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Exploring the physicochemical traits of diverse *Cucurbita moschata* D. pumpkin species cultivated in Vietnam

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Abstract The results showed significant variations in size, shape, color, weight, and biological characteristics between pumpkin varieties cultivated in Vietnam. Proximate components varied due to different species, and pumpkin strands are a notable source of β-carotene compared to skin and pulps. Pumpkin seeds were found to be rich in oils (25.0-42.4% DW). The study suggested a promising application for Vietnamese pumpkin components in the food industry, particularly in the formulation of foods for infants, the elderly, and those requiring bioactive compounds.

Keywords: Appearance, By-products, Pumpkins, Physiochemical properties

Introduction

The Cucurbitaceae family, a group of plants that occurs in tropical regions of the world, consists of about 120 genera that contain more than 800 species (Heneidak and Khalik, 2015). Among these, pumpkins have been appreciated for their high yields, long shelf life, and high nutritional values, especially due to their high amounts of carotenoids that act as antioxidants in the human body (Jamali *et al*., 2018).

Pumpkin has many health benefits, such as antidepressants, antidiabetic, antioxidant, anticarcinogenic, and anti-inflammatory properties, as the result of compounds that belong to the categories of alkaloids and flavonoids, in addition to palmitic, oleic, and linoleic acids found in various parts of the plant (fruit, seed, and leaf) (Yadav *et al*., 2010).

Pumpkin (*Cucurbita moschata* Duch.), known as scented pumpkin or squash, which is tolerant to hot and humid weather, is widely grown and consumed in many countries around the world (Jun *et al*., 2006; de Carvalho *et al*., 2012). In Vietnam, approximately 25 pumpkin species are widely used for human consumption, including pulp from fruits, seeds, flowers, and young

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leaves. The pulp of pumpkin fruits is a valuable source of vitamin A, fiber, and minerals, making it a highly nutritious food (Rakcejeva *et al*., 2011). Furthermore, pumpkin seeds contain 10.9 to 30.9% oil and are rich in unsaturated fatty acids ranging from 73.1 to 80.5%; the predominant fatty acids present were oleic, linoleic, palmitic, and stearic acids (Stevenson *et al*., 2007). Despite its nutritional importance, there is a lack of knowledge on the physiological parameters and nutritional compositions of the pumpkin species in Vietnam. The research aimed to fill this gap by investigating the appearance and physio-chemical properties of four distinct pumpkin species and their by-products (seeds, skins, and strands) cultivated in Vietnam.

Materials and methods

Materials

Four types of ripened pumpkins (*Cucurbita moschata* D.) were collected from markets in Can Tho City, Vietnam, and transported to the Food Technology Department of Can Tho University for analysis.

Physicochemical analysis

Total soluble solids (TSS) were determined using a refractometer (0-32%, Japan). The pH value was determined using an electronic pH meter (Vernier, USA). Hardness (g_f) was determined using the RHEO-TEX meter (SD-700II, Japan). The density of pumpkin fruit (g/cm^3) was determined by the division of its weight (g) by volume (cm^3), where the fruit volume was estimated using the water displacement method (Mohsenin, 1970).

The color coordinates were determined in the CIE-LAB system with lightness (L*), redness (a*), and yellowness (b*) using a colorimeter (FRU, China). Then, these values were used to calculate Chroma (C), indicating the color strength or intensity of the subject (McLellan *et al*., 1995):

$$C = \sqrt{(a^*)^2 + (b^*)^2} \tag{1}$$

The Hue angle (H) value is the name of a color family, indicating the color saturation of the subject (McLellan *et al*., 1995):

$$H = \arctan\left(\frac{b*}{a*}\right) \tag{2}$$

The moisture content was determined using the AOAC method No. 925.10; the total ash content was determined using the AOAC method No. 942.05; the total crude fiber content was analyzed using the AOAC method No. 985.29; the crude fat content was determined gravimetrically by the AOAC method No. 920.39. The crude protein content was calculated from the nitrogen content determined by the Kjeldahl method according to the AOAC method No. 920.87, and the protein was calculated using 6.25 as the nitrogen conversion factor using the method of AOAC (1920). The starch content was determined using the standard 3,5-dinitro salicylic acid (DNSA) method. Total starch was calculated as glucose x 0.9 (Świeca *et al*., 2017). Vitamin C content was measured using the 2,6-dichloroindophenol titrimetric method.

The total carotenoid content was determined according to the spectrophotometric method described by Rojas *et al*. (2020) with some modifications. Briefly, 0.25 g of dried sample powder was placed in a glass tube (tightly capped and lined with aluminum foil). Then 21 ml of the solvent solution (composed of ethanol and hexane in a 4: 3 proportion) was added. The sample with the solvent solution was placed in the ice box for 15 min and then homogenized for 1 min using an ultraturra homogenizer (Japan). The sample was then centrifuged at 8000 g for 10 min to collect the supernatant. The extraction procedure was repeated and the supernatants were then mixed. Then 5 ml of distilled water was added, stirred, and left at rest for 5 min to separate the phases. The hexanoic phase containing the extracted carotenoid was collected using a glass separation funnel. Then 2.5 ml of this phase was transferred to a quartz cuvette of 1 cm light path and the absorbance was read at 450 nm using hexane to calibrate. The carotenoid content of the sample expressed as β-carotene equivalents (mg/100 g DW) was calculated according to the formula:

$$\text{TC (mg/100 g DW)} = \frac{\text{A x 536.85 x V x } 10^{-1}}{\text{m}_{\text{dm}} \text{ x 137.4}} \quad (3)$$

Where A is absorbance, 536.85 is the molecular weight of β-carotene (g/mol), V is the volume of the hexanoic phase measured after separation from the aqueous phase (mL), 10^{-1} is the conversion unit factor, m_{dm} is the dry matter of the sample (g) and 137.4 is the extinction coefficient for β-carotene in hexane (mM^{-1}).

The β-carotene content was determined according to the spectrophotometric method described by Fikselová *et al*. (2008). The carotene content of β-carotene in the petroleum ether extract was determined spectrophotometrically, and the absorbance was measured at a wavelength of 450 nm. The concentration of carotenes expressed as β-carotene was calculated using the response factors as follows:

$$\beta\text{-carotene } (\mu\text{g/g DW}) = \frac{\text{A x V x d x } 10^{4}}{A_{1cm}^{1\%} \text{x } m_{dm}} \quad (4)$$

Where A is absorbance, V is the total volume of extract (mL), d is dilution (if any), 10^4 is the conversion unit factor, $A_{1cm}^{1\%}$ = 2592 is β-carotene extinction of -carotene in petroleum ether, and m_{dm} is the dry matter of the sample (g).

The total polyphenol content (TPC) was determined spectrophotometrically according to Foline-Ciocalteu method (Huynh *et al*.,

2014) with slight modifications, as described by Nguyen *et al*. (2019). The total phenolic content was expressed as milligrams of gallic acid equivalent per g of dry weight (mg GAE / g DW) using a standard curve of gallic acid in the range of 0-50 mg/L.

Data analysis

Data were calculated and graphed using Microsoft Excel 2021 (Microsoft Office, USA). A comparison of physicochemical properties between four types of pumpkins was made by analysis of variance at $\alpha=0.05$ in Statgraphics Centurion 19 (Statgraphics Technologies Inc., The Plains, Virginia). The results were reported as the mean value ± standard deviation of all independent replicates.

Results

Biological characteristics of different pumpkin species

The appearances and characteristics of four types of pumpkins PS01, PS02, PS03, and PS04 cultivated in Vietnam are illustrated in Table 1. The pumpkin with code PS01 is elliptical, whilst the others (PS02, PS03, PS04) are bean-shaped. Moreover, the PS01 and PS04 pumpkins have green skin, whereas the others have yellow skin, and all types of pumpkins have bright stripes along their bodies. Furthermore, PS01 had the highest weight and circumference ($p<0.05$) among four types of pumpkins (4545.7±951.3 g and 78.5±2.8 cm, respectively), while it had the lowest density ($p<0.05$, except for PS03). The codes PS03 and PS04 had similar morphological characteristics, that is, average fruit weight, height, and circumference, 501.2±65.1 and 436.1±29.2 g, 14.6±1.2 and 16.7±0.2 cm, 22.9±2.3 and 20.6±2.7 cm, respectively.

The proportion of different body parts between the four types of pumpkins is shown in Figure 1. The results showed that PS02 was the highest pulp (85.1±3.37%) whilst PS01 was the highest stem (14.4± 1.56%) among four types of pumpkins. The highest strand part was found for PS04 (7.95±0.2%), the others ranged from 2.2 to 4.3%. The ratio of seeds in four types varied from 1.6 to 2.25%, and the percentage of skin fluctuated from 6.69 to 10.27%.

Table 1. The appearance and characteristics of different types of pumpkin

Code	Pumpkin varieties	Characteristics			
		Weight (g)	Height (cm)	Circumference (cm)[1]	Density (g/cm^3)
PS01		4545.7±951^{a}	12.9± 2.0^{b}	78.5±2.8^{a}	0.85±0.05^{b}
PS02		802.3± 131.7^{b}	12.9± 1.5^{b}	31.4±4.3^{b}	1.13±0.08^{a}
PS03		501.2± 65.1^{b}	14.6± 1.2a^{b}	22.9±2.3^{c}	0.89±0.06^{b}
PS04		436.1± 29.2^{b}	16.7± 0.2^{a}	20.6±2.7^{c}	1.12±0.06^{a}

[1]: Average circumference of three body parts (top, middle, bottom) for the pumpkin species PS02, PS03, and PS04. The mean values with the different letters within the same column are significantly different at $p<0.05$.

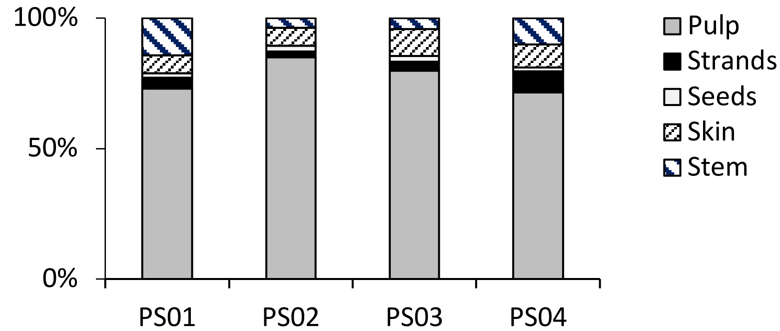

Figure 1. The percentage of different body parts among four types of pumpkin

Physiochemical properties of pulps in four kinds of pumpkin

The physiological parameters of four types of pumpkin pulp are shown in Table 2. The results illustrated that the moisture content of these pumpkin pulps ranged from 80.1 to 85.5%. PS02 type had the highest starch content (16.9±1.9%) compared to the others ($p<0.05$). The protein content in the pumpkin pulp was 0.28-0.40% and the ash content was 0.76-1.58%. The total soluble solid (TSS) of pumpkin pulps was the lowest for PS04 among the four kinds (5.6±0.6%) ($p<0.05$). The pH value ranged from 6.75 to 7.06 for all kinds. Pumpkin pulp hardness was the highest value of 1046.1±75.3 g_f for PS02, followed by PS01 (899.7±93.3 g_f).

Table 2. Physiochemical properties of four types of pumpkin pulp

Physio-chemical parameters		PS01	PS02	PS03	PS04
Moisture (%)		81.3±1.5^{bc}	80.1±2.3^{c}	83.9±1.1^{ab}	85.5±3.7^{a}
Starch (%)		9.3±2.1^{c}	16.9±1.9^{a}	12.6±2.3^{b}	12.3±2.3^{b}
Protein (%)		0.39±0.007^{a}	0.28±0.006^{c}	0.40±0.03^{a}	0.31±0.006^{b}
Ash (%)		0.87±0.05^{c}	1.36±0.12^{b}	1.58±0.08^{a}	0.76±0.11^{c}
pH		7.06±0.14^{a}	7.02±0.04^{a}	6.75±0.16^{b}	7.02±0.08^{a}
TSS		7.5±0.6^{a}	7.6±1.5^{a}	8.7±2.7^{a}	5.6±0.6^{b}
Hardness (g_f)		899.7±93.3^{b}	1046.1±75.3^{a}	664.2±62.3^{c}	840.3±164.6^{b}
Color	L*	77.05±5.70^{b}	79.92±3.90^{ab}	78.22±2.80^{b}	82.33±1.90^{a}
	a*	3.08±3.40^{c}	5.17±2.30^{b}	7.45±0.90^{a}	3.06±0.70^{c}
	b*	16.17±7.80^{b}	20.01±4.90^{ab}	18.06±3.50^{b}	23.64±2.20^{a}
	C	16.6±8.2^{b}	20.7±5.2^{ab}	19.6±3.5^{ab}	23.8±2.2^{a}
	H (°)	82.8±10.1^{a}	75.9±4.5^{b}	67.1±3.3^{c}	82.7±1.4^{a}
Vitamin C (mg/100 g)		18.7±2.3^{a}	11.3±4.2^{b}	14.3±4.6^{b}	13.8±4.3^{b}
Carotenoids (mg/100 g DW)		19.0±3.4^{b}	16.3±0.6^{b}	30.8±5.0^{a}	31.5±1.5^{a}
Total polyphenols (mg GAE/g DW)		3.6±1.5^{a}	3.2±0.9^{a}	3.6±0.6^{a}	2.7±0.3^{a}

Values are mean±SD, DW: dry weight. Mean values with the different letters within the same row are significantly different at $p<0.05$.

Regarding the color of the pumpkin pulps, the L* value (lightness or brightness) ranged from 77.05-82.33, the a* value (from -: green to +: red) ranged from 3.06-7.45 and the b* value (from -: blue to +: yellow) ranged from 16.17-23.64 (Table 2). As can be seen in the table, the L* and b* values of the pumpkin pulp of PS04 were the highest among the four types of pumpkins ($p<0.05$, except for PS02), while the a* value was the highest for PS03 ($p<0.05$). The C values were found to be in the range of 16.6 to 23.8 for all types while the H values ranged from 67.1 to 82.8^o (Table 2). Based on the results of color measurement and general observations, it was found that the pulp of PS04 was higher in yellow intensity and brighter than the others. Table 2 shows the physical properties of four types of pumpkin pulp, at which the vitamin C content in PS01 pulp was the highest value (18.7±2.3 mg/100 g) among these pumpkins ($p<0.05$), the lowest value was true for PS02 (11.3±4.2 mg/100 g). The total polyphenol content in the pumpkin pulps ranged from 2.7 to 3.6 mg GAE / g of DW (Table 2).

Chemical properties of by-products in four pumpkin species

The physiochemical properties of four pumpkin skins is shown in Table 3. The results showed that the moisture content in these pumpkin skins changed from 74.9 to 86.2%, with the figure being the highest for PS04. Protein and ash content in four types of pumpkin skin ranged from 1.60 to 2.15% and from 1.90 to 2.86%, respectively. As compared to the fiber content in four types of pumpkin skins, which was the highest (8.5%) for PS01, the lowest quantity was shown for PS03 (6.9%) ($p<0.05$).

Table 3. Physiochemical properties of four kinds of pumpkin skin

Physio-chemical parameters		**PS01**	**PS02**	**PS03**	**PS04**
Moisture (%)		74.9±2.0^c	79.6±0.9^b	79.7±0.7^b	86.2±0.4^a
Protein (%)		2.15±0.02^a	1.60±0.02^c	1.66±0.07^c	1.91±0.04^b
Ash (%)		2.07±0.09^b	2.76±0.14^a	2.86±0.10^a	1.90±0.09^c
Fiber (%)		8.5±0.00^a	7.4±0.00^c	6.9±0.00^d	7.7±0.00^b
Color	L*	71.39±1.60^{bc}	70.55±0.64^c	76.66±0.67^a	72.15±0.96^b
	a*	-0.61±0.36^c	0.43±0.62^b	3.86±0.36^a	-1.22±0.96^d
	b*	5.51±0.83^b	5.39±0.80^b	10.88±1.09^a	6.18±0.92^b
	C	5.6±0.8^b	5.4±0.9^b	11.6±1.1^a	6.3±0.9^b
	H (^{o})	96.5±3.9^b	86.1±5.5^c	70.4±1.8^d	101.4±2.3^a
Carotenoids (mg/100 g DW)		34.9±0.2^a	31.7±0.02^c	23.9±0.1^d	34.0±0.06^b
Total polyphenols (mg GAE/g DW)		3.5±0.5^b	2.4±0.3^c	4.2±0.4^a	2.8±0.2^c

Values are mean±SD, DW: dry weight. Mean values with the different letters within the same row are significantly different at $p<0.05$.

Turning to the color of these pumpkin skins, the L* value ranged from 70.55 to 76.66, the a* values for PS01 and PS02 were negative (-0.61 and -1.22, respectively); for PS02 and PS03, these values were positive (0.43 and 3.86, in turn). In addition, the value of b* was the highest (10.88, $p<0.05$) for PS03 compared to the others, ranging from 5.39 to 6.18. Furthermore, the C values of the PS03 skin were 11.6 and higher than those of the others, which ranged from 5.4 to 6.3. The colors were in quadrant I for the PS02 and PS03 skins (H values were 86.1° and 70.4°, respectively), while the colors were in quadrant II for the PS01 and PS04 skins (H values were 96.5° and 101.4°, respectively) (Table 3). The results showed that the skin of PS03 had a higher yellow intensity and was brighter than the skin of PS02, while the skin of PS04 had a higher green intensity and was brighter than the skin of PS01.

The total carotenoid content in PS03 pumpkin skin was 23.9±0.1 mg/100 g DW the lowest compared to the others ranging from 31.7 to 34.9 mg/100 g DW. The β-carotene in these pumpkin skins changed from 31.4 to 71.0 µg/g DW (Figure 2). The total polyphenol content in these pumpkin skins ranged from 2.4 to 4.2 mg GAE/g of DW.

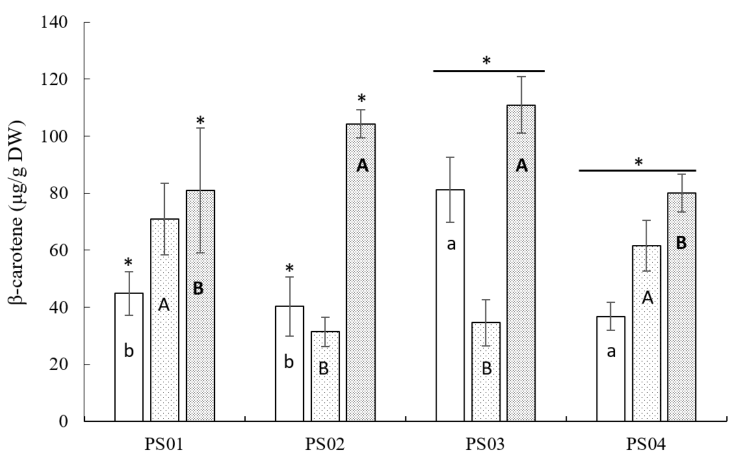

Figure 2. The β-carotene (µg/g DW) content of different types of pumpkin and body parts. Mean values with the different lowercase, UPPERCASE, and UPPERCASE letters are significantly different at $p<0.05$ for four types of pumpkin* express significant differences for pulp ☐, skin ☐, and strand ☐ within a type of pumpkin, $p<0.05$.

Pumpkin strands are part of the pumpkin fruit where the pumpkin seeds are attached to the inside of the flesh of the fruit. When pumpkin is processed as a food, this portion of the pumpkin is frequently discarded and regarded as a useless fruit. The chemical properties of four pumpkin strands is shown in Table

4. The results showed that the moisture content of the pumpkin strands ranged from 82.4 to 89.6%. The starch content for PS01 was the highest one (12.0±2.5%) among four types of pumpkin strands ($p<0.05$), followed by PS02 (8.6±4.4%), and the others ranged from 2.2 to 4.3%. The ash content of these pumpkin strands ranged from 0.87 to 1.55%.

The vitamin C content of the PS01 and PS02 strands was higher than of the others (Table 4). However, the vitamin C content in these pumpkin strands was less than that in its pulps (Tables 2 and 4). The total carotenoid content between these strands changed from 30.8 to 34.5 mg/100 g of DW. The β-carotene content of the PS02 and PS03 strands was 104.3 and 110.9 μg/g DW, respectively, while the others were found in the range of 80.1 to 81.0 μg/g DW (Figure 2). The total polyphenol content of these strands in this study ranged from 2.4 to 4.9 mg GAE/g DW.

Table 4. Chemical properties of four kinds of pumpkin strands

Chemical parameters	PS01	PS02	PS03	PS04
Moisture (%)	82.4±0.8^{c}	83.6±3.5^{bc}	85.5±0.9^{b}	89.6±0.7^{a}
Starch (%)	12.0±2.5^{a}	8.6±4.4^{b}	2.2±0.8^{c}	4.3±2.2^{c}
Ash (%)	1.11±0.28^{c}	1.33±0.09^{b}	1.55±0.08^{a}	0.87±0.08^{d}
Vitamin C (mg/100 g)	5.3±0.6^{b}	7.7±1.1^{a}	2.0±1.7^{c}	2.7±1.7^{c}
Carotenoids (mg/100 g DW)	34.9±0.3^{a}	32.5±1.1^{b}	34.5±0.2^{a}	30.8±1.1^{c}
Total polyphenols (mg GAE/g DW)	2.4±0.3^{c}	3.3±0.5^{b}	4.9±0.9^{a}	4.9±1.0^{a}

Values are mean±SD, DW: dry weight. Mean values with the different letters within the same row are significantly different at $p<0.05$.

The basic chemical parameters of these pumpkin seeds are shown in Table 5. The moisture content data was found in a 36.9 to 43.0% DW variation. The highest lipid content was observed for PS01 (42.4±0.3%) ($p<0.05$), followed by PS03 (39.4±0.4%), PS02 (33.1±0.6%), and PS04 (25.0±0.3%). Compared to the starch content of these pumpkin seeds, which was the highest for PS03 (9.6±0.9%), the lowest content was true for PS04 (2.4±0.6%, $p<0.05$). Regarding the protein content of these pumpkin seeds, which ranged from 1.7 to 2.5%. The ash content of these pumpkin seeds was found to be in the range of 2.7 to 3.6%.

Table 5. Chemical properties of four kinds of pumpkin seeds

Chemical parameters	PS01	PS02	PS03	PS04
Moisture (%)	39.2±1.2^{b}	42.8±1.9^{a}	36.9±0.9^{b}	43.0±3.3^{a}
Lipid (% DW)	42.4±0.3^{a}	33.1±0.6^{c}	39.4±0.4^{b}	25.0±0.3^{d}
Starch (% DW)	5.9±0.2^{b}	8.8±2.2^{a}	9.6±0.9^{a}	2.4±0.6^{c}
Protein (% DW)	4.1±0.5^{a}	3.6±0.5^{ab}	3.9±0.1^{a}	3.0±0.4^{b}
Ash (% DW)	5.9±0.1^{b}	6.2±0.3^{a}	4.6±0.1^{c}	4.8±0.3^{c}

Values are mean±SD, DW: dry weight. Mean values with the different letters within the same row are significantly different at $p<0.05$.

Discussion

It is found that all pumpkin species cultivated in Vietnam have a variety of properties. The results in biological characteristics of different pumpkin species were in agreement with the findings of Ahamed *et al*. (2012) and Devi *et al*. (2018) which indicated a large variation in weight, size, and shape (i.e. elliptical, broadly elliptical, pyriform, round, flattened, and oblong), skin color (i.e. green, brown, and yellow). Moreover, Ahamed *et al*. (2012) showed that the average fruit weight of pumpkins ranged from 1.5 to 4.2 kg depending on their genotype, and the circumferences of the pumpkin fruit changed from 46.3 to 77.1 cm. Varieties in pumpkin fruit weight have changed widely to over 25 kg have been noticed (Dhiman *et al.,* 2009; Devi *et al*., 2018). Furthermore, the variation in the proportion of pumpkin's body part was observed. Haridy and Hassan (2019) have reported that pumpkin fruits contain 70 to 86% edible portions that are similar to this study. Besides, Jacobo-Valenzuela *et al*. (2011) illustrated that the pulp of winter squash was 69±9.4%, the seeds were 11.6±4.8%, strands (placenta) was 3.9±2.4%, and the shell was 12.4±8.1% while Kulczyński *et al.* (2020) reported that pumpkin fruits' pulp, seed, and skin content was 57.3-83.6%, 2.4-8.8%, and 13.5-36%, respectively.

In this study, the results in chemical composition varied among four types of pumpkins. According to Haridy and Hassan (2019), pumpkin pulps contain 85-90% water, 0.7-1.5% ash, 1.0-2.1% protein, 0.3-0.6% fat, and 1.4-3.5% starch. Kim *et al*. (2012) reported that the pumpkin flesh of Cucurbitaceae species contains 84.0-96.8% moisture, 2.6-13.4% carbohydrate, 0.2-1.1% protein, 0.3-1.0% ash, and 1.5-17 μg/g β-carotene (equivalent 46.4-106.5 μg/g DW). The pulps of winter squash showed an average TSS value of 6.42% and an average pH value of 6.77 (Jacobo-Valenzuela *et al*., 2011). Kulczyński *et al.* (2020) showed the pH values of pumpkin flesh in the range of 5.5 to 6.5. Because multiple species and/or varieties of *Cucurbita* spp. are grown in various regions of the world, the approximate composition might vary a lot (Amin *et al*., 2019). Ahamed *et al*. (2012) also showed that the flesh colors of pumpkins were orange, deep orange, orange-yellow, yellow, pale green, and white. Jacobo-Valenzuela *et al*. (2011) have reported the average value of the color parameters L*, a*, and b* in the skin of *Cehualca* squashes were 75.66±13.77, 9.69±6.38 and 18.88±14.33, respectively. The color parameters L*, a*, and b* in its pulp were found with average values of 73.19±11.43, 5.57±6.71, and 43.86±13.94, respectively.

Bioactive chemicals (that is, polyphenols, carotenoids, ascorbic acid, tocopherols, etc.) have received a lot of attention in evolving their potential role in health and the preservation of food quality (Klejdus and Kováčik, 2016; Przybylska-Balcerek *et al*., 2019). According to Amin *et al*. (2019), the vitamin C content in the flesh of *C. maxima* species varied between 12.5 and 39.5 mg/100 g which were higher than the amount of Vitamin C in this study. In addition, the vitamin C content in the flesh of the *C. moschata* species was 42.0 to 83.1 mg/100 g DW (Kulczyński and Gramza-Michałowska, 2019). According to Walingo (2005), vitamin C plays significant functions in the body that enhance its role in the health status of the human body including stimulation of certain enzymes, collagen biosynthesis, hormonal activation, antioxidant, and detoxification, etc. Carotenoids are a group of phytochemicals that are responsible for the yellow to orange color in pumpkin flesh. The main carotenoid in pumpkin is β-carotene, with lesser amounts of lutein, lycopene, and cis-α-carotene (Seo *et al*., 2005). In addition to being potent antioxidants, some carotenoids are pro-vitamin A (i.e. α-carotene, β-carotene, β-cryptoxanthin) (Rao and Rao, 2007; Toti *et al*., 2018). The total carotenoid content in pumpkin pulp was the highest value for PS03 and PS04. The β-carotene content in pumpkin pulp was found between 31 and 70 μg/g (Murkovic *et al*., 2002). In the study of Kulczyński and Gramza-Michałowska (2019), the β-carotene content in the *C. moschata* pulps changed from 12.9 to 52.6 μg/g DW while the moisture content ranged from 82.5 to 91.5%. Polyphenols (that is, phenolic acids, flavonoids, tannins, etc.) from natural sources have been suggested to be a source of potential antioxidants (Tzima *et al*., 2018). Kulczyński *et al*. (2020) reported that the total polyphenol content in *C. pepo* and *C. moschata* flesh varied from 0.47 to 1.18 mg GAE/g DW. A growing number of studies suggest that consuming polyphenols may be essential to maintaining good health by controlling metabolism, weight, chronic disease, and cell proliferation (Cory *et al*., 2018). Various polyphenols contain antioxidant and anti-inflammatory properties that can have therapeutic and/or preventative effects on cancer, obesity, neurological diseases, and cardiovascular disease (Scalbert *et al*., 2005).

Regarding the physiochemical properties of by-products from these kinds of pumpkins, the findings indicated that the total polyphenol content was similar for their pumpkin peels and pulps. This result was in agreement with the study by Mala and Kurian (2016). Moreover, Figure 2 reveals that the pumpkin strands were explicitly observed to be a richer source of β-carotene than their skin and pulp in PS03 and PS04. In the case of PS01 and PS02, the β-carotene content of the strands was higher than its pulp. It seems that consumers have a habit of using the pulp and removing the strand when they prepare a variety of pumpkin dishes. Based on this finding, strands have emerged as potential sources of vitamin A for human and animal food. Golubkina *et al*. (2021) showed that β-carotene in Konfetka pumpkin placenta was up to 948 μg/g and was significantly higher than its peel (114 μg/g). More studies in this regard are needed to increase the application of pumpkin strands in the food chain soon. Furthermore, this study highlights the high percentage of lipids and ash in the pumpkin seed. According to Kim *et al.* (2012), pumpkin seeds (*C. pepo, C. moschata*, and *C. maxima*) contain 27.5-74.1% moisture, 44-52.4% fat, 27.5-30.9% protein, and 4.4-5.5% ash. Moreover, Elinge *et al.* (2012) also analyzed the nutritional composition of C. pepo seeds (DW) which were crude fat (38.0%), crude protein (27.5%), and ash (5.5%) while Gohari *et al*. (2011) found that *C. pepo* seeds contain oil, protein, and ash (DW) content of 41.59%, 25.4%, and 2.49%, respectively. In general, pumpkin seed oils are rich in essential fatty acids, especially polyunsaturated fatty acids such as oleic and linoleic (up to approximately 80% of pumpkin seed oil) (Nawirska-Olszańska *et al*., 2013). According to some previous studies, pumpkin seeds without hulls (kernels) contain 33-47% DW oil based on genotype (Idouraine *et al*., 1996; Seymen *et al*., 2016). In addition, they can be an excellent source of antioxidant compounds such as polyphenols, carotenoids, and tocopherols (Stevenson *et al*., 2007; Siano *et al*., 2016). Therefore, they have been suggested as sources of good edible oils due to their nutritional and health-protective value. The results of this study indicated great prospects for the utilization of Vietnamese pumpkin components (i.e. pulp, skin, strands, and seeds) in the food industry, as well as the production of baby, elderly, and biologically active foods.

The study highlighted significant variations among four types of Vietnamese pumpkins in morphology and biological characteristics. These differences in species may result in varying primary components. Antiradical activities were markedly higher in pumpkin pulps compared to their skin and strands. Also, comparison to the skins and pulp of the pumpkin, these pumpkin strands were found to be a robust source of β -carotene, while the seeds contained substantial lipid content. In general, these findings suggested a promising future for utilization of Vietnamese pumpkin elements in the food industry.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

Ahamed, K. U., Akhter, B., Islam, M. R., Ara, N. and Humauan, M. R. (2012). An assessment of morphology and yield characteristics of pumpkin (*Cucurbita moschata*) genotypes in northern Bangladesh. Tropical Agricultural Research and Extension, 14.

Amin, M. Z., Islam, T., Uddin, M. R., Uddin, M. J., Rahman, M. M. and Satter, M. A. (2019). Comparative study on nutrient contents in the different parts of indigenous and hybrid varieties of pumpkin (*Cucurbita maxima* Linn.). Heliyon, 5.

Association of Official Analytical Chemists and Association of Official Agricultural Chemists (US). (1920). Official methods of analysis of the Association of Official Analytical Chemists (Vol. 2). Association of Official Analytical Chemists.

Cory, H., Passarelli, S., Szeto, J., Tamez, M. and Mattei, J. (2018). The role of polyphenols in human health and food systems: A mini-review. Frontiers in Nutrition, 5:370438.

de Carvalho, L. M. J., Gomes, P. B., de Oliveira Godoy, R. L., Pacheco, S., do Monte, P. H. F., de Carvalho, J. L. V. and Ramos, S. R. R. (2012). Total carotenoid content, α-carotene and β-carotene, of landrace pumpkins (*Cucurbita moschata* Duch): A preliminary study. Food Research International, 47:337-340.

Devi, N. M., Prasad, R. and Palmei, G. (2018). Physico-chemical characterization of pumpkin seeds. International Journal of Chemical Studies, 6:828-831.

Dhiman, A. K., Sharma, K. D. and Attri, S. (2009). Functional constituents and processing of pumpkin: A review. Journal of Food Science and Technology, 46:411.

Elinge, C. M., Muhammad, A., Atiku, F. A., Itodo, A. U., Peni, I. J., Sanni, O. M. and Mbongo, A. N. (2012). Proximate, mineral and anti-nutrient composition of pumpkin (*Cucurbita pepo* L.) seeds extract. International Journal of Plant Research, 2:146-150.

Fikselová, M., Šilhár, S., Mareček, J. and Frančáková, H. (2008). Extraction of carrot (*Daucus carota* L.) carotenes under different conditions. Czech Journal of Food Sciences, 26:268-274.

Gohari, A. A., Farhoosh, R. and Haddad, K. M. (2011). Chemical composition and physicochemical properties of pumpkin seeds (*Cucurbita pepo* subsp. pepo Var. Styriaka) grown in Iran. Journal of Agricultural Science and Technology, 13:1053-1063.

Golubkina, N. A., Khimich, G. A., Antoshkina, M. S., Plotnikova, U. D., Nadezhkin, S. M. and Korottseva, I. B. (2021). Peculiarities of pumpkin carotenoid composition 'Konfetka'variety, prospects of utilization. Vegetable Crops of Russia, 1:111-116.

Haridy, A. G. and Hassan, M. A. (2019). Crop performance and fruit physicochemical properties and nutritional components of pumpkin (*Cucurbita moschata*) Cultivated at different densities. Assiut Journal of Agricultural Sciences, 50:125-148.

Heneidak, S. and Khalik, K. A. (2015). Seed coat diversity in some tribes of Cucurbitaceae: implications for taxonomy and species identification. Acta Botanica Brasilica, 29:129-142.

Huynh, N. T., Smagghe, G., Gonzales, G. B., Van Camp, J. and Raes, K. (2014). Enzyme-assisted extraction enhances the phenolic release from cauliflower (*Brassica oleracea* L. var. botrytis) outer leaves. Journal of Agricultural and Food Chemistry, 62:7468-7476.

Idouraine, A., Kohlhepp, E. A., Weber, C. W., Warid. and Martinez-Tellez, J. J. (1996). Nutrient constituents from eight lines of naked seed squash (*Cucurbita pepo* L.). Journal of Agricultural and Food Chemistry, 44:721-724.

Jacobo-Valenzuela, N., de Jesus Zazueta-Morales, J., Gallegos-infante, J. A., Aguilar-Gutierrez, F., Camacho-hernandez, I. L., Rocha-guzman, N. E. and Gonzalez-laredo, R. F. (2011). Chemical and physicochemical characterization of winter squash (*Cucurbita moschata* D.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 39:34-40.

Jamali, S. N., Kashaninejad, M., Amirabadi, A. A., Aalami, M. and Khomeiri, M. (2018). Kinetics of peroxidase inactivation, color, and temperature changes during pumpkin (*Cucurbita moschata*) blanching using infrared heating. LWT-Food Science and Technology, 93:456-462.

Jun, H. I., Lee, C. H., Song, G. S. and Kim, Y. S. (2006). Characterization of the pectic polysaccharides from pumpkin peel. LWT-Food Science and Technology, 39:554-561.

Kim, M. Y., Kim, E. J., Kim, Y. N., Choi, C. and Lee, B. H. (2012). Comparison of the chemical compositions and nutritive values of various pumpkin (*Cucurbitaceae*) species and parts. Nutrition Research and Practice, 6:21.

Klejdus, B., & Kováčik, J. (2016). Quantification of phenols in cinnamon: A special focus on "total phenols" and phenolic acids including DESI-Orbitrap MS detection. Industrial Crops and Products, 83:774-780.

Kulczyński, B. and Gramza-Michałowska, A. (2019). The profile of secondary metabolites and other bioactive compounds in Cucurbita pepo L. and Cucurbita moschata pumpkin cultivars. Molecules, 24:2945.

Kulczyński, B., Sidor, A. and Gramza-Michałowska, A. (2020). Antioxidant potential of phytochemicals in pumpkin varieties belonging to *Cucurbita moschata* and *Cucurbita pepo* species. CyTA-Journal of Food, 18:472-484.

Mala, K. S. and Kurian, A. E. (2016). Nutritional composition and antioxidant activity of pumpkin wastes. International Journal of Pharmaceutical, Chemical & Biological Sciences, 6.

McLellan, M. R., Lind, L. R. and Kime, R. W. (1995). Hue angle determinations and statistical analysis for multi quadrant Hunter L, a, b data. Journal of Food Quality, 18:235-240.

Mohsenin, N. N. (1970). Physical properties of plant and animal materials. Gordon and Breach.

Murkovic, M., Mülleder, U. and Neunteufl, H. (2002). Carotenoid content in different varieties of pumpkins. Journal of Food Composition and Analysis, 15:633-638.

Nawirska-Olszańska, A., Kita, A., Biesiada, A., Sokół-Łętowska, A. and Kucharska, A. Z. (2013). Characteristics of antioxidant activity and composition of pumpkin seed oils in 12 cultivars. Food Chemistry, 139:155-161.

Nguyen, N. M. P., Le, T. T., Vissenaekens, H., Gonzales, G. B., Van Camp, J., Smagghe, G. and Raes, K. (2019). In vitro antioxidant activity and phenolic profiles of tropical fruit by-products. International Journal of Food Science & Technology, 54:1169-1178.

Przybylska-Balcerek, A., Frankowski, J. and Stuper-Szablewska, K. (2019). Bioactive compounds in sorghum. European Food Research and Technology, 245:1075-1080.

Rakcejeva, T., Galoburda, R., Cude, L. and Strautniece, E. (2011). Use of dried pumpkins in wheat bread production. Procedia Food Science, 1:441-447.

Rao, A. V. and Rao, L. G. (2007). Carotenoids and human health. Pharmacological Research, 55:207-216.

Rojas, M. L., Silveira, I. and Augusto, P. E. D. (2020). Ultrasound and ethanol pre-treatments to improve convective drying: Drying, rehydration and carotenoid content of pumpkin. Food and Bioproducts Processing, 119:20-30.

Scalbert, A., Manach, C., Morand, C., Rémésy, C. and Jiménez, L. (2005). Dietary polyphenols and the prevention of diseases. Critical Reviews in Food Science and Nutrition, 45:287-306.

Seo, J. S., Burri, B. J., Quan, Z. and Neidlinger, T. R. (2005). Extraction and chromatography of carotenoids from pumpkin. Journal of Chromatography A, 1073:371-375.

Seymen, M., Uslu, N., Türkmen, Ö., Al Juhaimi, F. and Özcan, M. M. (2016). Chemical compositions and mineral contents of some hull-less pumpkin seeds and oils. Journal of the American Oil Chemists' Society, 93:1095-1099.

Siano, F., Straccia, M. C., Paolucci, M., Fasulo, G., Boscaino, F. and Volpe, M. G. (2016). Physico-chemical properties and fatty acid composition of pomegranate, cherry, and pumpkin seed oils. Journal of the Science of Food and Agriculture, 96:1730-1735.

Stevenson, D. G., Eller, F. J., Wang, L., Jane, J. L., Wang, T. and Inglett, G. E. (2007). Oil and tocopherol content and composition of pumpkin seed oil in 12 cultivars. Journal of Agricultural and Food Chemistry, 55:4005-4013.

Świeca, M., Dziki, D. and Gawlik-Dziki, U. (2017). Starch and protein analysis of wheat bread enriched with phenolics-rich sprouted wheat flour. Food Chemistry, 228:643-648.

Toti, E., Chen, C. Y. O., Palmery, M., Villaño Valencia, D. and Peluso, I. (2018). Non-provitamin A and provitamin A carotenoids as immunomodulators: Recommended dietary allowance, therapeutic index, or personalized nutrition. Oxidative Medicine and Cellular Longevity, 2018:4637861.

Tzima, K., Brunton, N. P. and Rai, D. K. (2018). Qualitative and quantitative analysis of polyphenols in Lamiaceae plants—A review. Plants, 7:25.

Walingo, K. M. (2005). Role of vitamin C (ascorbic acid) on human health-a review. African Journal of Food, Agriculture, Nutrition and Development, 5.

Yadav, M., Jain, S., Tomar, R., Prasad, G. B. K. S. and Yadav, H. (2010). Medicinal and biological potential of pumpkin: an updated review. Nutrition Research Reviews, 23:184-190.

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