, the PP-CK soup is suitable for protein-fortified diets. Its substantial beta-carotene content indicates potential provitamin A provision, while its high dietary fiber aids digestive health. Antioxidants like polyphenols and anthocyanins enhance their possible health benefits, contributing to their "superfood" status. This soup product has been shown to be rich in nutrients, offering a variety of health-promoting components and bioactive compounds. Its potential for further product development, particularly in creating consumer-friendly healthy soups, adds to its value. Consequently, current research is focusing on analyzing soups such as soup products made with purple sweet potatoes, enhanced with a blend of vegetables and freeze-dried chicken,[42]sprouted garden cress seed soup powder mixed with red kidney beans and amla were high in energy, protein, carbohydrates, iron, calcium, and vitamin C,[43] highly nutritious dried tomato soup powder, and rich in lycopene.[44] Seaweed soup had high energy, carbohydrates, and calcium.[45] Banana and other vegetable soups were especially diverse in nutritional composition and full of fiber.[46]

Conclusion

This research focused on optimizing the preliminary processing and drying techniques for purple sweet potatoes and Chinese kale to develop a novel vegetable soup product. The findings highlighted that blanching Chinese kale in a 1% NaCl solution proved effective, as it enhanced softening, improved contact, and inactivated degradation enzymes. This approach preserved the vegetables' color and texture. Additionally, blanching significantly reduced the loss of polyphenols and antioxidant capacity content. The freeze-drying method of blanched kale effectively preserves its nutritional value. Pre-gelatinize purple sweet potatoes by steaming them retained more anthocyanins than their boiled counterparts, highlighting the importance of selecting appropriate thermal processing methods to preserve bioactive compounds. In addition, the findings show that increased antioxidant activity corresponds to a darker color in PSP slices after steaming. This color change could be due to the release of anthocyanins from the tissue due to the breakdown of protein-pigment linkages generated by heat. Steaming the slices at 100 °C for 10 min probably generated enough tissue damage to release anthocyanins from the afflicted areas.47 Additionally, freeze-dried sweet potatoes showed the highest dietary fiber content, emphasizing the efficacy of this preservation technique in boosting nutritional density. Formulation development of purple sweet potato and Chinese kale soup (PP-CK) found that including 10% freeze-dried Chinese kale powder was optimal for the soup formulation. A final ratio of 1:5 PP-CK soup to hot water garnered consumer approval, illustrating the iterative process of food product development that balances nutritional objectives with sensory acceptability. Moreover, the nutritional profile of the resulting PP-CK soup exhibited high levels of calcium, dietary fiber, vitamin A, iron, and antioxidants, positioning it as a nutritious option for breakfast. In addition, it is recommended that additional research be done to explore alternative drying methods or pre-treatment for other vegetables and examine the product's shelf life of soup when packaged in appropriate materials. Finally, this research can be applied to developing high-quality, nutrient-rich dried soup products for the food industry, promoting sustainable use of underutilized ingredients, and creating functional foods for health-conscious consumers. It also supports standardized production methods for consistent quality.

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Conflict of interest

The author does not have any conflict of interest.

Data Availability Statement

The manuscript incorporates all datasets produced or examined throughout this research study.

Ethics Statement

This study involved human participants in a sensory test, which received approval from the Ethical Review Subcommittee for Human Research at the Research and Development Institute of Suan Dusit University (COA.NO: SDU-RDI-HS 2024-003), ensuring adherence to established ethical standards.

Informed Consent Statement

This study involved human participants in a sensory test, which received approval from the Ethical Review Subcommittee for Human Research at the Research and Development Institute of Suan Dusit University (COA.NO: SDU-RDI-HS 2024-003), ensuring adherence to established ethical standards. Therefore, informed consent was required.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to Reproduce Material from other Sources

Not Applicable.

Author Contributions

- **Suwanna Pichaiyongvongdee:** Funding acquisition, resources, supervision, conceptualization, methodology, wrote the result and discussion.
- **Boonyakrit Rattanapun:** Chemical analysis, final approval of the manuscript.
- **Wachira Singkong:** Writing – original draft, statistical data analysis.
- **Teeranuch Chysirichote:** Surveyed literature on product development.

- **Nujira Rasamipaiboon:** Assistant supervision, project administration.
- **Jiraporn Phongsopa:** Co-ordinate with external agencies.

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