Available online: www.notulaebotanicae.ro
Print ISSN 0255-965X; Electronic 1842-4309
Not Bot Horti Agrobo, 2019, 47(3):813-820. DOI:10.15835/nbha47311552
Original Article
AcademicPres
Notulae Botanicae Horti Agrobotanici Cluj-Napoca

# Physicochemical Quality, Antioxidant Capacity and Nutritional Value in Tuberous Roots of Some Wild Dahlia Species

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**Abstract**

The aim of this research was to evaluate the physicochemical quality, antioxidant capacity and nutritional value in tuberous roots of some wild dahlia species. The experiment was carried out in the Department of Plant Science of the Autonomous University Chapingo, Mexico. Plants were established in a randomized complete block design with five replications. The total soluble solids (TSS), titratable acidity (TA), vitamin C (VC), total phenols (TP), antioxidant capacity (AC), inulin and its proximate composition were evaluated. Among the materials analyzed, the most outstanding wild species were *Dahlia campanulata*, *D. coccinea* and *D. brevis*, where *D. campanulata* stood out for its concentration of VC (0.05 mg 100 $g^{-1}$), AC (1.88 mg VCEAC $g^{-1}$), inulin, DM and TC (72.25, 24.38 and 88.37%, respectively), however, the inulin content was similar to *D. coccinea* (66.17%), which was also outstanding with respect to the content of TP (1.74 mg GA $g^{-1}$). Likewise, *D. brevis* presented the highest values of RFi (5.49%) and A (78.42%). According to our results, the tuberous roots of wild dahlia species can be used as food, as well as being a source of selection of traits of nutraceutic interest for genetic improvement.

***Keywords:*** *Dahlia* sp.; edible tuber; fiber crude; nutraceutical and functional food; inulin content

***Abbreviations:*** TSS: total soluble solids; TA: titratable acidity; VC: Vitamin C; TP: total phenols; AC: antioxidant capacity; M: Moisture; DM: Dry matter; RP: Raw protein; RF: Raw fat; RFi: Raw fiber; TC: total carbohydrate; A: Ashes; HSMD: honest significant minimum difference; GA: gallic acid; VCEAC: Vitamin C equivalent antioxidant capacity

## Introduction

The *Dahlia* genus (Asteraceae) is composed of 37 species and Mexico is the center of origin and domestication of most of them (Castro *et al.*, 2015), and among the ornamental plants (cut flower, pot and as a structural element in the design and construction of gardens), are the most widely distributed worldwide with approximately 20,000 varieties (Arenas *et al.*, 2011, Jiménez, 2015), however, studies indicate that in the prehispanic era the tuberous roots of this plant were consumed as a source of carbohydrates, that is, as an equivalent of potatoes (*Solanum tuberosum* L.) (Santana *et al.*, 2016).

At present, the general consumption of food products with high caloric value and poor nutritional contribution, has increased the incidence of cardiovascular, neurodegenerative, chronic diseases and some cancer types (Das *et al.*, 2012; Lara *et al.*, 2014; Ciobanu *et al.*, 2016), however, a "boom" has also been generated in the search and analysis of natural foods with outstanding characteristics, from the nutritional point of view and health care (bioactive compounds) (Shahidi and Zhong, 2010; Doporto *et al.*, 2011; Rodríguez *et al.*, 2017; Frias *et al.*, 2019), and an alternative source of these compounds is found in wild plants (Pinela *et al.*, 2017). Fossil remains indicate the nutritional and medicinal use of diverse vegetal organs of wild plants (Vandoorne *et al.*, 2012), and in the particular case of the roots and underground storage organs, are no exception, being rich in polysaccharides and others

*Received: 06 May 2019. Received in revised form: 28 May 2019. Accepted: 29 May 2019. Published online: 31 May 2019.*

compounds (minerals, vitamins, phenolic compounds, proteins, fiber, among others) with a possible antioxidant effect (Zaldariene *et al*., 2012; Chandrasekara and Kumar, 2016).

Among the important components of the tuberous roots of the dahlia is inulin (Arenas *et al*., 2011; Ciobanu *et al*., 2016), a storage carbohydrate that has a wide nutritional and pharmaceutical importance (Melanie *et al*., 2015), due to its prebiotic activity, and constitutes an effective support treatment for acute and chronic intestinal disorders (Nsabimana and Jiang, 2011), also improves the bioavailability of calcium and magnesium, with promising evidence in the reduction of cancer risk, reinforcement of the immune response and protection against intestinal disorders, has a low caloric value, decreases the risk of high concentrations of triglycerides, in addition to favoring the development of beneficial bacteria in the colon (Santana *et al*., 2016; Başaran *et al*., 2017). It is for all the above, that the objective of the present investigation was to evaluate the physicochemical quality, antioxidant capacity and nutritional value in tuberous roots of some wild dahlia species (*Dahlia* spp.).

## Materials and Methods

### *Plant material and location of the experiment*

In this experiment, tuberous dahlia roots were used that were obtained from the species (*Dahlia brevis, D. merckii, D. coccinea* and *D. campanulata*) (wild) and cultivated (*D. x hortorum*), which were cultivated during the April-December 2016 in the Experimental Agricultural Field "San Martin" of the Autonomous University Chapingo, Mexico (19° 29′ 23", 98° 53′ 37" W and at 2 246 meters above sea level (masl)) with average annual temperature and precipitation of 18.9 °C and 619.3 mm, respectively. The analyzes of the plant material were carried out during the months of January-June 2017 in the Laboratory of Multiple Uses and Physiology of Fruit Trees of the Department of Plant Science of the Autonomous University Chapingo. On the other hand, among the most outstanding physical and chemical characteristics of the soil are: pH (7.48), electrical conductivity (0.73 dS $m^{-1}$), cation exchange capacity (24.4 cmol $kg^{-1}$), bulk density (1.29 g $cm^{-3}$) and clay-loam texture.

### *Crop management*

To multiply and obtain the plant material, it started in March 2016 with the greenhouse planting of the tuberous roots obtained from the previous cycle in boxes with peat (peat moss), whose buds emerged after 15 days. The field transplant was carried out in the month of April 2016, where the distance between plants and rows was 0.6 and 1 m, respectively. The supply of water and nutrients, was carried out by a drip irrigation system of 1-2 times per week with an expense of 0.5-3.5 L $plant^{-1}$, depending on the climatic conditions (environmental temperature and relative humidity) and phenological stages of the crop. The fertilization was carried out based on a previous analysis of soil fertility and the general formula of fertilization 120-0-200, which was split into two applications (the transplant and before the beginning of flowering). Weed control and some crop management practices such as hilling were carried out manually. At the time the plants stopped their growth and defoliation appeared (December), it is preceded with the harvest of the tuberous roots.

### *Experimental design*

They were established with an experimental design of randomized complete block with five replications where the experimental unit consisted of 14 plants (7.2 $m^2$). For laboratory analyzes, 500 g of tuberous roots of each species were taken as an experimental unit with five replications, where the content of total soluble solids, vitamin C, titratable acidity, antioxidant capacity, inulin content, as well as the proximal composition were evaluated (moisture, dry matter, crude protein, crude fat, crude fiber, total carbohydrates and ashes).

### *Parameters evaluated*

#### *Total soluble solids (TSS)*

The measurement of TSS was performed according to the methodology of the AOAC (2000). A PAL-1 manual digital refractometer (ATAGO®, Japan) was used, for which a drop of a tuberous root portion was extracted through a polypropylene mesh of 17 threads per $inch^2$ to avoid the passage of solid material, which it was deposited in the prism of the refractometer sampling area and the reading was obtained, then the sampling area was washed with distilled water and the next measurement was carried out. The results were expressed in °Brix.

#### *Titrable acidity (TA)*

Its determination was made according to the methodology of the AOAC (2000), for which 2 g of sample were weighed and homogenized with 10 mL of distilled water, later it was filtered with a polypropylene mesh and the final volume was determined, then a 5 mL aliquot was taken and a 1% phenolphthalein drop was added as indicator, neutralized with 0.1 N sodium hydroxide (NAOH). The results are expressed as a percentage of citric acid.

#### *Vitamin C (VC)*

It was carried out by the method described by Jagota and Dani (1982), with slight modifications. To 0.3 g of sample was added 5 mL of 10% trichloroacetic acid, then homogenized and agitated vigorously for 5 min in cold (ice), proceeded to centrifuge for 20 min at 20 000 rpm at 5 °C. Subsequently, an aliquot of 200 μL of the supernatant of each sample was taken, and 1.8 mL of bidistilled water and 200 μL of the 10% Folin-Ciocalteu reagent (v:v) were added. The mixture was vigorously stirred for 15 seconds and allowed to stand for 10 min, to subsequently perform the absorbance reading at 760 nm using the Genesys 10-S™ spectrophotometer (Thermo scientific, USA). The concentration was expressed in mg 100 $g^{-1}$, by calibrating a standard curve of ascorbic acid.

#### *Total phenols (TP)*

The determination of total phenols was carried out using the Folin-Ciocalteu method described by Waterman and Mole (1994), for which 0.5 g of sample was taken, adding 5 mL of 70% absolute ethyl alcohol (v:v), where 150 μL of this extract was taken, to which 850 μL of distilled water and 500 μL of the Folin-Ciocalteu reagent (2N) were added, the mixture was stirred and left to rest for 8 min. Subsequently, 1.5 mL of 20% $Na_2CO_3$ (w:v) was added, stirred and allowed to stand for 2 h under conditions of total darkness at room temperature (22 ± 1 °C). The absorbance value (760 nm) of the mixture was taken with a Genesys 10-S™ spectrophotometer (Thermo scientific, USA). The concentration was expressed as mg of gallic acid $g^{-1}$.

*Antioxidant capacity (AC)*

The determination of this variable was carried out according to the ABTS method (2,2'azinobis (3-ethylbenzthiazolin-6-sulfonic acid) modified by Ozgen *et al.* (2006), for which the radical $ABTS^{\bullet+}$ was formed after the reaction of ABTS (7 mM) with potassium persulfate (2.45 mM, final concentration) incubated at room temperature and in darkness for 16 h after the radical $ABTS^{\bullet+}$ was formed it was diluted with PBS (buffer solution of phosphate) (pH 7.4) until obtaining an absorbance value of 0.7 ± 0.1 at 734 nm (maximum absorption length) On the other hand, 0.5 g of sample were taken to which 5 mL of 70% absolute ethyl alcohol (v:v) was added, the sample was homogenized and left to stand for 24 hours. For the test, 100 μL of the extract of the sample and 3.9 ml of the $ABTS^{\bullet+}$ solution were mixed, resting for 2 h under conditions of total darkness, the absorbance reading at 734 nm was performed by the Genesys 10-S™ spectrophotometer (Thermo scientific, USA). The results are expressed as Vitamin C equivalent antioxidant capacity (mg VCEAC $g^{-1}$).

*Inulin*

The quantification of its content was carried out according to the methodology proposed by Anan'ina *et al.* (2009). The plant material (tuberous roots) were washed and cut into 1 cm fragments, which were dehydrated at 60 °C until constant weight was obtained, ground and stored for evaluation. For the test, 0.1 g of powdered sample was taken and 100 mL of distilled water was added, this mixture was kept in a water bath for 30 min and then kept at room temperature (22 ± 2 °C). A 1 mL was then extracted, to which 24 mL of 5% hydrochloric acid (v:v) was added, this mixture was placed in a water bath for 2.5 h. At the end of this period, it was kept under ambient temperature conditions. Each sample was assayed at 25 mL al with 5% hydrochloric acid (v:v), and the absorbance value was recorded at 285 nm using the Genesys 10-S™ spectrophotometer (Thermo Scientific, USA). The calculation of the inulin concentration was made by applying the following formula:

$$X = \frac{D \times 100 \times 25}{298 \times m \times l}$$

where X is the inulin content expressed as % fructose; D is the optical density of the test solution (λ= 285 nm); 298 corresponds to the specific rate of absorption of the fructose transformation product after acid hydrolysis; m is the weight of the sample (g).

*Proximate composition*

The proximate composition analysis was carried out using the methodology described by the AOAC (2000). The data is reported as % on dry weight basis.

*Statistical analysis*

An analysis of variance and a multiple comparison of Tukey's means ($P \leq 0.05$) were applied to the data obtained. Subsequently, a correlation analysis was carried out in order to determine the degree of association between the variables of TSS, TA, VC, AC and inulin, for which a matrix was constructed where the correlation coefficient of each variable was used. For all analyzes the statistical analysis package SAS (Statistical Analysis System) ver. 9.1 (SAS, 2003) was used.

**Results and Discussion**

*Physicochemical quality*

The results of the analysis of the physicochemical quality of the fruit are shown in Tables 1 and 2. The TSS content is an indicator of quality and can be used to define the appropriate time of harvest, as well as determining the flavor of the product and plays an important role in the maturation process (Frias *et al.*, 2019). Among the dahlia species analyzed, the highest TSS content was presented in *D. campanulata* (9.11 °Brix) with respect to *D. brevis* (4.98 °Brix), however, it did not statistically exceed *D. merckii, D. coccinea,* including the cultivated species *D. x hortorum* (Table1). What was shown by *D. brevis, D. merckii, D. coccinea* and *D. x hortorum* was similar to that reported by Vizzotto *et al.* (2017) in advanced selections (ILS 24, ILS 44, ILS 71) and the variety 'Beauregard' of sweet potato (*Ipomoea batatas (*L.*) Lam*) with values of 7.30, 7.60, 7.43 and 10.03 °Brix, respectively. Similarly, they were similar with the data mentioned by Scher *et al.* (2009) and Alles *et al.* (2015) in yacon (*Smallanthus sonchifolius*) (9.9 ± 0.01 and 8.5 ± 0.01 °Brix, respectively).

The accumulation of citric acid expressed as percentage of TA varied between 0.17 and 0.31, where this last value corresponds to the wild species *D. brevis*, which are lower than those indicated for *Smallanthus sonchifolius* by Scher *et al.* (2009). They also surpassed what was indicated by Vizzotto *et al.* (2017) for 12 genotypes (advanced selections and varieties) of sweet potato (*Ipomoea batatas*) with percentages between 0.12-0.18 of citric acid. On the other hand, Mussury *et al.* (2013) when evaluating periods of storage with different temperatures and packing for tuberous roots of ahipa (*Pachyrhizus ahipa*) they indicate an average value of 0.22% of citric acid, however, they also point out that the lowest values were observed when the material was unpacked and at room temperature, which can be associated with a decrease in the total concentration of organic acids due to the effect of ambient temperature, as indicated by Vizzotto *et al.* (2017).

Among the dahlia species analyzed, the wild species *D. campanulata* had the highest value of VC (0.05 mg 100 $g^{-1}$). A study conducted by Rautenbach *et al.* (2010) in four varieties of sweet potatoes grown with different irrigation

Table 1. Mean values of the content of total soluble solids, titratable acidity and vitamin C of tuberous roots of some wild varieties of dahlia

| Species | Total soluble solids (°Brix) | Titratable acidity (% citric acid) | Vitamin C (mg 100 $g^{-1}$) |
|---|---|---|---|
| *D. brevis* | 4.98 b | 0.31 a | 0.03 c |
| *D. merckii* | 7.92 a | 0.18 c | 0.03 b |
| *D. coccinea* | 8.12 a | 0.17 c | 0.02 c |
| *D. campanulata* | 9.11 a | 0.21 bc | 0.05 a |
| *D. x hortorum* | 7.80 a | 0.25 b | 0.02 c |
| HSMD | 1.74 | 0.05 | 0.01 |

Note: Values with the same letter within the column are statistically the same according to the Tukey's test ($P \leq 0.05$). HSMD: honest significant minimum difference.

Table 2. Concentration of total phenols, inulin and antioxidant capacity of tuberous roots of some wild varieties of dahlia

| Species | Total phenols (mg GA $g^{-1}$) | Antioxidant capacity (mg VCEAC $g^{-1}$) | Inulin (%) |
|---|---|---|---|
| *D. brevis* | 0.99 c | 0.72 c | 55.00 c |
| *D. merckii* | 0.60 d | 0.62 c | 59.36 bc |
| *D. coccinea* | 1.74 a | 0.83 b | 66.17 ab |
| *D. campanulata* | 1.06 c | 1.88 a | 72.25 a |
| *D. x hortorum* | 1.40 b | 0.91 b | 57.95 bc |
| HSMD | 0.30 | 0.11 | 8.68 |

Note: Values with the same letter within the column are statistically the same according to the Tukey's test ($P \leq 0.05$). HSMD: honest significant minimum difference.

regimes (30, 60 and 100%), indicate a positive relationship between the concentration of vitamin C and the irrigation regime used, with values ranging from 15.5 to 32.2 mg/100 g. Barrera and Picha (2014) when determining the concentration of ascorbic acid in buds, branches, petioles, young and mature leaves as well as in roots, found that the highest values of this compound were for young leaves (121 mg/100 g) with respect to roots (15.9 mg/100 g), behavior linked to the role played by ascorbic acid to eliminate free radicals generated in a highly oxidative environment during the process of photosynthesis (Sreeramulu and Raghunath, 2010). Likewise, the concentration of vitamin C in plants varies depending on the genotype, organ sampled and edaphoclimatic conditions of development (Grace *et al.*, 2014), without forgetting that it is one of the main non-enzymatic antioxidant compounds since in association with other components of the antioxidant system protects and regulates oxidative damage resulting from metabolism and presence of pollutants (ozone, heavy metals and salt stress) (Mazid *et al.*, 2011; Akram *et al.*, 2017).

Another very important component within the bioactive compounds are the phenolic compounds, and in this work was found variation ($P \leq 0.05$), whose values fluctuated between 0.60 and 1.74 mg $g^{-1}$ where *D. coccinea* stands out with the highest value, followed by the species cultivated *D.* × *hortorum* with 1.40 mg $g^{-1}$. These results were lower than those reported by Sreeramulu and Raghunath (2010) in various crops such as cassava (*Manihot esculenta*) (137.55 ± 6.04 mg GA 100 $g^{-1}$), beet (*Beta vulgaris*) (169.41 ± 40.19 mg GA 100 $g^{-1}$), sweet potato (*Ipomoea batatas*) (53.70 ± 3.44 mg GA 100 $g^{-1}$) and potato (*Solanum tuberosum*) (38.42 ± 0.62 mg GA 100 $g^{-1}$). In previous studies conducted in yacon (*Smallanthus sonchifolius*) from Bolivia, Ecuador, New Zealand and Germany by Lachman *et al.* (2007) reported a content of total phenols between 5 and 12 g $kg^{-1}$, however, this data was lower than what was observed by these same authors in the rhizomes of this plant. On the other hand, great variability is also reported in the content of total phenols determined in roots and underground botanical structures of other crops such as potatoes (*Solanum tuberosum*) (Teow *et al.*, 2007), ahipa (*Pachyrhizus ahipa*) (Dini *et al.*, 2013) and olive (*Olea europea* L.) (Petridis *et al.*, 2012), which could be explained by the stress caused by environmental factors (salinity, humidity, temperature changes as well as the attack of pests and diseases) to which the roots are subjected (Shahidi and Zhong, 2010; Petridis *et al.*, 2012).

The high incidence of cardiovascular, neurodegenerative, chronic diseases and some cancer types (Ciobanu *et al.*, 2016) increases the need to consume horticultural products with functional attributes that contribute to maintaining human health (Sreeramulu and Raghunath, 2010). In this study, it was found that the tuberous roots of the wild species *D. campanulata* showed significant statistical differences with respect to the AC (1.88 mg VCEAC $g^{-1}$), followed by *D. coccinea* and *D.* × *hortorum* with 0.83 and 0.91 VCEAC $g^{-1}$, respectively. These results are lower than those observed by Floegel *et al.* (2011) in potato (41.4 mg VCEAC 100 $g^{-1}$) and by Sreeramulu and Raghunath (2010) in carrot (*Daucus carota* L.), beet (*Beta vulgaris* L.) and cassava (*Manihot esculenta*). In this sense, Das *et al.* (2012) point out that the presence of antioxidant vitamins (vitamin C) and various secondary metabolites such as polyphenolic compounds (flavonols, flavones, flavonone and anthocyanins) can inhibit or reduce the oxidative stress generated by photosynthesis and reactive oxygen species (Frias *et al.*, 2019). Additionally, the ability of antioxidants to act on oxidative compounds may vary due to crop management conditions (water deficit, salinity and soil conditions), climatic factors (temperature and relative humidity), genetic factors such as variety and phenological status of the crop (Galani *et al.*, 2017), without ignoring the evaluation method, as well as, can be influenced by the extraction conditions: solid-solvent ratio, time, pH, temperature and type of solvent (Floegel *et al*., 2011; Rodríguez *et al*., 2017).

A common characteristic among tuberous roots is the presence of reserve carbohydrates (glucose, galactose, sucrose and fructose) (Jiménez, 2015), however, the dahlia plant has between 38 and 53% inulin (fructosans) at its roots, that among its qualities it is found that it does not contribute to the increase of glucose levels in the blood, which makes its consumption very attractive in diabetic persons (Anan'ina *et al*., 2009; Arenas *et al*., 2011; Başaran *et al*., 2017). In this research, the wild species *D. campanulata* and *D. coccinea* presented the highest percentages of inulin (72.25 and 66.17, respectively), however, *D. coccinea* was similar to that observed in *D. merckii* (59.36%) and the *D.* × *hortorum* cultivated specie with 57.95%. In this regard, an interesting comparison is represented by the red chicory (*Cichorium intybus* (var. *sativum*), a plant cultivated in Eastern Europe and whose inulin content is about 80% of the dry weight of its roots, according to previous reports by Başaran *et al*. (2017) and Vandoorne *et al*. (2012) similar values (75-80 g/100 g) are reported by Khuenpet *et al*. (2017) for tuberous roots of Jerusalem artichoke (*Helianthus tuberosus*). However, Castro *et al*. (2013) indicate a content of 35 g 100 $g^{-1}$ in roots of yacon (*Smallanthus sonchifolius*), which is lower than the concentrations obtained in this work. The modification of pH (5 and 10) of the extraction medium can alter the inulin yield in dahlia, as indicated by Melanie *et al*. (2015) with values between 29.35 and 43.77%, respectively. Likewise, the inulin content in collections of wild dahlia (*Dahlia coccinea*) ranged between 23.9-42.5 g/100 g (Santana *et al*., 2016), however, when these plants were cultivated, their concentration increased significantly. These results suggest that the inulin concentration is associated with genetic, physiological and environmental factors (temperature and photoperiod) (Başaran *et al*., 2017), without considering the changes suffered by the root over time, due to the fact that as the roots get older, they accumulate reserves in the form of inulin and longer-chain fructans (Aduldecha *et al*., 2016).

*Proximal composition*

The values of the proximate composition are shown in Table 3. With 88.71% humidity, the wild species *D. brevis* was significantly the highest, followed by *D. merckii* and *D.* × *hortorum* (cultivated) (83.21 and 82.37%, respectively). In this regard, Nsabimana and Jiang (2011) when determining moisture content in cultivars of *D. pinnata* with yellow flower color ('HGH' and 'JJ'), white ('BJ' and 'LB') and red ('MLH' and 'XM') grown in Lanzhou (China), their values fluctuated between 83.36 and 86.49%, where 'MLH' was the most outstanding. Similar results are reported in yacon roots (*Smallanthus sonchifolius*) (69 to 83%) (Choque-Delgado *et al*., 2013) and beet (*Beta vulgaris*) (63.48 and 78.09%) (Pan *et al*., 2015). In contrast, plants such as cassava (*Manihot esculenta*) have lower values (63-65%) (Dini *et al*., 2012), which suggests that tuberous dahlia roots have a low content of dry matter and less storage time (Galani *et al*., 2017).

The dry matter content fluctuated between 11.29 and 24.38%, in which *D. campanulata* stood out significantly, followed by *D. coccinea* with 19.74%. Studies carried out on the chemical composition in tubers of 12 varieties of *Dioscorea* (*D. rotuntada* and *D. alata*) by Otegbayo *et al*. (2012), indicate contrasting values between 30.88 and 37.86% for *D. rotuntada* and from 19.54 to 29.34% in *D. alata*, the latter values being similar to what was observed in *D. campanulata* and *D. coccinea*. Likewise, lower values (11.2 and 13.7%) are reported in carrot (*Daucus carota* L.) by Bach *et al*. (2015).

On the other hand, as part of the proximate composition carried out in this study, an important parameter is related to protein, where the highest concentration was found in the wild species *D. merckii* (10.16%) and *D. coccinea* (9.52%), as well as the cultivated species *D.* × *hortorum* (10.14%), these values exceed what is indicated for different varieties of *D. pinnata* (2.85 to 5.16%) by Nsabimana and Jiang (2011), in the same way for 'Adu' and 'Berkume' (*Ipomoea batatas*) with percentages of 2.07 and 2.76, respectively (Mitiku and Abera, 2017). However, similar values between 7.9 ± 0.5 to 11.5 ± 1.2% are reported in other tuberous roots of plants native to southern America such as the ahipa (*Pachyrhizus ahipa*) (Dini *et al*., 2013).

In this study, the wild species *D. merckii and D. brevis* showed the highest concentration of crude fat (0.75 and 0.54%, respectively), which surpass those reported by Nsabimana and Jiang (2011) in *D. pinnata* (0.08 -0.39%), as well as that indicated by Doporto *et al*. (2011) in tuberous roots without epiphymis of ahipa (*Pachirhyzus ahipa*) with values between 0.25 ± 0.03 and 0.39 ± 0.01%, however, if it was similar to that observed in *D. coccinea* and *D. x hortorum* with 0.23 and 0.43%, respectively. The obtained results indicate that the consumption of tuberous roots of these wild species of dahlia, can be an alternative of healthy

Table 3. Proximate composition of tuberous roots of some wild varieties of dahlia

| Species | (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | M | DM | RP | RF | RFi | TC | A |
| *D. brevis* | 88.71 a | 11.29 d | 9.32 b | 0.54 ab | 5.49 a | 78.42 d | 6.23 a |
| *D. merckii* | 83.21 b | 16.79 c | 10.16 a | 0.75 a | 3.60 bc | 81.04 c | 4.44 b |
| *D. coccinea* | 80.26 c | 19.74 b | 9.52 ab | 0.23 c | 3.44 bc | 83.08 b | 3.73 bc |
| *D. campanulata* | 75.62 d | 24.38 a | 5.00 c | 0.49 b | 2.88 c | 88.37 a | 3.25 c |
| *D. x hortorum* | 82.37 b | 17.63 c | 10.14 a | 0.43 bc | 4.00 b | 81.10 c | 4.33 b |
| HSMD | 1.41 | 1.41 | 0.73 | 0.21 | 0.83 | 1.50 | 0.75 |

Note: M: Moisture; DM: Dry matter; RP: Raw protein; RF: Raw fat; RFi: Raw fiber; TC: total carbohydrates; A: Ashes. Values with the same letter within the column are statistically the same according to the Tukey's test (P ≤ 0.05). HSMD: honest significant minimum difference.

feeding, because their caloric contribution is low (Lara *et al*., 2014; Castro *et al*., 2015) and their fiber content, which improves digestibility in diabetic patients, reduces blood cholesterol and obesity (Anan'ina *et al*., 2009), as well as can help in the prevention of cardiovascular diseases and cancer (Başaran *et al*., 2017). In this sense, *D. brevis* was the one that showed the highest fiber content, which can surpass that reported in the varieties 'Albik', 'Rubik' and 'Sauliai' of Jerusalem artichoke (*Helianthus tuberosus* L.) by Zaldariene *et al*. (2012) with 4.10 ± 0.39, 4.28 ± 0.18 and 3.49 ± 0.02%, respectively. On the other hand, they do not surpass that reported in the varieties 'BJ' (7.51 ± 0.04%) and 'LB' (7.21 ± 0.02%) (*D. pinnata*) by Nsabimana and Jiang (2011), however, these same authors indicate for 'HGH', 'JJ' and 'XM' of the same species, a lower fiber content (between 4.05 and 5.06%), which suggests a strong interaction between the genotype and edaphoclimatic conditions during its cultivation (Santana *et al*., 2016; Grudzińska *et al*., 2016).

As observed in the data referring to carbohydrate content, *D. campanulata* was the one that showed statistical differences with 88.37%, where *D. brevis* was the lowest (78.42%). Similar percentages of carbohydrates (between 87.2 ± 0.3 and 92.03 ± 0.05) in ahipa (*Pachyrhizus ahipa*) are reported by Doporto *et al*. (2011), likewise Nsabimana and Jiang (2011) report 86.46 ± 0.02% for *D. pinnnata* 'HGH', however, these authors also indicate lower data (between 73.93 ± 0.02 and 81.81 ± 0.06%) in 'JJ', 'BJ', 'LB', 'MLH' and 'XM', respectively.

Among the wild species analyzed, *D. brevis* showed significant values with respect to the ash content with 6.23%, which was higher than that reported by Nsabimana and Jiang (2011) in *D. pinnata* (between 2.86 and 4.29%). Mitiku and Abera (2017) report in sweet potato (*Ipomoea batatas*) 'Adu' and 'Berkume' with 3.38 ± 0.01 and 5.32 ± 0.09% ash, respectively. However, lower ash% (2.53%) are reported in yacon (*Smallanthus sonchifolius*) by Choque-Delgado *et al*. (2013).

*Pearson's correlation*

According to the Pearson's correlation analysis (Table 4), a positive correlation can be observed between the content of TSS and AC (0.534), TSS and inulin (0.588), VC and AC (0.815), VC and inulin (0.543) and AC and inulin (0.681), while TSS and TA (-0.674) as well as TA and inulin (-0.425) showed a negative correlation. The observed positive correlation indicates a partial association between the analyzed variables of TSS, VC and AC, where with an increase in some of them, the value corresponding to AC and inulin, does so in a variable proportion. In this regard, Ciobanu *et al*. (2016) point out that inulin is the main reserve carbohydrate in the tuberous roots of dahlia, and that its accumulation contributes as energy source (solubilization of simple sugars) for the growth and development of new shoots of the next cycle. Likewise, it is well known that vitamin C is one of the most important hydrosoluble antioxidant vitamins that contributes to the blockage and elimination of prooxidant radicals as indicated by Frias *et al*. (2019). In this study, the content of TP did not present a significant correlation with AC, which contrasts with that reported by Galani *et al*. (2017) in roots of *Solanum tuberosum*, which can be attributed to the contribution of some non-phenolic compounds such as vitamins and minerals to antioxidant activity (Das *et al*., 2018; Grudzińska *et al*., 2016).

Table 4. Pearson correlation coefficients for physicochemical quality and inulin content variables in tuberous roots of some wild varieties of dahlia

| | TSS | TA | VC | TP | AC | Inulin (%) |
|---|---|---|---|---|---|---|
| TSS | 1 | -0.674** | 0.483* | 0.134 | 0.534** | 0.588** |
| TA | | 1 | -0.215 | -0.042 | -0.089 | -0.425* |
| VC | | | 1 | -0.390 | 0.815** | 0.543** |
| TP | | | | 1 | 0.093 | 0.144 |
| AC | | | | | 1 | 0.681** |
| Inulin | | | | | | 1 |

Note: TSS: Total soluble solids (°Brix); TA: Titratable acidity (% citric acid); VC: Vitamin C (mg 100 $g^{-1}$); TP: Total phenols (mg GA $g^{-1}$); AC: Antioxidant capacity (mg VCEAC $g^{-1}$). *, ** significant at 1 and 5% respectively.

## Conclusions

Among the genotypes analyzed, the wild species *D. campanulata* stands out for its concentration of VC, AC, inulin, DM and TC, however, the inulin content was similar to *D. coccinea*, which was also outstanding with respect to the content of TP. Likewise, *D. brevis* presented the highest values of RFi and A. These results position wild dahlia species as a good option to be used as nutraceutical food and contribute to health care, where similarly, the variability observed allows these species to be susceptible to be a source of selection of traits of nutraceutical interest for genetic improvement.

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