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Journal of Plant Biochemistry & Physiology

Review Article

Winter squash (*Cucurbita moschata* D.) Displays Promising Nutritional Aspects in Fruits, Seeds and in the Seed Oil

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ABSTRACT

The fruits of winter squash (*Cucurbita moschata* D.) are important sources of bioactive components such as carotenoids, phenolic compounds, and flavonoids. The seed oil of *C. moschata* has a high content of unsaturated and monounsaturated fatty acids, associated with high levels of antioxidant components, making its use promising for human consumption. In this review, we address the genetic variability expressed by the germplasm of *C. moschata*, the nutritional aspects of fruit pulp and seed oil, emphasizing the importance of this vegetable in human feeding.

Keywords: Bioactive compounds; Carotenoids; *Cucurbita moschata*; Fatty acids; Genetic variability

INTRODUCTION

Winter squash (*Cucurbita moschata* Duchesne) is one of the species of greatest socioeconomic importance in the *Cucurbita* genus. Characteristically, plants of the genus *Cucurbita* have an annual cycle and indeterminate growth habit. Archaeological evidence points out that *C. moschata* was domesticated in Latin America and consensually, it is assumed that Colombia is its primary center of diversity [1,2].

With the process of dispersion, *C. moschata* was introduced in the continents of North America and Asia. Characteristically, *C. moschata* expresses high genetic variability in all the regions where it is cultivated [3-5], partly as a result of natural hybridization between populations of this species. The variability of *C. moschata* is especially high in Brazil [6-8], something closely related to the populations involved in its cultivation, predominantly family-based farmers. The selection practiced over time by these populations, associated with the exchange of seeds practiced between them, has contributed to the extension of the genetic variability in this species.

Most of the socioeconomic importance of *C. moschata* is associated with the nutritional aspects of its fruits and seeds. The fruit pulp, the most consumed part in the production of *C. moschata*, expresses a series of sensory/nutritional characteristics that make it very attractive for consumption. The fruit pulp of *C. moschata* has high levels of minerals such as K, Ca, P, Mg and Cu [9] which makes it an excellent source of these nutrients.

The expression of high levels of carotenoids in the fruit pulp is a distinct aspect of *C. moschata* [10]. A study of [11] demonstrated that the carotenoid profile in the pulp fruit of *C. moschata* is quite diverse, and reported the identification of 19 different carotenoids. This study also reported predominance of carotenoids such as β and α -carotene, important precursors of Vitamin A. Associated with its importance in human nutrition, the cultivation of *C. moschata* commonly is based on the use of low technological level. Together with other aspects, it has promoted the adoption of *C. moschata* as a strategic crop for biofortification programs aiming at the reduction of nutritional deficiency such as vitamin A deficiency [12].

The use of *C. moschata* seeds and seed oil in human consumption is a promising aspect in the production of this vegetable. The seeds have a protein content equivalent to 30% of their composition and lipid content of up to 49% [13]. Analysis of the fatty acid profile has shown that the seed oil of *C. moschata* consists of about 70% unsaturated fatty acids and a high content of monounsaturated fatty acids. Associated with this, studies have shown that the seed oil of *C. moschata* is rich in bioactive components such as vitamin E and carotenoids [14] which are important antioxidants in human feeding.

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Received: April 15, 2020; **Accepted:** April 29, 2020; **Published:** May 06, 2020

Citation: Gomes RS, de Almeida CF, Chagas RR, Júnior RM, Fara JS, da Silva DJH (2020) Winter squash (*Cucurbita moschata* D.) Displays Promising Nutritional Aspects in Fruits, Seeds and in the Seed Oil. J Plant Biochem Physiol. 8:248. DOI: 10.35248/2329-9029.20.8.248

BOTANICAL ASPECTS OF *C. MOSCHATA*

Winter squash (*Cucurbita moschata* Duchesne) is a vegetable belonging to the *Cucurbitaceae* family and the genus *Cucurbita*. It is a diploid species with 40 chromosomes organized in pairs (2n=2x=4O). The genus *Cucurbita* has 24 species, of which five are cultivated, namely, *C. moschata*, *C. argyrosperma*, *C. ficifolia*, *C. maxima*, *C. moschata* and *C. pepo*. These species are important in human feeding due to nutritional aspects of its fruits and seeds, sources of vitamins, minerals, fibers and antioxidant components [15,10].

Characteristically, plants of the genus *Cucurbita* have annual cycle and indeterminate growth habit [16]. They have herbaceous-prostrate stem, dark green, with tendrils and adventitious roots that help tem fixing. Plants of the genus *Cucurbita* are monoic, with a predominance of male flowers. They have large solitary gamopetal flowers, with tubular-bell-shaped corolla and yellow color. The ovary of plants in the genus *Cucurbita* is inferior with three to five placentas [15]. Concerning *C. moschata*, its plants commonly express vigorous growth. Additionally, its leaves express well-marked angles, covered with trichomes, which differentiates it from other species of the *Cucurbita* genus.

DOMESTICATION AND GENETIC DIVERSITY OF *C. MOSCHATA*

Studies show that *Cucurbita moschata* was domesticated in Latin America. Corroborating this, archaeological evidence of *C. moschata* consumption dates more than 7000 years to regions of Colombia and Ecuador [1,2]. As [17] initially, the use of this species involved the consumption of its seeds, followed by the use of the fruit pulp, based on the selection of fruits with less bitter pulp. By consensus, it is assumed that Colombia is the primary center of diversity for *C. moschata* and that the cultivation of this crop in part of the American continent precedes the Pre-Colombian era [1,2].

Characteristically, *C. moschata* expresses high genetic variability in all regions where it occurs [3-5] resulting in wide variation in the size and shape of fruits, in the patterns of color and texture of peel and fruit pulp (Figure 1).

Figure 1: Fruits of *C. moschata* displaying the variability in dimensions, shapes and color of fruits. Personal archive.

The variability of *C. moschata* is especially high in Brazil [6-8] something closely related to the populations involved in its cultivation, predominantly family-based farmers. The selection practiced over the time by these populations, associated with the exchange of seeds practiced between them and the natural occurrence of hybridizations in the germplasm of *C. moschata*, has expanded its variability, which allows the identification of promising genotypes in terms of production, fitness cultivation and nutritional aspects of fruits and seeds. With the dispersion process, C. moschata was introduced in the continents of North America and Asia.

C. MOSCHATA IS A VEGETABLE OF HIGH SOCIOECONOMIC IMPORTANCE

The high volume and value of production are remarkable aspects of *C. moschata* socioeconomic importance. It is estimated that together with other cucurbits such as *C. pepo* and *C. maxima*, the cultivated area and world production of *C. moschata* in 2019 was approximately 2 million hectares and 25 million tons, respectively [18] most of it concentrated in China and India. In Brazil, with a cultivated area of approximately 90 thousand hectares, a production estimated in more than 40 thousand tons/year and an annual production value of around 1.5 million reais [19] this crop assumes accentuated importance, especially in the family farming.

C. moschata is one of the vegetables of greatest socioeconomic importance in the *Cucurbita* genus, especially due to the high nutritional value of its fruits and seeds, aspects that will be discussed in more detail in the two following sessions.

FEEDING USE AND NUTRITIONAL ASPECTS OF FRUIT PULP OF *C. MOSCHATA*

The fruit pulp is the most consumed part of the production of *C. moschata*. It is used as an ingredient in various dishes such as stews, soups, pies, cakes, and candies, besides being in fresh dishes and the preparation of purees. The use of fruit pulp of *C. moschata* may vary considerably between the different regions where this vegetable is consumed.

A series of sensory/nutritional characteristics make the fruits of *C. moschata* a very attractive food for consumption. The color is a remarkable aspect in the fruit pulp of *C. moschata*, which expresses wide variation, with shades varying from a light yellow to an intense orange (Figure 2). Associated with this, the carbohydrate content represents most of the dry matter of fruit pulp, about 4% [20] giving the pulp a slightly sweet taste, making it very appealing for consumption.

Figure 2: Variation in the color of fruit pulp of *C. moschata*. The sections correspond to the middle part of fruits, cut in transverse and in a similar state of ripeness. Personal archive.

The consumption of *C. moschata* fruits supplies to human nutrition a series of essential components, besides important bioactive compounds. The fruit pulp of *C. moschata* has high levels of minerals such as K (42194. 000 mg/kg), Calcium (6684.85 mg/kg), P (3040.48 mg/kg), Mg (1590.40 mg/kg), and Cu (8.44 mg/kg) [9]. This makes it an excellent source of these nutrients, having, in a portion of 100 grams of pulp, 20% more than the daily intake recommended for them. Distinctly, *C. moschata* expresses high levels of carotenoids in the fruit pulp, making it an important source of these components [10-12]. Additionally, the fruit pulp of *C. moschata* represents an excellent source of antioxidant components such as phenolic compounds and flavonoids [20,21].

A study of [11] showed that β and α-carotene, important precursors of Vitamin A, consisted of the main carotenes in the fruit pulp of *C. moschata*, corresponding to the largest proportion of the total carotenoid content. So far, this vegetable is one of the best sources of carotenoids such as β-carotene, with levels higher than those reported for other carotenogenic vegetables such as carrots [10]. In this regard, it should be pointed out that the pro-vitamin A activity of carotenoids is conditioned by the presence, in their structures, of ring forms known as β-ionone, and by the presence of polyene chains. With two β-ionone rings and a polyene chain, β-carotene, has the highest pro-vitamin A activity, compared to other carotenoids with only one β-ionone ring, such as α-carotene and β-cryptoxanthin [22,23].

Associated to its importance in human nutrition, the cultivation of *C. moschata* is commonly based on the use of low technological level, which, together with other aspects, has fostered the adoption of this species as a strategic crop in biofortification programs aiming to circumvent nutritional deficiencies such as vitamin A deficiency. *C. moschata* assemble aspects that are essential in a biofortification program such as high production potentials and profitability, high efficiency in reducing micronutrient deficiencies in humans and good acceptability by producers and consumers in the growing regions [24]. As an example *C. moschata* has been considered a crop strategic for the Brazilian Biofortification Program (BioFORT), led by the Brazilian Enterprise of Agricultural Research (Embrapa), aiming biofortification in precursors of vitamin A [25].

NUTRITIONAL ASPECTS OF SEED OIL OF *C. MOSCHATA*

The use of the seeds and seed oil of *C. moschata* in human feeding is a promising aspect of the production of this vegetable. According to [13] *C. moschata* seeds have protein content equivalent to 30% of their composition and lipid content close to 49%. The profile of fatty acid of *C. moschata* seed oil consists of about 70% of unsaturated fatty acids and a high content of monounsaturated fatty acids such as oleic C18: 1 (Δ 9) [26, 27]. In this sense, there is, from the part of health specialists, an incentive to the consumption of unsaturated fatty acids instead of saturated, based on the consensus that this reduces the risk of cardiovascular diseases [28-30]. Associated with this, studies show that the seed oil of *C. moschata* is rich in bioactive components such as vitamin E and carotenoids [14] important antioxidants in human feeding.

Plant breeding programs targeting the quality improvement in different oilseed species commonly focus on increasing the oxidative stability of the oil, which is determined by the balance of fatty acids [31]. Compared to other fatty acids, oleic acid has greater oxidative stability since it has only one unsaturation with this, breeding program commonly prioritize the increasing of oleic content [32].

As an example of breeding programs, the Federal University of Viçosa (UFV) has been developing a breeding program aiming the improvement of fatty acid profile and seed oil productivity of *C. moschata*. In the initial stage of the program, [27] assed the fatty acid profile of seed oil of 54 accessions of *C. moschata* maintained at the UFV Vegetable Germplasm Bank (BGH-UFV). This author reported the observation of high variability for characteristics such as the seed mass/fruit mass ratio, and for the number and mass of seeds per fruit, characteristics positively correlated with the production of seed oil in *C. moschata*. This author also reported the observation of variability in the composition of the fatty acid profile between the accessions and the identification of the accessions BGH-7765, BGH-4615 and BGH-7319 as those most promising for the production of seed oil, as they expressed greater oleic acid content and lower linoleic acid content. In this same line, when evaluating accessions of *C. moschata* maintained at BGH-UFV [33] he reported even higher variability for the seed mass/fruit mass ratio, and for the number and mass of seeds per fruits.

As mentioned previously, *C. moschata* commonly expresses vigorous growth, which difficult the adoption of lower spacing between plants during cultivation, consisting of a limiting aspect for obtaining higher yields of seeds and seed oil in this crop. With this, the breeding program of *C. moschata* carried in the UFV has, successfully, emphasized the achievement of more compact genotypes. This has been done based on the transfer of alleles related to a compact growth habit to genotypes of *C. moschata* with potential for the production of seed oil [34,35]. It should be mentioned that the seeds of *C. moschata* in most cases are still discarded during the consumption of this vegetable in Brazil; with this, the use of seeds of this vegetable can provide an improvement in human nutrition, in addition to increasing the income of those involved in its production.

CONCLUSION

C. moschata is a vegetable of high socioeconomic importance, especially due to the nutritional aspects of its fruits and seed oil. Associated with this, this vegetable commonly expresses high genetic variability, facilitating the identification of genotypes with superior nutritional aspects.

The pulp of *C. moschata* fruits expresses high levels of carotenoids, making it an important source of carotenoids in human feeding, in addition to being an excellent source of antioxidant components such as phenolic compounds and flavonoids. The use of *C. moschata* seed oil in human feeding is a promising aspect in terms of nutrition due to its high content of unsaturated and monounsaturated fatty acids, associated with the presence of antioxidant components. *C. moschata* is an important crop in human nutrition and in promoting food security where it is grown, especially in less developed regions.

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