Physicochemical, nutritional and functional properties of *Cucurbita moschata*

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Abstract *Cucurbita moschata* is widely planted in most parts of the world, and is rich in carotenoids, vitamins, dietary fiber, minerals, and phenolic compounds. It also has important medicinal value. Some related research has proven that *Cucurbita moschata* has the potential ability to induce anti-obesity, anti-diabetic, antibacterial, and anti-cancer effects. At the same time, it has attracted more attention in the medical field. These nutrients and bioactive compounds in *Cucurbita moschata* have important effects on human health. In order to make better use of this crop, it still needs further study. Therefore, the purpose of this article is to summarize the physicochemical properties and nutritional components of *Cucurbita moschata*, and to

provide a reference for further research on the benefits of on human health.

Keywords *Cucurbita moschata* · Physicochemical property · Nutritional component · Functional property · Human health

Introduction

Cucurbita moschata has been widely cultivated in many countries since ancient times. The genus *Cucurbita* belongs to the *Cucurbitaceae* family and *Cucurbitales* order (Armesto et al., 2020). Pumpkin species originated from the American continent, from two different points of origin. One origin point includes Mexico and Central and South America; the species found here include *Cucurbita moschata*, *Cucurbita ficifolia*, *Cucurbita pepo*, and *Cucurbita mixta*. The other origin point is in South America, which includes the species *Cucurbita maxima* (Armesto et al., 2020; Jacobo-Valenzuela et al., 2011b). The food crop *Cucurbita moschata* plays a vital role in the diet of both rural and, to some extent, urban areas in the Americas (Lira and Montes, 1992). It can be prepared via a variety of cooking methods, where it is used not only as a vegetable, but also as an ingredient in the production of bread, flour, soup, pies, and other foods (Doymaz, 2007; Guiné et al., 2012).

Cucurbita moschata likes to grow in warm tropical areas and water-rich environments, as it is not cold-resistant but is high-temperature resistant instead. It can, however, resist both drought and frost during its flowering period (Jacobo-Valenzuela et al., 2011b). The peel is tough and strong, keeps well, and is difficult to be damaged during transportation. It can be stored for more than 3 months under

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normal temperatures, which makes it not only suitable for daily consumption, but also for heavy processing, and as such, it is widely used in the food industry.

In many countries, such as the United States, Mexico, India, China, and Brazil, *Cucurbita moschata* is traditionally used as a medicine (Jacobo-Valenzuela et al., 2011b; Yadav et al., 2010). It is rich in vitamin A, vitamin B, vitamin C, various minerals, carotene, eight kinds of amino acids necessary for the human body, and also contains trace elements such as phosphorus, potassium, calcium, magnesium, zinc, and silicon. Modern nutrition science and medicine have shown that *Cucurbita moschata* can effectively prevent hypertension, diabetes, liver disease, and strengthen the human immune system (Priori et al., 2017). Polysaccharides, dietary fiber, pectin, and other substances in *Cucurbita moschata* have important positive physiological effects on the human body (Jacobo-Valenzuela et al., 2011b).

Cucurbita moschata is used in many fields. In food processing, Lee et al. (2002) have studied the physical properties and sensory perception of noodles supplemented with *Cucurbita moschata* powder. Aziah and Komathi (2009) studied the physical and chemical properties of peeled and unpeeled *Cucurbita moschata* flour and compared it with wheat flour. In the medical research field, Jun et al. (2006) extracted pectin polysaccharides from the peel of *Cucurbita moschata*, and they found that pectin can promote the growth of beneficial bacteria in the intestines. In other research, Zaccari et al. (2007) identified changes in β -carotene content during the storage of *Cucurbita moschata*.

Although *Cucurbita moschata* has been widely cultivated in various regions of the world and some related experimental research has been carried out on it, there is still a lot unknown about the *Cucurbita moschata* variety, which is worthy of further research. The aim of this article is to summarize the physicochemical, nutritional components and function in health of *Cucurbita moschata* as a whole to help people better understand the variety of *Cucurbita moschata*, and to build a basic foundation that can aid future experimental research.

Morphology of *Cucurbita moschata*

There is no uniform shape of *Cucurbita moschata*, and there is a large variation in its physical and chemical properties in the data (Jacobo-Valenzuela et al., 2011a). Their sizes, shapes, and colors exhibit a high degree of diversity. The flesh is relatively thick, and the plant stems have abundant short pubescence (Ku et al., 2005). The length of the seed is between 8.00 and 22.41 mm (Lira and Montes, 1992; Wu et al., 2011; Yildiz et al., 2013), the

width is between 1.00 and 14.10 mm (Jacobo-Valenzuela et al., 2011b; Lira and Montes, 1992; Wu et al., 2011; Yildiz et al., 2013), the thickness is between 1.58 and 4.52 mm (Jacobo-Valenzuela et al., 2011b; Teotia et al., 1989; Wu et al., 2011; Yildiz et al., 2013), and the average weight is between 0.063 and 0.190 g (Darrudi et al., 2018; Teotia et al., 1989; Wu et al., 2011). The outer appearance of *Cucurbita moschata* is smooth; the length of the fruit is between 13.21 and 91.99 cm, the width is between 9.46 and 55.40 cm, the thickness is between 0.58 and 6.95 cm, and the weight is between 0.59 and 8.75 kg, as shown in Table 1.

Cucurbita moschata comes in many colors, such as brown, orange, and so on. The difference in color is partly due to the difference in the content of carotenoids in *Cucurbita moschata* (Meléndez Martínez et al., 2004). However, the longer it is stored for, the lower the a and b color value of the *Cucurbita moschata* flesh (Gliemmo et al., 2009).

Jacobo-Valenzuela et al. (2011b) summarized the four shapes of *Cucurbita moschata* as: “Ovalada”, “Bule”, “Buchona”, and “Herradura” among which the most common morphology is “Buchona”, and the least common morphology is “Bule”. The color range of the peel is: L value of between 45.46 and 100.00; a value of between -9.83 and 24.51 ; and a b value of between -21.12 and 54.05 (Jacobo-Valenzuela et al., 2011a). The reported values for the L value, a value, and b value color parameters in the pulp of *Cucurbita moschata* is between 40.30 and 100.00, -13.14 and 33.09 , and -12.65 and 63.70 , respectively, as seen in Table 2.

Nutritional components and functions of *Cucurbita moschata*

Montes et al. (2004) evaluated some physical characteristics of *Cucurbita moschata* and concluded that the fruit of *Cucurbita moschata* comes in different shapes, colors, sizes, and seed types. Guiné et al. (2012), Jacobo-Valenzuela et al. (2011b), and Roura et al. (2007) evaluated the chemical composition (moisture, protein, lipid, crude fiber, and crude ash) of a particular type of *Cucurbita moschata* (Table 3). They concluded that the moisture content of the shell is between 80.04 and 88.47%, the protein content is between 2.59 and 4.45%, the fat content is between 0.31 and 0.49%, and the ash content is between 1.06 and 1.13% (Jacobo-Valenzuela et al., 2011a). The pH value of the pulp is between 4.27 and 7.79 (Armesto et al., 2020; Gliemmo et al., 2014; Jacobo-Valenzuela et al., 2011a; Jacobo-Valenzuela et al., 2011b). The moisture content of the pulp is between 79.00 and 93.00%, the protein content is between 0.76 and 19.61%, the fat content is between

Table 1 Physical characterization of *Cucurbita moschata*

No	Determination	Value	Reference
1	Fruit		
2	Length (cm)	13.21–91.99	Montes et al. (2004), Jacobo-Valenzuela et al. (2011a) and Tamil selvi et al. (2012)
3	Width (cm)	9.46–55.40	Montes et al. (2004), Jacobo-Valenzuela et al. (2011a) and Tamil selvi et al. (2012)
4	Thickness (cm)	0.58–6.95	Montes et al. (2004), Jacobo-Valenzuela et al. (2011a) and Tamil selvi et al. (2012)
5	Weight (kg)	0.59–8.75	Montes et al. (2004), Jacobo-Valenzuela et al. (2011a), Jacobo-Valenzuela et al. (2011b), Darrudi et al. (2018) and Tamil selvi et al. (2012)
6	Seed		
7	Length (mm)	8.00–22.41	Lira and Montes (1992), Wu et al. (2011) and Yildiz et al. (2013)
8	Width (mm)	1.00–14.10	Jacobo-Valenzuela et al. (2011b), Lira and Montes (1992), Wu et al. (2011), Yildiz et al. (2013)
9	Thickness (mm)	1.58–4.52	Jacobo-Valenzuela et al. (2011b), Teotia et al. (1989), Wu et al. (2011) and Yildiz et al. (2013)
10	Average weight (g)	0.063–0.190	Darrudi et al. (2018), Teotia et al. (1989) and Wu et al. (2011)

Table 2 Physicochemical characterization of *Cucurbita moschata*

No	Composed	Content	References
1	Pulp		
2	pH	4.27–7.79	Armesto et al. (2020), Gliemmo et al. (2014), Jacobo-Valenzuela et al. (2011a), Jacobo-Valenzuela et al. (2011b) and Tamer et al. (2010)
3	L	40.30–100.00	Armesto et al. (2020), Gliemmo et al. (2014), Jacobo-Valenzuela et al. (2011a), Que et al. (2008), Sim et al. (2020) and Tamer et al. (2010)
4	a	(–)13.14–33.09	Armesto et al. (2020), Gliemmo et al. (2014), Jacobo-Valenzuela et al. (2011a), Que et al. (2008), Sim et al. (2020) and Tamer et al. (2010)
5	b	(–)12.65–63.70	Armesto et al. (2020), Gliemmo et al. (2014), Jacobo-Valenzuela et al. (2011a), Que et al. (2008), Sim et al. (2020) and Tamer et al. (2010)
6	Shell		
7	L	45.46–100.00	Jacobo-Valenzuela et al. (2011a)
8	a	(–)9.83–24.51	Jacobo-Valenzuela et al. (2011a)
9	b	(–)21.12–54.05	Jacobo-Valenzuela et al. (2011a)

0.04 and 3.81%, and the ash content is between 0.57 and 13.45%, as shown in Table 3. Indrianingsih et al. (2019) studied the antioxidant activity, physicochemical and chemical properties of two pumpkin varieties (*Cucurbita moschata* and *Cucurbita maxima*). It is concluded that the antioxidant activity of *Cucurbita moschata* seeds is higher than that of *Cucurbita maxima* seeds. At the same time, the content of fat and protein in *Cucurbita moschata* seeds were also higher than that in *Cucurbita maxima* seeds, which were 28.49% and 19.23%, respectively. The carbohydrate content in the pulp of *Cucurbita moschata* is as high as 78.64%, which is completely higher than that in the pulp of *Cucurbita maxima* (69.51%). *Cucurbita moschata* is rich in dietary fiber, vitamin A, vitamin C, and vitamin E. It is also rich in manganese, magnesium, and potassium,

which are essential for the human body. Jun et al. (2006) also found that *Cucurbita moschata* contains large amounts of pectin, mineral salts, carotene, vitamins, and other substances that are beneficial to human health. It is well-suited for patients with hypertension, coronary heart disease, and hyperlipidemia, and is especially beneficial for elderly, obese, and hypertensive people.

Vitamins

Vitamin A

Vitamin A is mainly present in the pulp and fruit juice. The majority of it is in the form of carotene, which

Table 3 Chemical characterization of *Cucurbita moschata*

No	Composed	Content	References
1	Pulp		
2	Moisture (%)	79–93	Armesto et al. (2020), Guiné et al. (2012), Jacobo-Valenzuela et al. (2011a), Jacobo-Valenzuela et al. (2011b), Kulczyński and Gramza-Michałowska (2019), Roura et al. (2007) and Usha et al. (2010)
3	Protein (%)	0.76–19.61	Armesto et al. (2020), Guiné et al. (2012), Jacobo-Valenzuela et al. (2011a), Jacobo-Valenzuela et al. (2011b), Sim et al. (2020) and Usha et al. (2010)
4	Fat (%)	0.04–3.81	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Jacobo-Valenzuela et al. (2011b), Sim et al. (2020) and Usha et al. (2010)
5	Ash (%)	0.57–13.45	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Jacobo-Valenzuela et al. (2011b), Sim et al. (2020) and Usha et al. (2010)
6	Carbohydrates (%)	4.38–53.32	Armesto et al. (2020), Sim et al. (2020) and Usha et al. (2010)
7	Crude fiber(%)	0.51–2.97	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011b) and Tamil selvi et al. (2012)
8	Vitamin C (mg/100 g)	10.84–83.05	Kulczyński and Gramza-Michałowska (2019), Roura et al. (2004) and Roura et al. (2007)
9	Vitamin A (mg/g)	4.32–20	Evangelina et al. (2001), Jacobo-Valenzuela et al. (2011b)
10	Lutein (μg/g)	0.03–115.6	Bergantin et al. (2018), Evangelina et al. (2001), Jacobo-Valenzuela et al. (2011b) and Kulczyński and Gramza-Michałowska (2019)
11	Dietary fiber (%)	14.78–30.02	Jacobo-Valenzuela et al. (2011a) and López-Mejía et al. (2019)
12	β-carotene (μg/g)	0.006–2340	Armesto et al. (2020), Bergantin et al. (2018), Evangelina et al. (2001), Jacobo-Valenzuela et al. (2011b) and Kulczyński and Gramza-Michałowska (2019)
13	α-carotene (μg/g)	6	Evangelina et al. (2001)
14	Zeaxanthin (μg/g)	5.2–21.2	Kulczyński and Gramza-Michałowska (2019)
15	Total phenolic content (mg GAE/100 g) ¹⁾	476.6	Tamer et al. (2010)
16	Total phenolic content (mg CAE/100 g) ²⁾	26.31–79.86	Priori et al. (2017)
17	Gallic acid (mg/100 g)	5.31–25.62	Kulczyński and Gramza-Michałowska (2019)
18	Rutin (mg/100 g)	0.130–46.930	Enneb et al. (2020), Kulczyński and Gramza-Michałowska (2019)
19	Quercetin (mg/100 g)	0.350–4.510	Enneb et al. (2020) and Kulczyński and Gramza-Michałowska (2019)
20	Phenolics (mq C/g) ³⁾	1.38	Jacobo-Valenzuela et al. (2011a)
21	Shell		
22	Moisture (%)	80.04–88.47	Jacobo-Valenzuela et al. (2011a)
23	Protein (%)	2.59–4.45	Jacobo-Valenzuela et al. (2011a)
24	Fat (%)	0.31–0.49	Jacobo-Valenzuela et al. (2011a)
25	Ash (%)	1.06–1.13	Jacobo-Valenzuela et al. (2011a)
26	Dietary fiber (%)	34.94–44.62%	Jacobo-Valenzuela et al. (2011a)
27	Lutein (μg/g)	10.7–12.7	Jacobo-Valenzuela et al. (2011b)
28	β-carotene (μg/g)	37.6–63.22	Jacobo-Valenzuela et al. (2011b)
29	Phenolics (mq C/g)	1.38	Jacobo-Valenzuela et al. (2011a)
30	Seed		
31	Moisture (%)	6.81–23.07	Yildiz et al. (2013)
32	Protein (%)	19.23	Indrianingsih et al. (2019)
33	Fat (%)	28.49	Indrianingsih et al. (2019)

¹⁾GAE = Gallic acid equivalents²⁾CAE = Chlorogenic acid equivalents³⁾mq = milliequivalents, C = Catechin

works to maintain epidermal cell function and to prevent night blindness and dry eye. Evangelina et al. (2001) found that the vitamin A content in fresh pumpkin

samples is 432 μg RE/100 g, suggesting that *Cucurbita moschata* can be an important source of vitamin A original in Table 3.

Vitamin C

There is an abundant amount of vitamin C in the *Cucurbita moschata*, and the vitamin C content varies with the maturity stage. The retention rate of vitamin C is also very high, even when *Cucurbita moschata* are hot-processed. The vitamin C content in mature *Cucurbita moschata* pulp is 22.87 mg/100 g (Roura et al., 2007). Del Caro et al. (2004) proved that vegetables with high vitamin C content could help reduce the risk of cancer, diabetes, and cardiovascular and nervous system diseases. Roura et al. (2004) found that the vitamin C content at the start of the storage period for ready-to-use diced *Cucurbita moschata* was 15.7 mg/100 g, and the content was 28.4 mg/100 g after 15 days. Kulczyński and Gramza-Michałowska (2019) experimented with different *Cucurbita moschata* samples and found that the ascorbic acid content was between 41.98 and 83.05 mg/100 g (dry mass).

Dietary fiber

Dietary fiber is a general term that refers to macromolecular substances that are mainly composed of polysaccharides, which are not easily digested and absorbed by the human body. It is a polymer composed of cellulose, pectin, hemicellulose, glycoprotein, and other substances.

In their experiments, López-Mejía et al. (2019) found a dietary fiber content of 30.02% in dehydrated pumpkin pulp. Jacobo-Valenzuela et al. (2011a) carried out experiments on the pulp and peel of *Cucurbita moschata*. They found that the total dietary fiber content in the pulp of *Cucurbita moschata* was between 14.78 and 22.75%, and the total dietary fiber content in the shell was between 34.94 and 44.62%. According to their experimental results, about 83% of the dietary fiber was insoluble dietary fiber. Saura-Calixto et al. (2000) reported that the total dietary fiber content (dry mass) of potato and apple is 11.10 and 12.10%, respectively. The dietary fiber content of these fruits is lower than the content of *Cucurbita moschata* pulp (Table 3).

A large number of studies have already proven that dietary fiber has beneficial physiological effects such as reducing plasma cholesterol, preventing obesity, improving blood sugar production response, preventing constipation and colon cancer, preventing gallstones, and preventing breast cancer (De Escalada Pla et al., 2007).

Pumpkin Polysaccharide

Pumpkin polysaccharide is an important active substance in *Cucurbita moschata*, and is also recognized as a hypoglycemic substance. In recent years, it has been found that pumpkin polysaccharides have not only obvious hypoglycemic effects, they also have significant effects in reducing blood lipids and enhancing antioxidant, antitumor, and immune systems, showing that they have the capacity for use in a broad range of categories (Caili et al., Caili et al., 2006). Paper chromatography has been used to determine the types of monosaccharides present in pumpkin polysaccharides. Some studies found that pumpkin polysaccharides consisted of galactose, glucose, arabinose, xylose, and glucuronic acid (Kong and Jiang, 1999; Maran et al., 2013). High-performance capillary electrophoresis was used to determine the monosaccharides present as glucose, glucuronic acid, galactose, pectinose, xylose, and rhamnose (Yang et al., 2007).

Carotenoids

Evangelina et al. (2001) found that *Cucurbita moschata* is rich in β -carotene and lutein, as well as α -carotene and ζ -carotene. β -carotene is converted into vitamin A after being absorbed by the human body, which can effectively protect visual function and prevent night blindness. At the same time, β -carotene works to scavenge free radicals.

Bergantin et al. (2018), Evangelina et al. (2001), Jacobo-Valenzuela et al. (2011b) and Kulczyński and Gramza-Michałowska (2019) found that the lutein content of different kinds of *Cucurbita moschata* is about 0.03–115.6 $\mu\text{g/g}$, and a β -carotene content of about 0.006–2340.000 $\mu\text{g/g}$ (Table 3). Carotenoids are antioxidants that enhance the body's immunity and reduce the occurrence of cancer, chronic diseases, and embolic vascular diseases. Evangelina et al. (Evangelina et al., 2001) and Rodríguez-Amaya (2003) have shown that diets rich in carotenoids can enhance the body's immune response and reduce the risk of chronic diseases such as cancer, cardiovascular disease, and atherosclerosis. Lee et al. (Lee et al., 2002) concluded that carotenoids could act as traps for catching free radicals, thereby inferring that they may play an important role in cancer prevention. Kim et al. (2016) used baked *Cucurbita moschata*, steamed *Cucurbita moschata*, and β -carotene to treat both mouse splenocytes and RAW 264.7 macrophage cells isolated from mouse spleen simultaneously, and found that *Cucurbita moschata* and β -carotene might induce spleen cells and macrophages to produce Th1 cytokines, enhancing the immunity of the body.

Total phenolic compounds

The biological activity of phenolic compounds may be related to their antioxidant capacity, because phenolic compounds can chelate metals to inhibit lipoxygenase activity and scavenge free radicals (Martínez-Valverde et al., 2000; Yen et al., 1993). At the same time, phenolic compounds also play an important role in the growth and reproduction of plants, which can improve the resistance of plants to pathogens and affect the color of fruits and vegetables (Acunha, 2013).

Priori et al. (2017) found that the phenolic compound content per 100 g of fresh weight of 10 kinds of *Cucurbita moschata* was between 26.31 and 79.86 mg.

Enneb et al. (2020) extracted the quercetin and rutin from the pulp, fiber and seed of *Cucurbita moschata* with four different solvents (methanol, ethyl acetate, hexane, chloroform). The quercetin and rutin were detected in ethyl acetate extract and methanol extract by Shimadzu UFLC XR system. The quercetin content was 0.533 mg/100 g and 0.350 mg/100 g, respectively. The rutin content was 0.250 mg/100 g and 0.130 mg/100 g, respectively. Kulczyński and Gramza-Michałowska (2019) studied six varieties of *Cucurbita moschata*. Among the six varieties, “butternut” had the richest contents of rutin and quercetin, was 46.93 mg/100 g and 4.51 mg/100 g (dry mass), respectively.

Quercetin derivatives are mainly found in vegetables and fruits, and have a variety of biological activities, which can prevent cancer, neurodegenerative diseases, and cardiovascular diseases (David et al., 2016). Rutin is a phytochemical with multiple pharmacological activities and it can effectively prevent neuroinflammation, depression, stroke and other diseases (Ganeshpurkar and Saluja, 2017).

Jacobo-Valenzuela et al. (2011a) found that the average phenolic content in *Cucurbita moschata* was 1.38 mg C/g, and the average phenolic content in the peel is 5.14 mg C/g (dry mass). Que et al. (2008) carried out hot air drying and freeze-drying experiments on *Cucurbita moschata*. They found that the total antioxidant activity of hot air-dried *Cucurbita moschata* powder is significantly higher than that of freeze-dried *Cucurbita moschata* powder. This may be because the heat treatment caused an increase in the total polyphenol content in the *Cucurbita moschata* (Piga et al., 2003). Tamer et al. (2010) found that the total phenolic content in fresh *Cucurbita moschata* was 476.63 ± 0.91 mg GAE/100 g. Li et al. (2009) isolated two kinds of phenol glycosides from *Cucurbita moschata* seeds; their structures were identified as (2-hydroxy) phenylcarbonyl 5-O-benzoyl- β -D-apiofuranosyl(1 $\rightarrow$ 2)- β -D-glucopyranoside and 4- β -D-(glucopyranosyl

hydroxymethyl)phenyl 5-O-benzoyl- β -D-apiofuranosyl(1 $\rightarrow$ 2)- β -D-glucopyranoside.

Mineral elements

Mineral elements are widely dispersed in nature and play important roles in the human body. Although there are some minerals acquired through the human diet, insufficient intake still frequently occurs (Sichieri et al., 2000). Some vegetables have high mineral content, so it is important to eat enough vegetables. Paulauskiene et al. (2018) fertilized pumpkins with four different fertilizers (humic substances fertilizer, complex fertilizers, compost and mixtures of complex fertilizers, and humic substances fertilizers). It showed that zinc, calcium, sodium, manganese, and iron in the pumpkin fruits of all fertilization experimental groups have increased.

Calcium

Calcium deficiency is closely related to bone deformities and abnormal blood pressure. Calcium plays an important role in the shaping of bones and teeth, blood coagulation, and nerve transmission. Of the minerals present in *Cucurbita moschata*, its calcium content is relatively high (Table 4). Priori et al. (2017) found that the content of calcium in 10 kinds of *Cucurbita moschata* ranged from 2.26 g/kg to 7.49 g/kg (dry mass). Jacobo-Valenzuela et al. (2011a) found that the calcium content in the pulp of *Cucurbita moschata* was between 311.337 and 985.433 mg/100 g, and the calcium content in the shell was between 435.013 and 686.578 mg/100 g. Armesto et al. (2020) determined that the calcium content in *Cucurbita moschata* was between 26.66 and 31.16 mg/100 g. Kulczyński and Gramza-Michałowska (2019) experimented with six varieties of *Cucurbita moschata* and found that the calcium content was between 152.34 and 281.23 mg/100 g (dry mass). The reason for these differences in the findings may be due to different experimental materials or different measurement methods. Gomes et al. (2019) obtained calcium content of 12.01 and 8.72 mg/100 g from the pulp of two grapes (white grape and red grape), which are far lower than the content of *Cucurbita moschata* (Table 4).

Manganese

Manganese is an essential trace element for the human body, as it forms part of several enzymes that have important physiological functions in the body. The manganese content in *Cucurbita moschata* is relatively low (Table 4). Jacobo-Valenzuela et al. (2011a) found that the manganese content of *Cucurbita moschata* is between 0.51

Table 4 The content of mineral compounds in *Cucurbita moschata*

No	Minerals	Content (mg/100 g)	References
1	Pulp		
2	Mn	0.051–162.68	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Kulczyński and Gramza-Michałowska (2019) and Priori et al. (2017)
3	Mg	17.47–492.718	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Kulczyński and Gramza-Michałowska (2019) and Priori et al. (2017)
4	Fe	0.18–8.409	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Kulczyński and Gramza-Michałowska (2019) and Priori et al. (2017)
5	K	3.39–7386.90	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Kulczyński and Gramza-Michałowska (2019) and Priori et al. (2017)
6	Ca	23.00–985.433	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Kulczyński and Gramza-Michałowska (2019) and Priori et al. (2017)
7	Cu	0.14–1.042	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a) and Priori et al. (2017)
8	Zn	0.39–4.02	Armesto et al. (2020), Jacobo-Valenzuela et al. (2011a), Kulczyński and Gramza-Michałowska (2019) and Priori et al. (2017)
9	Na	47.24–346.92	Armesto et al. (2020) and Jacobo-Valenzuela et al. (2011a)
10	Shell		
11	Mn	0.235–1.48	Jacobo-Valenzuela et al. (2011a)
12	Mg	251.887–492.718	Jacobo-Valenzuela et al. (2011a)
13	Fe	5.318–8.409	Jacobo-Valenzuela et al. (2011a)
14	K	1786.027–3076.58	Jacobo-Valenzuela et al. (2011a)
15	Ca	435.013–686.578	Jacobo-Valenzuela et al. (2011a)
16	Cu	0.278–0.815	Jacobo-Valenzuela et al. (2011a)
17	Zn	1.882–4.901	Jacobo-Valenzuela et al. (2011a)
18	Na	61.667–77.232	Jacobo-Valenzuela et al. (2011a)

and 6.90 mg/kg, and the manganese content of the shell was between 2.35 and 14.80 mg/kg. Priori et al. (2017) found that the manganese content ranged from 2.33 mg/kg to 13.94 mg/kg (dry mass).

Potassium

Potassium is a very important mineral for the human body and plays a fundamental role in acid–base regulation and body fluid balance. It is also an essential component for heart, kidney, muscle, nerve, and digestive system functioning. The health benefits of getting enough potassium include a lower risk of hypokalemia, osteoporosis, hypertension, stroke, kidney stones, and asthma (Larsson et al., 2008; Swain et al., 2008). In terms of mineral content, potassium was the most abundant. Priori et al. (2017) found that the potassium content in 10 kinds of *Cucurbita moschata* ranged from 33.9 to 94.6 g/kg (dry mass). Jacobo-Valenzuela et al. (2011a) found that the potassium content in the pulp of *Cucurbita moschata* was between 3017.013 and 4941.67 mg/100 g, and the potassium content in the shell was between 1786.027 and 3076.580 mg/100 g. Armesto et al. (2020) determined that the potassium

content in *Cucurbita moschata* was between 244.67 and 294.61 mg/100 g. Kulczyński and Gramza-Michałowska (2019) experimented with six varieties of *Cucurbita moschata* and found that the potassium content was between 4104.30 and 7386.90 mg/100 g (dry mass) (Table 4). The results of these experiments are hugely different, which may be due to the different varieties and maturity levels of the *Cucurbita moschata*.

Magnesium

Magnesium mainly exists in green plants, coarse grains, nuts, and other foods, and affects many cellular biological functions.

Magnesium is the main cation in human cells and is an essential substance for the basic biochemical reactions of various cells in the body. Magnesium is a necessary element and plays important roles in normal neuromuscular function and blood sugar conversion (De Baaij et al., 2015).

Priori et al. (2017) found that the magnesium content in 10 kinds of *Cucurbita moschata* ranged from 0.8 to 2.9 g/kg (dry mass). Jacobo-Valenzuela et al. (2011a) found that

the magnesium content in the pulp of *Cucurbita moschata* was between 121.401 and 161.507 mg/100 g, and the magnesium content in the shell was between 251.887 and 492.718 mg/100 g. Armesto et al. (2020) determined that the magnesium content in *Cucurbita moschata* was between 17.47 and 25.54 mg/100 g. Kulczyński and Gramza-Michałowska (2019) experimented with six varieties of *Cucurbita moschata* and found that the magnesium content was between 81.15 and 135.54 mg/100 g (dry mass).

Iron

Iron deficiency has a serious impact on human health and has been described as one of the most widespread health problems by the World Health Organization. The necessary iron level for an individual depends on many factors, such as age, gender, and diet.

The iron content in *Cucurbita moschata* is relatively low (Table 4). Priori et al. (2017) found that the iron content in 10 kinds of *Cucurbita moschata* ranged from 1.8 to 5.9 mg/kg (dry mass). Jacobo-Valenzuela et al. (2011a) found that the iron content in the pulp of *Cucurbita moschata* was between 2.969 and 3.348 mg/100 g, and the iron content in the shell was between 5.318 and 8.409 mg/100 g. Armesto et al. (2020) determined that the iron content in *Cucurbita moschata* was between 0.80 and 1.63 mg/100 g. Kulczyński and Gramza-Michałowska (2019) experimented with six varieties of *Cucurbita moschata* and found that the iron content was between 1.24 and 2.59 mg/100 g (dry mass). The different iron concentrations may be due to the different varieties of *Cucurbita moschata* used, different maturity levels, and different dry or wet weights.

Copper

The copper content in *Cucurbita moschata* was between 0.140 and 1.042 mg/100 g (Table 4). Priori et al. (2017) found that the copper content in *Cucurbita moschata* ranged from 5.78 to 8.93 mg/kg (dry mass). Kulczyński and Gramza-Michałowska (2019) experimented with six varieties of *Cucurbita moschata* and found that the copper content was between 0.26 and 0.53 mg/100 g (dry mass). Jacobo-Valenzuela et al. (2011a) found that the copper content of the shell was between 0.278 and 0.815 mg/100 g.

Zinc

Zinc is an essential trace element for human beings, animals, plants, and microorganisms. There are about 2 billion people with a zinc deficiency, which can cause many diseases (Prakash et al., 2015; Prasad, 2003).

Jacobo-Valenzuela et al. (2011a) found that the zinc content in the pulp was between 1.868 and 2.692 mg/100 g. Armesto et al. (2020) determined that the zinc content in *Cucurbita moschata* was between 0.39 and 0.45 mg/100 g.

Sodium

Excessive sodium intake can cause some non-communicable diseases (such as high blood pressure, cardiovascular disease, stroke, etc.), while reduced sodium intake can lower blood pressure and increase the risk of related non-communicable diseases (He and MacGregor, 2009).

Jacobo-Valenzuela et al. (2011a) found that the sodium content in the pulp of *Cucurbita moschata* was between 53.211 and 78.591 mg/100 g, and the content of sodium in the shell was between 61.667 and 77.232 mg/100 g (Table 4). Armesto et al. (2020) determined that the sodium content in *Cucurbita moschata* was between 47.24 and 63.26 mg/100 g. Kulczyński and Gramza-Michałowska (2019) experimented with six varieties of *Cucurbita moschata* and found that the sodium content was between 219.05 and 346.92 mg/100 g (dry mass).

The function of *cucurbita moschata*

Cucurbita moschata is rich in elements that are essential nutrients. In the past few decades, many researchers have studied *Cucurbita moschata*, and have found that *Cucurbita moschata* has many medicinal applications, such as deworming, anti-diabetes, antibacterial, anticancer, and anti-obesity properties (Caili et al., 2006; Jacobo-Valenzuela et al., 2011b). With the popularization of pumpkin cultivation, this variety of pumpkin has gradually entered people's field of vision, especially in traditional medicine, because of its rich bioactive substances and medicinal value, researchers have focused on this plant. In the study of bioactive substances, many epidemiological studies have been carried out, which have stimulated a number of animal model, cell culture studies and clinical trials designed to test this pharmacological actions (Caili et al., 2006).

Anti-obesity

Hossain et al. (2018) evaluated the potential anti-obesity properties of fermented *Cucurbita moschata* extract, and the results showed that the extract inhibited the mRNA expression of fat genes (PPAR γ , C/EBP α , C/EBP β , C/EBP γ , and SREBP-1C) in mice. They concluded that the fermented *Cucurbita moschata* could be used as a potential drug to control obesity. Lee et al. (2012) isolated dehydrodiconiferyl alcohol (DHCA) from a water-soluble

Table 5 Important bioactive compounds from *Cucurbita moschata* and their biological activities

No	Biological activity	Source	Pumpkin compound(s)	Major findings	References
1	Anti-obesity	Pulp	Extract	Regulation of adipogenic/lipogenic transcriptional factors	Hossain et al. (2018)
2		Dried stems	Dehydrodiconiferyl alcohol	Mitotic clonal expansion and lipogenic genes	Lee et al. (2012)
3	Anti-diabetic	Fruit	Two new tetrasaccharide glyceroglycolipids	Possess glucose-lowering activities	Jiang and Du (2011)
4	Anti-helminthic	Seeds	Antiparasitic agent	Minimum inhibitory concentration	Díaz et al. (2004)
5	Anticancer	Seeds	—	Decreased risk for all four sites of cancer	Huang et al. (2004)
6		Seeds	Ribosome-inactivating protein designated Moschatin	Inhibit the growth of melanoma cells M21.	Xia et al. (2003)
7		Juice	—	Suppressed the incidence of aberrant cells	Ito et al. (1986)
8		Fruit	lycopene, carotene, carotene, cryptoxanthin, lutein and zeaxanthin	Protective against prostate cancer.	Jian et al. (2005)
9	Antibacterial	Pulp	Water soluble polysaccharides	High antibacterial activity against <i>Bacillus subtilis</i> , <i>Staphylococcus aureus</i> , and <i>Escherichia coli</i>	Qian (2014)
10		Seeds	Antibacterial peptides.	Functional antimicrobial agents	Dash and Ghosh (2018)
11		Seeds	Antifungal peptide	Inhibited translation	Wang and Ng (2003)
12	Anti-fatigue	Fruit	Extract	Decreased plasma lactate and ammonia levels and creatine kinase activity	Wang et al. (2012)

extract of *Cucurbita moschata*. DHCA can inhibit the DNA binding activity of C/EBP β , thus inhibiting the proliferation of mitotic clones, and can also directly inhibit the expression of fat production regulators in 3T3-L1 and primordial embryonic fibroblasts (Table 5).

Anti-diabetic

In recent years, many studies have shown that *Cucurbita moschata* has a variety of health effects; among them, the research on its effect on diabetes has attracted much attention. The pulp and seed of *Cucurbita moschata* showed hypoglycemic activity in both normal animals and tetraoxopyrine-induced diabetic rats (Table 5).

Two novel tetrasaccharide glyceroglycolipids (QGMG-3, QGMG-2) were extracted from *Cucurbita moschata* and found to reduce the blood sugar level of diabetic mice significantly. These glyceroglycolipids could be used as a candidate drug for the treatment of type II diabetes (Jiang and Du, 2011).

Anti-helminthic

The seeds of *Cucurbita moschata* can be used as an insect repellent and can be eaten fresh or roasted, which can relieve the symptoms of abdominal cramps and bloating

caused by intestinal worms. In the clinical study, it was reported that pumpkin seeds have a minimum inhibitory when ingested at a concentration of 23 g of pumpkin seeds to 100 g of distilled water can produce an anti-helminthic effect (Díaz et al., 2004).

Anticancer activity

Cancer treatment is very difficult, and most cancers are still not completely curable. The main reason is that cancer has the properties of infinite replication and diffusion transfer. As such, it poses a massive challenge to researchers and medical professionals. It has been found that the risk of cancer can be reduced by consuming more vegetables and fruits (Craig, 1997).

Preliminary research on both a crude extract of *Cucurbita moschata* and several purified components such as proteins and polysaccharides showed that these components in *Cucurbita moschata* have anticancer effects on melanoma, leukemia, etc. However, there is a lot of uncertainty, as while some researchers found that boiled pumpkin juice can significantly inhibit the occurrence of cancer cells, others found that fresh pumpkin juice can enhance the growth of cancer cells (Caili et al., 2006; Ito et al., 1986; Xia et al., 2003). Through case reference studies and hospital-based comparisons, it is concluded that

regular intake of pumpkins, and regular exercise can reduce the risk of cancer of stomach, intestine, lung, and breast cancer (Huang et al., 2004). Xia et al. (2003) extracted a new type of ribosome-inactivating protein (RIP) designated Moschatin from mature *Cucurbita moschata* seeds and purified it to homogeneity. They concluded it is a type 1 RIP and found that this ribosome-inactivating protein can effectively inhibit the growth of M21 melanoma cells.

Alongside that, increasing the intake of lycopene, α -carotene, β -carotene, β -cryptoxanthin, lutein, and zeaxanthin can reduce the risk of prostate cancer, available by eating more tomatoes, pumpkin, spinach, watermelon, and citrus fruits (Jian et al., 2005).

Antibacterial activity

Bacteria, viruses, fungi, and other parasites can cause many diseases and can also affect economic development. A new type of antifungal peptide with a molecular weight of 8 kDa was isolated from *Cucurbita moschata* seeds. At a dose of 375 μ g, it inhibited *Botrytis cinerea*, *Fusarium oxysporum*, and *Mycosphaerella oxysporum*, and it inhibited the translation of acellular rabbit reticulocytes when IC₅₀ was 1.2 μ M (Wang and Ng, 2003). Three basic proteins isolated from *Cucurbita moschata* seeds: MAP2 (MW: 2249D), MAP4 (MW: 4650D), and MAP11 (MW: 11696D) can inhibit the growth of yeast cells. Among them, MAP11 (MW: 11696D) is the most effective inhibitor, but MAP2 (MW: 2249D) and MAP4 (MW: 4650D) did not inhibit the growth of *Escherichia coli* (Caili et al., 2006; Vassiliou et al., 1998).

Based on the results of experiments with *Cucurbita moschata*, people in developing countries should be encouraged to eat more pumpkins because some of the ingredients in *Cucurbita moschata* can prevent organisms that cause infectious diseases. Qian (2014) studied the extraction of a water-soluble polysaccharide from *Cucurbita moschata* and its antibacterial capacity, and concluded that it had a strong antibacterial effect on *Bacillus subtilis*, *Staphylococcus aureus*, and *Escherichia coli*. Wang et al. (2017) extracted a protein-bound polysaccharide (PSP-I) from *Cucurbita moschata* seeds through hot water extraction and ethanol precipitation, and tested the antibacterial activity by used four common bacterial strains. The minimal inhibitory concentrations of PSP-I against *Bacillus subtilis*, *Staphylococcus aureus*, *Pichia fermentans* and *Escherichia coli* were 62.5, 7.8, 125.0 and 15.6 μ g/mL, respectively. The results indicated that PSP-I may be a new type of antibacterial compound. The peptides extracted from *Cucurbita moschata* seeds can significantly inhibit *Acinetobacter baumannii*, with a lethal concentration of 122.9 ± 3.2 μ g/mL. As such, these peptides can be used as

an antibacterial agent in nutritious foods and food systems (Dash and Ghosh, 2018).

Other functionalities

Two kinds of extracts were obtained from the pulp of *Cucurbita moschata* using chloroform and ethyl acetate, respectively, and these extracts showed significant anti-complement activity in the complement system (Yang et al., 2002). Suphakarn et al. (1987) found that children supplemented with 60 mg/kg (weight) of pumpkin seeds daily had a reduced occurrence of bladder stones. An ethanol extract obtained from *Cucurbita moschata* can lower plasma lactate and ammonia levels and reduce creatine kinase activity. This mechanism is related to the increase in energy stored (as glycogen) and released (as blood glucose), and the decrease in plasma lactic acid, ammonia, and creatine kinase. Therefore, CME may have anti-fatigue pharmacological effects (Wang et al., 2012). *Cucurbita moschata* seeds are rich in omega-3 fatty acids, which may reduce blood pressure to a certain extent (Kamarubahrin et al., 2018).

Bahramsoltani et al. (2017) studied the healing ability of *Cucurbita moschata* peel extraction on burn wounds. The results showed that *Cucurbita moschata* could act as a burn healing agent due to its high mucus content and the strong antioxidant capacity.

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Compliance with ethical standards

Conflict of interest None of the authors of this study has any financial interest or conflict with industries or parties.

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