AcademicPres

Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic 1842-4309

Not Bot Hort Agrobot Cluj, 2011, 39(1):34-40

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

Chemical and Physicochemical Characterization of Winter Squash (*Cucurbita moschata* D.)

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Abstract

Winter squash cv 'Cehualca' (*Cucurbita moschata* Duchense) is a seasonal crop that has been used as food and animal feed. The objective of the present study was to characterize physical, chemical and physicochemical properties of the winter squash cv 'Cehualca'. Morphological, chemical and physicochemical analyses were performed, including fiber, carotenoids, phenolic and mineral contents in the winter squash. The morphological analysis showed that the squash 'Cehualca' did not have a homogeneous morphology. Data about their physical and physicochemical characteristics showed large variability. Also, high content of carotenoids and dietary fiber was observed in squash. The oil and total phenolic content was low in comparison with other fruits. The mineral content exceeded the values recommended to meet the nutritional needs of consumers, except for sodium (both in pulp and shell), potassium and magnesium in the shell.

***Keywords*:** carotenoids, fiber, minerals, squash, total phenolic content

Introduction

Winter squash cv 'Cehualca' (*Cucurbita moschata* Duchense) has been essential in the diet of rural communities and some urban areas of Latin American countries, and other parts of the world (Lira and Montes, 1992). *C. moschata* is eaten as vegetable and cultivated for its young shoots, fleshy edible flowers and fruit. This cultivar is extremely variable in their fruit and seeds morphology. This makes it difficult to describe the vegetable, classify it taxonomically (Lira and Montes, 1992).

Numerous culinary uses of this crop either as a vegetable or as an ingredient in food preparations like pies, soups, stews and breads has been reported (Pinho *et al.,* 2011; Doymaz, 2007). Also, this squash has been reported for their use as traditional medicine with antidiabetic, antihypertensive, antitumor, immunomodulation, antibacterial, antihypercholesterolemia and antiinflammation activities (Fu *et al.,* 2006).

It is believed that squash is a healthy and functional vegetable because of its rich nutrients and bioactive compounds contents such as phenolics, flavonoids, vitamins (including β-carotene, vitamin A, vitamin B2, α-tocopherol, vitamin C, and vitamin E), amino acids, carbohydrates and minerals (especially potassium), and its low energy content (about 17 Kcal/100 g of fresh pumpkin) and its large amount of fiber (Tamer *et al.,* 2010).

The bioactivity of phenolics could be related to their antioxidant behaviour, which is attributed to their ability to chelate metals, inhibit enzymes and scavenge free radicals (Martinez-Valverde *et al.,* 2000). However, few studies have been published about the health promoting phenolics in *C. moschata*.

The objective of the present study was to characterize physical, chemical and physicochemical properties of the winter squash.

Material and methods

Materials

The squash (*Cucurbita moschata* Duchense) was purchased directly from producers of San Ignacio, Sinaloa, Mexico (in 2008 and 2009). 260 squash samples were selected visually to fulfill a level of ripeness, physical appearance and uniform color.

Physical characterization

Morphological characterization

The same terms used in different parts of Sinaloa, Mexico to refer to this cultivar were used along this study. They were inspired on the basic shapes presented regularly by these squash samples (Fig. 1).

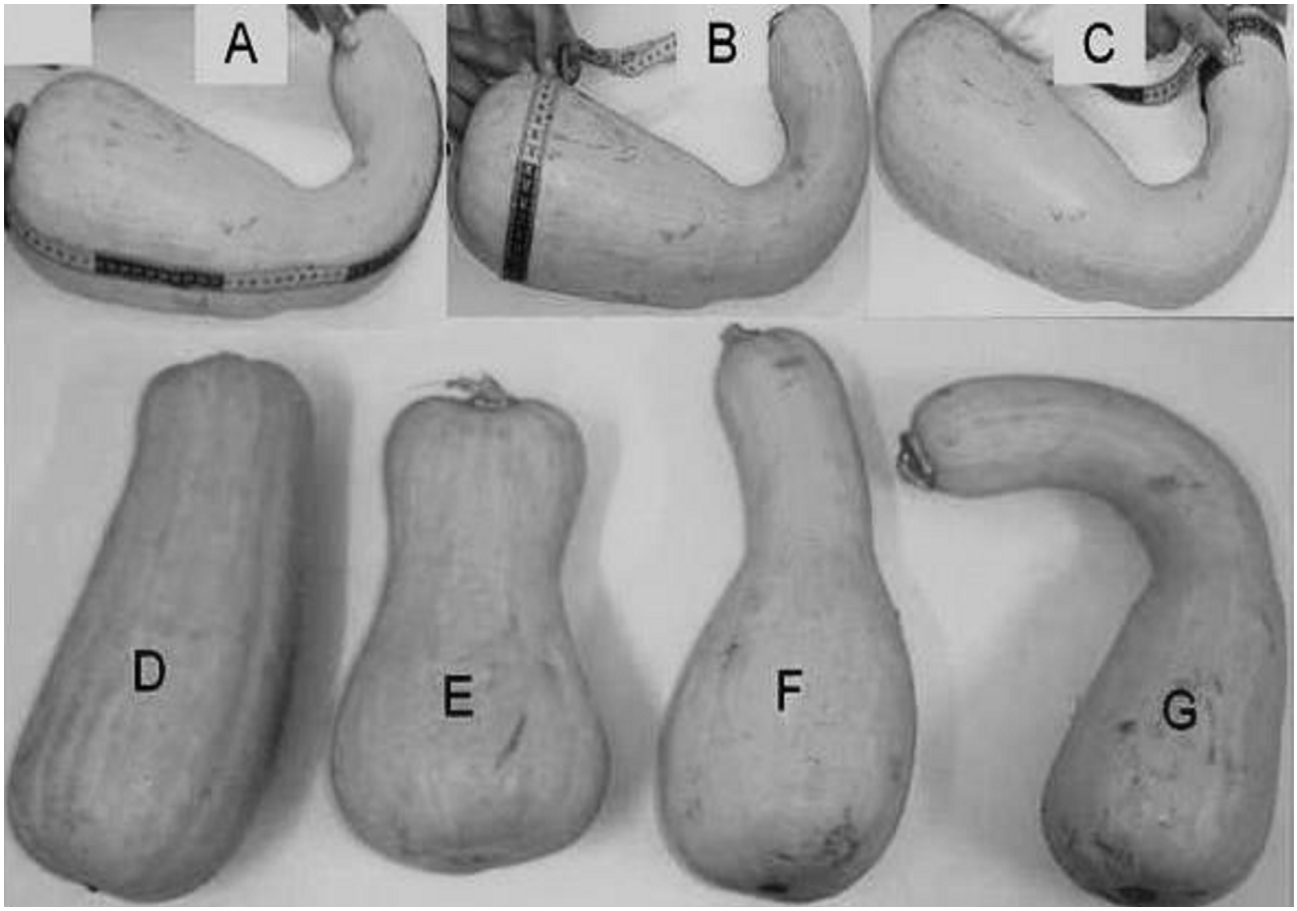

Fig. 1. Physical and morphological characterization of winter squash cv. 'Cehualca'(*Cucurbita moschata* D.). Top images show length (A) width (B)neck width (C) determinations. Bottom images show squash shape types: "ovalada" (D), "bule" (E), "buchona" (F) and "herradura"(G)

Fruit dimensions

The length was measured with a tape flexible meter along the curvature of the stalk from end to end (Fig. 1A). The diameter of the bulb was measured by placing the flex meter around the bulb of the squash (Fig. 1B). The diameter of the neck was determined around the thickening section at the end of the neck (Fig. 1C).

Fruit and fruit components weight

Each squash samples and their pulp, shell and seed yield were weighted individually (Balance, Torrey, EQ-5/10, Monterrey, Mexico).

Physicochemical characterization

Color was determined using a Minolta colorimeter (Croma Meter CR-210, Japan). Five readings of parameters L*, a* and b* on the samples were performed. Three measurements were done on the bulb at a distance of 120° in between the fourth reading was done at half the body of the squash and the last at the swelling of the neck. This procedure was performed to determine both the shell and pulp color.

Soluble solids, pH and acidity

Soluble solids (SS, °Brix) were determined from a sample of squash juice (manually obtained) in a Milton Roy refractometer. This procedure was carried out in triplicate. The pH was determined by hydrogen-ion activity (pH)-electrometric method (Method 2-52, AACC, 1990). The acidity was determined following the methodologies proposed by the AOAC (2000) (Method 970.64).

Chemical characterization

Reducing sugars, pectins and minerals

Proximate composition was evaluated following the methodology proposed by AOAC (Methods 920.125, 920.85, 920.86, 923.03, 925.09, AOAC, 1990). Reducing sugars were obtained by Lane-Eynon General Volumetric Method (AOAC 1975). Pectins were determined by the method reported by the AOAC (1975). Minerals were determined using the 955.06 AOAC method (AOAC, 1990), and an atomic absorption spectrophotometer (VARIAN, SpectrAA 220), with air-acetylene flame and hollow cathode lamps of calcium, magnesium, potassium,

sodium, iron, manganese, copper and zinc, making the determination at a wavelength of 422.7, 285.2, 769.9, 589.9, 248.3, 279.5, 324.8 and 213.9 nm, respectively.

Total, soluble and insoluble dietary fiber

Total, soluble and insoluble dietary fiber were determined according to Prosky *et al.* (1988), and the 991.42 AOAC Method (AOAC, 1995).

Total carotenoids

Total carotenoids were determined by method 45.1.04 of the AOAC (1995).

Total phenolic content

Phenolic compounds from shell and pulp were extracted with acetone (80%) and quantified using the reactive of Folin-Ciocalteu, following the recommendations of Xu and Chang (2007) and Garrido *et al.* (2007).

Statistical analysis

The data were analyzed with descriptive statistics using the statistical software Microsoft Office Excel 2003.

Results

Physical, physicochemical and chemical characteristics showed a great variability coefficient higher than 13% in most parameters (Tab. 1-3), except for pH values, moisture, total dietary fiber (TDF), insoluble dietary fiber (IDF) and total phenolic contents from squash shell.

Physical characterization

Morphological characterization

Fig. 1 showed the morphological classification of experimental squash samples, and could be seen that the form of *C. moschata* was diverse. The morphological classification resulted in four basic forms: type *"ovalada"* (oval) (Fig. 1D), type *"bule"* (bottle shape) (Fig. 1E), type *"buchona"* (maw shape) (Fig. 1F) and type *"herradura"* (horseshoe shape) (Fig. 1G). Between these, the type *"buchona"* was the form of the squash with a dominant 46.46%, followed by the type *"ovalada"* with a 39.76%, type *"herradura"* was present in 10.24%; and a minor proportion was type *"bule"* with a 3.54% of the total.

Physicochemical characterization

The average value of color parameters L*, a* and b* in the surface of the shell of 'Cehualca' squashes were 75.66, 9.69 and 18.88 respectively (Tab. 2). The color parameter L*, a* and b* of the pulp presented a moderate correlation with parameter L* (-0.5517), a* (0.5535) and b* (0.6256) of shell, with average values L*, a* and b* of 73.19, 5.57 and 43.86 respectively ($p < 0.001$).

The pulp of *C. moschata* showed average values of 6.42 % soluble solids, 0.04 % total acidity as citric acid and pH: 6.77 (Tab. 2).

Tab.1. Physical characterization of *Cucurbita moschata*

Determination	Average*	SD	VC (%)	Min	Max	n
External lenght (cm)	54.24	10.26	18.91	30.00	90.00	260
Bulb diameter (cm)	43.72	8.32	19.04	23.20	91.00	260
Neck diameter (cm)	28.70	6.56	22.85	17.60	55.40	260
Internal thickness (cm)	2.06	6.99	33.96	0.58	5.42	145
Fruit weigth (Kg)	3.25	0.96	29.66	1.52	7.75	260
Structural Components of fruit (%)						
Pulp	69.03	9.44	13.68	30.51	90.14	185
Seed	11.61	4.76	40.98	4.35	39.92	185
Placenta	3.91	2.42	61.81	0.39	18.19	160
Shell	12.36	8.10	65.57	3.51	82.10	135

* = Dry base, SD = Standard Deviation, VC = Variability Coefficient, Min = Minimum Value, Max = Maximum Value; n = number of the sample used. In each squash, analysis were done at least by 3 measurements.

Tab. 2. Physicochemical characterization of *Cucurbita moschata*

Statistical parameter	Shell			Pulp			Soluble solids. (°Brix)	pH	Acidity (%, citric acid)
	Color parameter								
	L*	a*	b*	L*	a*	b*			
Average**	75.66	9.69	18.88	73.19	5.57	43.86	6.42	6.77	0.04
SD	13.77	6.38	14.33	11.43	6.71	13.94	2.26	0.70	0.04
VC (%)	18.20	64.01	75.88	15.62	120.69	31.79	35.16	10.38	106.77
Min	45.46	-9.83	-21.12	45.44	-13.41	-12.65	1.00	4.27	0.01
Max	100.00	24.51	54.05	100.00	35.41	60.00	15.00	7.79	0.26
n	295	295	295	95	95	95	88	95	95

** = Dry base, SD = Standard Deviation, VC = Variability Coefficient, Min = Minimum Value, Max = Maximum Value; n = number of the sample analyzed (except in color of seed where n = number of seed analyzed)

Tab. 3. Chemical characterization of 'Cehualca' (*Cucurbita moschata* D.)

	Average*	SD	VC (%)	Min	Max	N
Pulp						
Moisture (%)	91.55	1.07	1.73	89.61	92.89	12
Protein (%)	1.41	0.28	20.15	1.07	1.89	12
Oil (%)	0.07	0.03	39.05	0.04	0.13	12
Ash (%)	0.89	0.15	16.97	0.70	1.09	12
Crude Fiber (%)	1.06	0.15	13.92	0.85	1.24	12
Total Dietary Fiber (TDF) (%)	19.10	3.09	16.20	14.78	22.75	9
Dietary Fiber Insoluble (DFI) (%)	15.68	6.24	39.79	3.09	22.72	9
Dietary Fiber Soluble (DFS) (%)	4.00	0.85	21.21	3.19	5.74	9
Pectin (%)	7.34	1.14	15.53	1.14	8.30	9
Reducing sugars (%)	1.69	0.39	23.37	1.01	2.44	50
Carotenoids (mg β-Carotene/g)	2.67	1.10	41.28	4.79	1.32	17
Phenolics (mq C/ g)	1.38	0.54	39.03	1.75	0.1	7
Shell						
Moisture (%)	85.90	2.10	2.44	80.04	88.47	12
Protein (%)	3.66	0.07	19.25	2.59	4.45	12
Oil (%)	0.40	0.07	16.21	0.31	0.49	12
Ash (%)	1.38	0.18	12.92	1.13	1.06	12
Crude Fiber (%)	2.86	5.44	189.89	0.13	13.92	12
Total Dietary Fiber (TDF) (%)	40.07	0.24	0.61	34.94	44.62	12
Dietary Fiber Insoluble (DFI) (%)	37.69	2.6	11.89	34.67	42.76	12
Dietary Fiber Soluble (DFS) (%)	2.60	0.43	16.52	2.19	3.34	12
Pectin (%)	5.53	0.92	16.68	0.92	6.84	12
Carotenoids (mg β-Carotene/g)	0.33	21.73	6.57	0.13	0.50	12
Phenolics (mq C/ g)	5.14	0.39	7.65	5.42	4.86	7

* = Dry base, SD = Standard Deviation, VC = Variability Coefficient, Min = Minimum Value; Max = Maximum Values, mq = milliequivalents, C = Catechin, n = number of the sample analyzed.

Tab. 4. Mineral content in winter squash cv. 'Cehualca' (*Cucurbita moschata* D.)

	Average (mg/kg)	SD	VC (%)	Min	Max	N	Recommended Dietary Allowance RDA (mg)
Pulp							
Fe	31.69	2.46	7.76	29.69	33.48	9	8-18
Mn	3.33	0.38	11.40	0.51	6.90	9	1.8-2.3
Zn	23.88	1.39	5.84	18.68	26.92	9	8-11
Cu	8.44	0.32	3.79	7.40	10.42	9	0.7- 0.9
Na	700.2	181.52	25.92	532.11	785.91	9	1200-1500
K	42194.00	863.88	2.04	30170.31	49416.70	9	4500-4700
Ca	6684.75	181.52	2.71	3113.37	9854.33	9	1-1.3
Mg	1590.40	31.96	2.01	1214.01	1615.07	9	210-420
P	3040.48	45.54	1.50	2406.99	3553.36	9	700-1250
Shell							
Fe	63.98	6.93	10.83	53.18	84.09	9	8-18
Mn	7.33	0.93	12.74	2.35	14.8	9	1.8- 2.3
Zn	31.42	2.49	7.91	18.82	49.01	9	8-11
Cu	5.37	0.49	9.06	2.78	8.15	9	0.7-0.9
Na	707.22	149.00	21.07	616.67	772.32	9	1200-1500
K	2255.53	494.63	2.22	17860.27	30765.8	9	4500-4700
Ca	5856.66	94.94	1.62	4350.13	6865.78	9	1-1.3
Mg	3441.83	72.10	2.10	2518.87	4927.18	9	210-420
P	7998.87	34.46	0.43	6065.97	11312.84	9	700-1250

Chemical characterization

Chemical characterization was determined by reducing sugars, pectins; total, soluble, and insoluble dietary fiber, total carotenoids, phenolic compounds and minerals in both pulp and shell of the winter squash *cv* 'Cehualca', and the results were presented in Tab. 3. It could be seen that 'Cehualca' squash had a good carotenoid content, while it had low phenolic content. Also, approximately 83% of the dietary fiber content corresponds to insoluble dietary fiber (IDF).

Mineral content in both pulp and shell were shown in Tab. 4. Except for sodium (Na), both pulp and shell and Potassium (K) in shell, the mineral values exceed the maximum average amount necessary to meet the nutritional needs of Dietary Reference Intakes (US Institute of Medicine, 2001).

Disscusion

Physical characterization

Morphological characterization

All morphological forms of the 'Cehualca' squash had in common an ovary or bulb in agreement with Lira and Montes (1992). They reported that these species of vegetables may have different forms, but all vegetables keep the ovary type.

Physicochemical characterization

The physical characteristics data showed great variability, these results agreed with Lira and Montes (1992); they reported that the size of this cultivar was too variable. Montes *et al.* (2004), reported for 'Cehualca' squash values of the length (13.21-91.99 cm) and width (11.69-29.75 cm); higher variation of thickness (1.80-6.95 cm) and weight (1.70-8.75 kg), and higher variability in the values of length and less variability in width than values found in the present work.

Noseworthy and Loy (2008) reported lower weight values of 'Cehualca' than the weight values found in the present study, for *C. moschata* (0.35-0.96 kg) and *C. maxima* (0.91-2.04 kg). Karkleliene *et al.* (2008) reported that pumpkin *pepo* 'Beloruskaja' and 2 cultivars of *maxima* squash ('Bambino' and 'Gele Reuzen') had higher weight (7.1, 8.4 kg, respectively), lower diameter (27.0 and 29.3 cm, respectively) and shorter length (29.3 cm and 35.22 cm, respectively) than the reported in the present study.

Color, soluble solids, acidity and pH are the quality parameters in fruit and vegetables. The color is an indicator of ripeness in fruit and vegetables, and the brightness value (L*) enhances by their color**.** Que *et al.* (2007) reported values for freeze-dried 'Cehualca' flour higher than in the present work for L* (80.15), a* (13.43) and b* (48.63). Karkleliene *et al.* (2008) determined color in two cultivars of *Cucurbita maxima* Duch. ('Gele Reuzen' and 'Bambino'), and found higher values in the parameters a* (16.65) and b* (54.92) and lower values in the parameter L* (71.00) in comparison with the present study. Tamer *et al.* (2010) reported lower values of L* (49.6) and higher values in a* (21.9) and b* (31.0). Soluble solids determined in the present experimental work were lower than the reported by Roura *et al.* (2007) and Noseworthy and Loy (2008) (8-11 and 7.0-8.7 °Brix, respectively) for *C. moschata*. The pH values were higher than the reported by Tamer *et al.* (2010) (5.80) in *C. moschata*.

Chemical characterization

Reducing sugar values were lower than some fruits such as peach and nectarine, guava, sand, apple and banana (Salunkhe and Kadam, 1995). While carotenoids content in pulp were higher than the reported for C. *moschata* (Gonzalez *et al.*, 2001; Pandey *et al.*, 2003: Tamer *et al.*, 2010), it was also higher than shell, and their values showed great variability; this agrees with the variation in total carotenoids reported in different studies, and might be due to agricultural factors such as climate, growing conditions, harvesting season, and ripeness (Setiawan *et al.,* 2001).

The bioactivity of phenolic compounds could be related to their antioxidant capacity, which is attributed to their ability to chelate metals, inhibit lipoxygenase and scavenge free radicals (Martínez-Valverde, 2000). The phenolic compounds found in C. *moschata*, were higher in shell than in pulp. Tamer *et al.* (2010) reported higher values of phenolic compounds in *C. moschata* than those found in the present work.

Saura-Calixto *et al.* (2000) reported lower values of dietary fiber (total, insoluble and soluble) in several fruits than those found in pulp of *C. moschata*. They reported IDF content (dry basis) of banana, potato, apple and orange as 14.9, 11.1, 12.1 and 15.3% respectively.

Except for sodium (Na), in both pulp and shell and Potassium (K) in shell, the mineral values were greater than the necessary to meet the recommended dietary allowances (US Institute of Medicine, 2001). Iron content was superior than squash seed (13.1 mg/kg) (Alfawaz, 2004). The amount of K was higher than cabbage (34.5 mg/kg) as reported by Majkowska-Gabomska and Wierzbicka (2008). Montiel-Herrera *et al.* (2005) reported Cu values of nanche fruit as 5.3 mg/kg.

Both pulp and shell of 'Cehualca' squash presented higher amount of Fe, Mn, Zn, Cu, Ca, Mg and P than the suggested for recommended dietary allowances (RDA) (US Institute of Medicine, 2001). On the other hand, Na value was low when compared with the RDA (US Institute of Medicine, 2001).

Moisture results are shown in Tab. 3. The result of Moisture in squash was similar to the reported by Fedha *et al.* (2010) for *C. moschata* and *C. maxima*.

The results obtained about protein are shown in Tab. 3. The protein content was lower than protein content reported by Fedha *et al.* (2010) for *C. moschata*. Differences in protein level could be related to different agricultural

practices and harvesting date. Rouphael and Colla (2005) showed that *C. pepo* harvested in spring time has more nitrogen than the harvested in summer time.

Ash results for 'Cehualca' are shown in Tab. 3. Ash content was higher than the reported by Fedha *et al.* (2010) and similar for other *Cucurbitaceae* as *P. fistolosus* (Hussain *et al.,* 2009).

Oil results for 'Cehualca' are shown in Tab. 3. Oil content was lower than the reported by Hussain *et al.* (2009) for *P. fistolosus*.

Pectin content in 'Cehualca' (Tab. 3) was similar to reported by Kostalova *et al.* (2009) for *C. pepo* 'Styriaca', and higher than the reported by Baker (1997) for American squash.

Conclusions

Physical, physicochemical and chemical characteristics of 'Cehualca' squash showed a great variability. The proximate analysis showed low contents of oil. 'Cehualca' had high content of carotenoids, dietary fiber and minerals. The mineral content exceeded the values recommended to meet the nutritional needs of consumers, except for sodium (both pulp and shell), potassium and magnesium in the shell. The total phenolic content was lower in comparison with other fruits; however the high mineral content and high level of fiber present in 'Cehualca' squash are reasons to recommend the consumption of this product.

Acknowledgments

Antonio Meneses Arrellano and NJV thanks scholarship from PROMEP.

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