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RESEARCH ARTICLE

Effect of boiling on nutritional, antioxidant and physicochemical properties of edible plants (*Malva parviflora* and *Myrtillocactus geometrizans*)

Sandoval-Gallegos Eli Mireya[1], Arias-Rico José[2], Cruz-Cansino Nelly del Socorro[1], Deyanira Ojeda-Ramírez[3], Zafra-Rojas Quinatzin Yadira[1], Hernández-Ávila Juan[4], Ramírez-Moreno Esther[1]*

[1]Área Académica de Nutrición, Centro de Investigación Interdisciplinario, [2]Área Académica de Enfermería, Instituto de Ciencias de la Salud,Circuito Actopan-Tilcuautla s/n. Ex-hacienda La Concepción, 42160 San Agustín Tlaxiaca, Hidalgo, México, [3]Área Académica de Veterinaria, Instituto de Ciencias Agropecuarias, Instituto de Ciencias Agropecuarias, Rancho Universitario, Av. Universidad Km. 1 Ex-Hda. de Aquetzalpa AP 32, CP 43600, Tulancingo. Hidalgo, [4]Área Académica de Ciencias de la Tierra y Materiales, Instituto de Ciencias Básicas e Ingeniería, Ciudad del Conocimiento, Carretera Pachuca- Tulancingo Km. 4.5, Col. Carboneras, Mineral de la Reforma, Hgo

ABSTRACT

The aim of the present research was to determine the effect of boiling on nutritional composition, total phenolic compounds, antioxidant capacity, physicochemical and morphological characteristics of two edible plants *Malva parviflora* (mallow leaf) and *Myrtillocactus geometrizans* (garambullo flower). The plants had an important nutritional composition as carbohydrates (48-70 %), dietary fiber (36-42 %) and protein (13 %), as well as total phenolic compounds (468-750 mg GAE/100 g db) with a high antioxidant capacity. However, boiling originated the decrease of soluble compounds, carbohydrates, total phenolic compounds, antioxidant capacity and physicochemical properties. Plants changed to dark colors and physicochemical properties were affected, except to water retention capacity, oil retention capacity and viscosity, which had the same values in mallow leaves (raw and boiled), but increased water retention capacity in garambullo flowers, it may be by changes in the morphology observed. Therefore, is to suggest the raw consumption or with minimal cooking of these plants to avoid changes caused by thermal treatment.

Keywords: *Plants; antioxidants; boiling; nutrimental composition; physicochemical properties*

INTRODUCTION

Mexico is distinguished for having a great regional biological diversity of plants. There are about of 25,000 to 30,000 species, which 7,461 are registered, and 2,168 are considered edible species (Mapes and Basurto, 2016), from example: *Erythrina americana, Yucca filifera, Chenopodium* spp., *Suaeda torreyana, Portulaca oleracea, Porophyllum* spp., *Agave salmiana*, *Amaranthus hybridus* L., *Malva parviflora, Myrtillocactus geometrizans,* among others. These plants have an important role in complementing population diet with great impact on health due to they provide dietary fiber, vitamins, minerals and antioxidant compounds (Cilia López et al., 2015; Kibar and Kibar, 2017; Pinela et al., 2017).

The structural matrix of plants mainly formed of dietary fiber (soluble and insoluble fiber) determine the physicochemical characteristics and therefore healthy properties after being consumed (Ahmed et al., 2011; Lattimer and Haub, 2010; Dhingra et al., 2012; Deepak and Sheweta, 2019). When the food is subjected to several thermal treatments (boiling, fraying, dry, blanched, among others), several changes are carried out with the disruption of the food matrix (composed mostly of dietary fiber). The rheological properties of the cooked vegetables are dependent on the cellular disruption and the ability of fibers to absorb and hold water (Waldron, Parker, and Smith, 2003; Vetter and Kunzek, 2002). The interaction of water with fibers such as pectin, β-glucan or gums with high molecular weight causes a high viscosity in the food, which may exhibit a positive action on the glycemic response, cholesterol and lipids (Guillon and Champ, 2000; Vetter and Kunzek, 2002). The free diffusion of water and low molecular weight compounds that could be in the matrix

***Corresponding author:**
Esther Ramírez Moreno, Centro de Investigación Multidisciplinario Área Académica de Nutrición Instituto de Ciencias de la Salud (ICSa) Universidad Autónoma del Estado de Hidalgo Circuito Actopan-Tilcuautla s/n. Ex hacienda La Concepción. San Agustín Tlaxiaca. C.P. 42160 Pachuca, Hidalgo, México. **Tel.:** 771 7172000 ext. 4316. **E-mail:** esther_ramirez@uaeh.edu.mx

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(Southon and Faulks, 2002) will influence the color, texture, flavor and nutritional value of cooked vegetables in different ways. The release of compounds of the food matrix (as sugar molecules by hydrolysis of complex glycosidic chains, fat, protein molecules, minerals and bioactive compounds) are leaching into the boiling water (Nafir et al., 1992; Traoré et al., 2017; Okibe et al., 2015; Ikanone and Oyekan 2014; D. T. and Crosby, 2016). In addition, other reactions could take place in the food during thermic treatment, as the formation of complexes between fiber and other released compounds of the food (Takeyama, Yokokawa and Tanimura, 1996), reactions of degradation (oxidation of vitamin C), diminution of antinutritional compounds (oxalic acid, phytic acid), and therefore, the increasing of the bioavailability of some nutrients by their transformation into more active molecular structures (Southon and Faulks, 2002).

There are limited studies on the effect of cooking on many edible wild leaves and flowers of high consumption in mexican gastronomy. Finding only research on changes of the cooked edible plants as *Chenopodium* spp., *Suaeda torreyana, Portulaca oleracea and Porophyllum* spp. (Arias-Rico et al., 2020), and reports forms of consumption of flowers such as squash blossoms, flowers as coral trees and yucca, mexican marigolds, dahlias, cactus flowers, among others (Mulík and Ozuna, 2020). Few studies cover the importance of the changes in the thermic treatment in edible plants as mallow leaves, while in garambullo flowers the research have been on phytochemicals and antioxidants properties (Abdalla and el-Aal, 2016; Singh, 2017; Pinedo-Espinoza et al., 2020). However, there is a lack of studies to be carried out that complement the information in both plants.

For this reason, the purpose of study was to determine the effect of boiling on nutritional composition, total phenolic compounds, antioxidant capacity, physicochemical and morphological characteristics of two edible plants *Malva parviflora* (mallow leaf) and *Myrtillocactus geometrizans* (garambullo flower).

MATERIALS AND METHODS

Plant materials and sample preparation

Fresh plants mallow leaves (*Malva parviflora*) and garambullo flowers (*Myrtillocactus geometrizans*) were purchased from the local market in Pachuca, Hidalgo, Mexico during the period January to June 2019. The general characteristics of the studied plants were described in Table 1. The samples were manually cleaned with distilled water and chopped. Then, the non-edible portions in both samples were discarded. An edible part of these plants (leaves and stems) was maintained in raw and another part was boiled. Boiling conditions were performed by preliminary experiments carried out for each vegetable, considering the minimum cooking time to reach similar softness, palatability, and taste according to the Mexican consumption habits. Each plant batch was divided into three parts to have at least three repetitions in the experiments. A total of 10 g of plant was chopped and boiled in a beaker with 100 mL of distilled water (relation 1:10 food/water) (Figure 1) to complete the cooking (around 90 seconds). The boiling water was drained off for 60 s. Raw and cooked plants were freeze-dried (Freeze dryer VWR26671-581 Labconco, USA), ground to 500 mm mesh, and stored at -20 ◦C in black bags for further analysis. All determinations of proximal analysis, antioxidant, and physicochemical properties were performed in lyophilized samples at least in triplicate. Results of processed samples have been corrected considering a factor that takes into account the soluble solids' loss due to changes of moisture after processing.

Chemical analysis

Proximate analysis

Samples were analyzed using AOAC methods (Latimer, 2012): moisture (method 925.09), protein (method

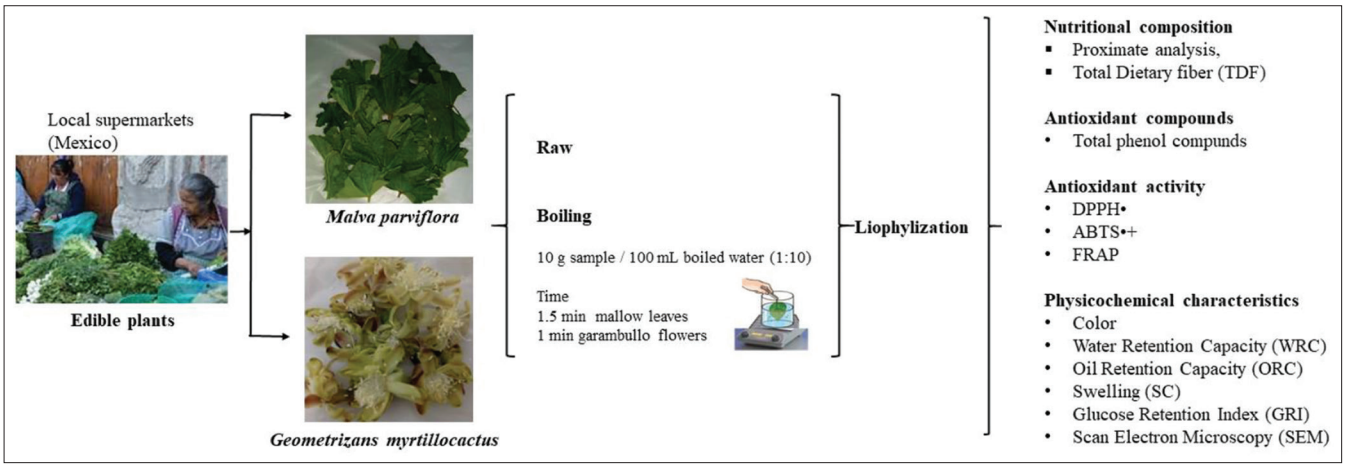

Figure 1. Graphical abstract methodology.

Table 1: Botanical characteristics and thermal treatment conditions of studied plants.

Plants photographs	Plants name	Edible parts
	*Scientific name: Malva parviflora L.* Common name: Spanish: Malva; English: Mallow Is an herbaceous plant, 50 to 70 cm high, reniform, wavy leaves; light lilac flowers; fruit of a squat appearance, blooms from July to September. It is found as ruderal and weeds (Villavicencio-Nieto and Pérez-Escandón, 2006).	Leaves and stems
	*Scientific name: Myrtillocactus geometrizans:* Common name Spanish: gflor de garambullo; English: garambullo flower Flower of Myrtillocactus geometrizans: The flower of garambullo grows at the top of the arborescent, erect cacti. The flowers of garambullo are planned in the areolas, have a white corolla (Muñoz Zurita, 2012).	flowers

950.48), fat (method 983.23) and ash (method 930.05) Finally, carbohydrates were calculated by difference of the proximate parameters. The results were expressed as grams per 100 grams of dried basis (g/100 g db) according with the following formula:

Total Carbohydrates=(100[moisture+protein+lipids+ash]

Total dietary fiber

Total dietary fiber (TDF), soluble (SDF) and insoluble (IDF) dietary fiber were analyzed according to AOAC (Latimer, 2012), with an enzymatic–gravimetric method using a Total Dietary Fiber Assay Kit (Sigma TDF-100A Kit, Sigma-Aldrich). All the results were expressed as grams per 100 grams of dried basis (g/100 g db).

Antioxidant capacity

Antioxidant compounds extraction

The extraction of antioxidants from dried plants was performed in two extraction cycles with aqueous-organic solvents with different polarities (Saura-Calixto et al., 2007). 250 mg of sample with 10 mL of methanol:water (50:50, v/v) was stirred during 1 h and centrifuged (3000 *g*, 15 min) (Allegra 25R ™, Beckman Coulter, CA, USA), then the supernatant was transferred to a volumetric flask of 25 mL. The pellet was re-extracted with 10 mL of acetone:water (70:30, v/v) and centrifuged again. Then, the combination of both supernatants was carried out and the flask was graduated to 25 mL using previously prepared solutions of methanol and acetone (50:50, v/v). The extract was used to determine total phenolic content and antioxidant capacity.

Total phenolic content was performed according to the Folin-Ciocalteu procedure (Montreau, 1972; Singleton et al., 1999). Gallic acid was used as a reference standard, and the results expressed as milligrams of gallic acid equivalents per 100 g of dry basis (mg GAE/100 g db).

The antioxidant activity was evaluated by radical scavenging assays: DPPH$^{\bullet}$ (Brand-Williams et al., 1995 and described by Morales and Jiménez-Pérez (2001) and ABTS$^{\bullet+}$. (Re et al., 1999 and described by Kuskoski et al., 2005). In both determinations Trolox was used as a standard and the results were expressed as micromol of trolox equivalents per 100 g of dried basis (μmol TE/100 g db).

FRAP ferric reducing antioxidant power was accomplished according to the methodological process described by Benzie and Strain, (1996) and referred methodology by Gulcin et al., (2003). Ferrous sulfate was used as standard and the result was expressed as micromoles of Fe (II) per 100 g of dried basis [μmol Fe (II)/100 g db].

Physicochemical analysis

Color

The color parameters were measured with a Minolta CR300 Japan colorimeter using a CIELab system on the basis of CIE *L* (luminosity)*, *a* (redness)* and *b* (yelloness)* values. Also, Hue angle [h°= tg-1(b/a)] and chroma [C= ($a^{*2} + b^{*2}$) ½)] parameters (Janin et al., 2001) were calculated.

Functional properties

The water retention (WRC) and swelling (SC) capacity were analyzed according to Robertson et al., (2000) methodology. The results of WRC were expressed as g/g, while SC was defined as mL/g db.

The oil retention capacity (ORC) was determined under the methodology of Garau et al., (2007). ORC was expressed as oil retained by 1 g of sample.

To measure the viscosity, a dispersion with distilled water (3 %) was obtained from each lyophilized sample using a Brookfield DV-E viscometer at temperatures of 27°C. The results were expressed as centipoise (cP).

The glucose retention index (GRI) was determined on the basis of the retardation of diffusion of glucose according to Goñi et al., (2002) and de Cortes Sánchez-Mata et al., (2002) methodology according the next formula:

$$GRI = 100 - \frac{(Glucose\ diffused\ bag\ with\ fiber)}{(Glucose\ diffused\ bag\ without\ fibre)} * 100$$

SEM (Scanning electron microscopy)

To determine the microstructure of plants, the scanning electron microscopy (SEM) was used. An amount of dried sample was placed on samples holders with Denton Vacuum LLC (Moorestown NJ, USA), at a pressure of 20 millitorr and a current of 20 mA for 4 minutes. The samples were covered with gold and were observed in a JEOL IT300 to x1000.

Statistical analysis

All the determinations were performed in triplicate and the results of the evaluated samples were expressed by mean ± standard error of the mean (SE). To determine the difference and the levels of statistical significance between raw and cooked of each plant a Student t test was used (95%) using the statistical package SPSS System for WINTM version 19.0.

RESULT AND DISCUSSION

Nutritional composition

Proximal analysis

These plants are used by populations into their traditional dishes, and usually are consumed boiled.

Table 2 shows the results of chemical composition of the studied food vegetable (mallow leaves and garambullo flowers). In general, the raw wild foods had a range of moisture between 94 – 97 % and characterized mainly by carbohydrates 48 - 70 %, followed by protein (13 - 34 %) and ashes (8 - 13 %). On the other hand, both plants had a low content of lipids of around 2 %, therefore these foods are considered as low-calorie foods (Pinedo-Espinoza, et al., 2020). These results were similar to other studies in jew´s mallow leaves and mallow leaves (*Malva parviflora*) (Abdalla and el-Aal, 2016) and garambullo flower (Pinedo-Espinoza et al., 2020).

The thermal treatment caused an increase ($p<0.05$) of 6 % (mallow leaves) and 15 % (garambullo flower) in carbohydrates and the content of proteins increased in mallow leaves (26 %) while garambullo flowers decreased (2.8 %) in comparison with raw samples. The increase in carbohydrate content could be attributed to hydroxylation of complex glucidic chains freeing sugar molecules, while that the high proteins content could be explained by the nature and form of proteins of the plants (Traoré et al., 2017). A significant loss of soluble compounds was observed in both studied samples, as in ethereal extract (around 23 - 55 %) and ashes (50 %), similar to other studies (Ahmed and Ali, 2013; Arias-Rico, 2020).

Total dietary fiber (TDF)

Wild plants are related to human nutrition and folk medicine because of its high content of dietary fiber (Koca et al., 2015). A content of TDF in raw mallow leaf was obtained (36.47 g/100 g db), composed mainly of IDF (31.32 g/100 g db) and the rest of SDF (5.15 g/100 g db) (Table 2). It was higher compared to a study on *Malva neglecta Wallr* leaves (Koca et al., 2015). The garambullo flowers had a content of 42.98 g/100 g db of TDF, with a high content of IDF (40.02 g/100 g db) in comparison with SDF (2.96 g/100 g db). Several authors established the content of crude fiber on garambullo flowers (6.92 g/100 g db) as well as in different edible flowers (*Aloe vera, Agave salmiana, Arbutus xalapensis, Cucurbita pepo, Erythrina americana, Erythrina caribaea, Euphorbia radians, Yucca filifera*) (12-17 g/100 g db) (López-Cervantes et al., 2018; Sotelo et al., 2007), however, this methodology underestimate value dietary fiber in the foods due to loss of fiber material chemical treatment produced (Dhingra et al., 2012).

The thermal processing showed a decrease ($p<0.05$) in TDF (12.2- 26.8 %) of the studied samples which could be attributed to partial degradation of cellulose and hemicellulose into simple carbohydrates during boiling (Zia-ur-Rehman et al., 2003). In comparison with the raw samples, the fraction of SDF increased (19 and 8 %), with an important decrease of IDF (35 and 13 %) in mallow leaf and garambullo flower, respectively. These changes could be caused by modification of the structure of fiber (Caprita et al., 2011) as depolymerization of the cell walls (Huang and Hsieh, 2019) or disruption of covalent and non-covalent bonds between polysaccharide chains and proteins moieties or glycosidic linkages on the dietary fiber components affected by heat treatment (Bader Ul Ain et al., 2019; Caprita et al., 2011; Margareta and Nyman, 2003; Yang et al., 2017) increasing the SDF content. The changes on the wall cell and therefore in the food matrix cause important changes of physicochemical properties of the vegetable foods (Fouad And Rehab, 2013; Miglio et al., 2008; Ramírez-Moreno et al., 2013).

Total phenolic compounds and antioxidant capacity

The antioxidant compounds as phenols are substances with a main function on the oxidation process, inhibiting free radicals, therefore, these bioactive compounds have important physiological effects (Farhan et al., 2012). Vasco et al., (2008) establishes that foods could be classified according to phenolic compounds in low content (< 100 mg GAE/100g db), medium (101-1000 mg GAE/100 db) and high content

Table 2: Effect of thermal treatment on nutritional composition of edible plants in Mexico (g/100 g db).

Parameter	Mallow leaf		Garambullo flower	
	Raw	Boiled[A]	Raw	Boiled[A]
Moisture	97.51 ± 0.29	98.14 ± 0.04	94.56 ± 0.86	94.16 ± 0.38
Carbohydrate	48.05 ± 0.73	51.96 ± 1.31*	70.75 ± 0.56	81.58 ± 0.54*
Protein	34.94 ± 0.62	44.05 ± 1.26*	13.25 ± 0.15	12.87 ± 0.06*
Etheral extract	1.84 ± 0.12	1.41 ± 0.59*	2.30 ± 0.53	1.02 ± 0.27*
Ash	12.82 ± 0.49	6.50 ± 0.20*	8.23 ± 0.57	4.35 ± 0.42*
Total dietary fiber	36.47 ± 0.01	26.69 ± 0.01*	42.98 ± 1.37	37.73 ± 0.15*
Dietary fiber fractions				
Soluble	5.15 ± 0.00	6.12 ± 0.00*	2.96 ± 0.00	3.20 ± 0.00*
Insoluble	31.32 ± 0.02	20.56 ± 0.01*	40.02 ± 1.37	34.53 ± 0.02*

Values are mean ± SEM (n=3) *The asterisk indicates a significant difference between raw and boiled of each plant. [A] Corrected value taking into account the soluble solid loss during cooking, [B] Carbohydrates were calculated substrate the values of moisture, protein, ethereal extract and ash.

(>1001 mg GAE/100g db). In this case, the studied plants presented a medium content of polyphenols, raw mallow leaf was of 468.43 mg GAE/100 g db, while raw garambullo flower showed a value of 750.89 mg GAE/100 g db (Table 3). In comparison with other studies in other mallow leaves the TPC content of mallow leaf was low due they found values of TPC between 789 - 1180 mg GAE/100g db (Abd El-Salam and Morsy, 2019). While TPC from garambullo flower was higher than the found by others studies (35 - 189 mg GAE/100 g db) (Solís-Ramírez and García-Vieyra, 2017; Pinedo-Espinoza et al., 2020). The variable polyphenols content between studies of these plants may be due to several factors such as the botanical characteristics, antioxidant composition, time and the used of different solvents for extraction (Abd El-Salam and Morsy, 2019; Farhan et al., 2012; Messaoudi et al., 2015; Mohammed et al., 2014; Petkova et al., 2019; Solís-Ramírez and García-Vieyra, 2017).

The efficacy of antioxidant compounds in samples were analyzed by DPPH$^{\bullet}$, ABTS$^{\bullet+}$ and FRAP methodologies. The values of antioxidant capacity of mallow leaves measured by DPPH$^{\bullet}$, ABTS$^{\bullet+}$ and FRAP were of 1,264.11 μmol TE/100 g db, 331.01 μmol TE/100 g db and 5.55 μmol Fe (II)/100 g db, respectively, while garambullo flowers showed higher values of 1,4004.90 μmol TE/100 g db, 2,344.94 μmol TE/100 g db and 95.72 μmol Fe (II)/100 g db, respectively (Table 3). The values of antioxidant activity measured by the three methodologies in mallow leaf were higher in ABTS$^{\bullet+}$ than other study of *Malva sylvestris* (ABTS$^{\bullet+}$ 34 μmol TE/100 g db) (Benso et al., 2016) and lower in *Malva parviflora* [FRAP 65,416 μM Fe (II)/100 g db] (Teixeira et al., 2016). The activity antioxidant by mallow leaf could possibly possess radical scavengers activity and therefore maintain a good antioxidant activity (Abd El-Salam and Morsy, 2019).

The values of DPPH$^{\bullet}$ inhibition shown by antioxidant values from garambullo flowers were found among the ranges reported for other edible flowers 2,300 - 67,500 μmol TE/100 g db (Pinedo-Espinoza et al., 2020)

Figure 2. (a-d) Samples of mallow leaves and garambullo flowers before and after of boiled.

and low in ABTS$^{\bullet+}$ in comparison with other study (24,523 - 180, 700 mmol/TE 100 g) (Hu et al., 2019). FRAP values of garambullo flowers here reported were found among the values of other studies (0.02 - 112.49 μmol Fe II/100g db) (Li et al., 2014; Roy et al., 2011). The antioxidant capacity in flowers of garambullo could be correlated with the content of phenolic compounds or other metabolites as phloridzin and rutin mainly, compounds considered as good antioxidants (Pinedo-Espinoza et al., 2020; Hu et al., 2019; Shi et al., 2019).

Furthermore, the cooking significantly affected the TPC, inducing a decrease of 22 % in mallow leaf and 10 % in garambullo flower, respect to TPC in raw samples (Table 3),

which are according with the loss of TPC in other studies of cooked vegetables as pepper, squash, green beans, peas, leek, broccoli and spinach (12-26 %) (Turkmen et al., 2005). These losses could be attributed to the diffusion of these soluble compounds into the boiling water or the degradation of these compounds during boiling (Gunathilake et al., 2018; Preti et al., 2017). The losses of bioactive compounds could be strongly related with the decrease of the antioxidant activity of the boiled samples, because mallow leaf and garambullo flower showed a decrease ($p<0.05$) around 30 % of antioxidant capacity measured as DPPH•, ABTS$^{\bullet+}$ and FRAP, with a strong affectation in garambullo flowers (around 30 % until 70 %).

Physical-chemical properties

Color

The parameters of color (*L**, *a**, *b**, h° and C) are shown in Table 4. In the fresh samples, the luminosity showed 31.37 and 44.53 values in mallow leaf and garambullo flower, respectively. The color presented by raw mallow leaf was found in the yellow-green quadrant (values of *a** -3.56 and *b** 14.73) which contributes with a fresh appearance characteristic of chlorophyll content, while the garambullo flower was observed in the yellow-red quadrant (values of *a** 1.13 and *b** 13.60). This color could be due to the presence of phenolic compounds, carotenoids or betalains. Hue showed values of 103.09 and 85.20, while in chroma had results of 15.31 and 13.64 in mallow leaves and garambullo flowers, respectively. The cooking in plants caused color changes (Figure 2). The luminosity increased slightly in both samples, while in the color parameters of *a** and *b**, mallow leaf tended to greener color (*a** -8.80 and *b** 14.50) and garambullo flowers tended to be redder color (*a** 3.76 and *b** 11.66) (Table 4). In addition, hue angle increased green tonality in mallow leaves and decreased the red tonality in garambullo flowers. The color saturation (chroma) was maintained ($p>0.05$) in both plants. The green color developed after boiling could not necessarily be attribute to the normal conversion of chlorophyll to pheophytin (Trivedi et al., 2018), but probably caused by other derivatives of chlorophyll (chlorophyllides) that change from non or less- colored precursor of green color to more visible green color (Turkmen et al., 2005) or this caused by the inactivation of enzymes to avoid changes of color (Mohamed et al., 2012). On the other hand, the deaeration of plants tissue substituting oxygen by water molecules of the boiling causes the loss of opacity of the plants to an increase in the intensity of green color (Turkmen et al., 2005). While that the changes of color to red tonalities in garambullo flowers could be due to the compounds present in the flowers such as carotenoids or betalains, since the caraotenoids may trans - cis transformated of double bonds and therefore leads a decrease of color intensity (Khoo et al., 2011; Schieber and Carle, 2005). After thermal treatment, the betalains could be have several changes as isomerization, deglycosylation, hydrolysis, dehydrogenation and decarboxylation (Rodriguez-Amaya, 2019) or the loss of these hydrosoluble compounds for leaching into cooking water (Sawicki and Wiczkowski, 2018).

Properties of dietary fiber (WRC, ORC, SC, viscosity and GRI)

The functional or technological properties of powder plants are determined by the soluble and insoluble fractions, which have an important impact on functionality and nutritional effects (Lecumberri et al., 2007). The studied samples were characterized with a high content of insoluble

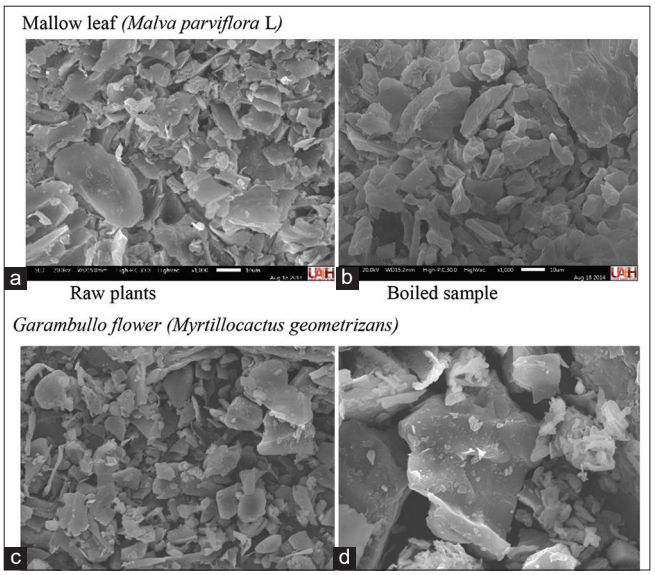

Figure 3. Scanning electron microscopy (SEM) of raw a) and c), and boiling b) and d) tissues of mallow leaf (*Malva parviflora* L.) and garambullo flower (*Myrtillocactus geometrizans*), respectively.

Table 3: Effect thermal treatment on total phenolic compounds and antioxidant activity of edible plants in Mexico (100 g db)

Parameter	Mallow leaf		Garambullo flower	
	Raw	Boiled	Raw	Boiled
TPC (mg GAE)	468.43 ± 4.18*	364.07 ± 4.21	750.89 ± 9.95*	672.53 ± 4.14
DPPH (µmol TE)	1264.11 ± 109.34*	947.77 ± 38.63	14004.90 ± 2694.74*	4192.81 ± 1292.63
ABTS $^{\bullet+}$ (µmol TE))	331.01± 4.45*	243.37 ± 3.37	2344.94 ± 9.73*	1638.95 ± 79.51
FRAP (µmol Fe (II)	5.55 ± 0.17*	3.98 ± 0.07	95.72 ± 0.94*	68.72 ± 0.72

Values are mean ± SEM (n=3) *The asterisk indicates a significant difference between raw and boiled of each sample. [A] Corrected value taking into account the soluble solid loss during cooking.

Table 4: Effect thermal treatment on physico-chemical characteristics of edible plants.

Parameter	Mallow leaf		Garambullo flower	
	Raw	Boiled[A]	Raw	Boiled[A]
Color				
L*	31.37 ±0.86	32.10±1.65*	44.53 ± 1.76	50.83 ± 1.84*
a*	-3.56 ± 2.81	-8.80 ± 0.81*	1.13 ± 0.25	3.76 ± 1.30*
b*	14.73 ± 0.64	14.50 ± 1.50	13.60 ± 0.60	11.66 ± 0.30*
h*	103.09 ± 10.18	121.32 ± 2.86*	85.20 ± 1.27	72.26 ± 5.55*
croma	15.31 ± 1.13	16.97 ± 1.50	13.64 ± 0.58	12.29 ± 0.61
WRC[a] (g/g db)	5.43 ± 0.44	5.31 ± 0.15	5.99 ± 0.15	7.79 ± 0.16*
ORC[b] (g/g db)	2.22 ± 0.38	2.15 ± 0.19	2.40 ± 0.29	1.92 ± 0.30
SC[c] (mL/g db)	2.46 ± 0.05	0.96 ± 0.11*	2.87 ± 0.12	2.40 ± 0.24*
Viscosity (mPa)	6.80 ± 0.17	7.10 ± 0.45	7.05 ± 0.47	7.42 ± 0.10
GRI[d] (mg/g)	4.45 ± 0.13	1.23 ± 0.14*	2.96 ± 0.46	2.38 ± 0.11*

Values are mean ± SEM (n=3) *The asterisk indicates a significant difference between raw and boiled of each plant. [a]WRC: Water Retention Capacity, [b]ORC: Oil Retention Capacity, [c]SC: Swelling Capacity, [d]GRI: Glucose Retention Index. [A] Corrected value taking into account the soluble solid loss during cooking

dietary fiber (85-93 % of total dietary fiber). The results of WRC, ORC, SC and viscosity in raw samples presented values behaved similarly (Table 4).

The values obtained of WRC (around 5 g/g db) and SC (around 2 mL/g db) (Table 2) were similar to commercial supplements of dietary fiber which are characterized as high content of insoluble fiber (WRC of 3.1 to 4.8 g/g db and 6 mL/g db of SC) (Goñi and Martin-Carrón, 1998) and fiber-rich cocoa products (WRC and SC of 4.76 g/g and 6.52 mL/g, respectively). The data of ORC (2 g/g db) were similarities with to the values reported for extracted pectins of agroindustrial residues as soy hull, passion fruit peel and orange pomace (among 2 - 4 g/g db) (de Moura et al., 2017). According to Benítez et al., (2017), particles with bulk density had a higher capacity to absorb or bind lipid components related with a greater surface area.

The results of viscosity in mallow leaf and garambullo flower (6.80-7.05 cP) had the same behavior that some edible plants (*Chenopodium nuttalliae safford*, *Suaeda Torreyana. Watson*, *Portulaca oleracea* L., *Chenopodium album* L. and *Porophyllum ruderale* with values of 2.56–7.68 cP) (Arias-Rico et al., 2020).

Glucose retention index

The GRI is considered an important *in vitro* index to assess the effect of fiber on delay in glucose absorption by gastrointestinal tract (López et al., 1996), mallow leaves showed a higher GRI than garambullo flowers (4.11 g/g db and 2.96 mg/g db, respectively); however, both were similar to obtained for fiber-rich cocoa products (4.40 mg/g db) (Lecumberri et al., 2007).

Several conditions such as thermal processing (boiling), by cross-links holding the cell wall, type and duration time, temperature and hydration grade, among others, could cause the solubilisation of pectic components, often accompanied by the swelling of cell wall (Holland et al., 2020; Waldron et al., 2003). These gradual changes originated from the disruption of the cell wall (cellulose) and the exposure to the environment of the protoplasmic structure, affected the hydration and oil properties (Paciulli et al., 2016; Ranganathan et al., 2016; Xu et al., 2015). The values of ORC and viscosity of both samples studied remained (p>0.05) after cooking, the maintenance of viscosity could be due to minimal increases of soluble components (SDF) after thermic treatment in our study. On the other hand, the SC decreased (p<0.05) in both samples (60 % in mallow leaves and 16 % in garambullo flowers) as well as GRI (between 16 to 19 %). These last could be due to the restructuring of the matrix towards a less compact plant structure after treatment (Margareta and Nyman, 2003; Raghavendra et al., 2006; Requena et al., 2016). The WRC remained in the mallow leaf, while an increase in garambullo flowers was observed. The increase of WRC may be due to hydrophilic matrix of IDF (do not form gelatinous matrix) in which also water is entrapped (Vázquez-Ovando et al., 2009). These changes physically modify the plant fiber, impacting on technological functionality and beneficial effects on health (Holland et al., 2020; Paciulli et al., 2016; Ranganathan et al., 2016).

Scanning Electron Microscopy (SEM)

The function of heat treatment is focused on modifying the sensory characteristics as well as ensuring safety foods. Nevertheless, this treatment could cause change on the matrix of plants. Figure 3 shows the morphology of the tissue of the plant studied raw and boiled. It can be observed in Figure 3a and Figure 3c tissue regular and smooth texture in raw mallow leaves and garambullo flowers, respectively. After boiled treatment there is more amorphous extracellular matter in both samples (mallow leaf and garambullo flower), irregular fragments and small clumps stiffer were observed (Figure 3b and Figure 3d). After cooking treatment the organization of plants is lost due to that the heating provoke alterations in the

microstructure of plants tissue, causing modification on texture by loss of turgor pressure and occluded air, thermal degradation of middle lamella pectins and others cell wall polysaccharides that constitute plant tissue (Gonzalez and Barrett, 2010; Llano et al., 2003), having to the end an impact on physicochemical properties of dietary fiber, nutrimental composition and sensory characteristics (Butz et al., 2002; Gonzalez and Barrett, 2010).

CONCLUSION

According to the results the plants presented an important nutritional composition related to protein, dietary fiber and antioxidant contents. However, the thermal treatment provoked changes on the soluble compounds, mainly carbohydrates and total phenolic compounds, affecting the nutritional composition and antioxidant capacity. Also, cause alterations in physicochemical properties as a consequence plants matrix altered. Short time thermal treatments led modifications as darker colors, hydration properties, water retention capacity in garambullo flowers, swelling and oil retention capacity in the other plant. On the other hand, it showed a decrease in glucose retention index. All the changes could be attributed to modifications in plant structures. In this sense, short thermal treatments are recommended to minimize changes of these plants or inclusive intake raw from these. Further research could be extended to other edible plants. Moreover, studies in plants should be redirected to conducting studies related to human health.

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Authors' contributions

Ramírez-Moreno E. conceived, designed the experiments, and analyzed the data, in addition to serving as director of the thesis of E.M.S.-G.; Sandoval-Gallegos E.M. performed the experiments and analyzed the data; Arias-Rico J.; Cruz-Cansino N. S.; Ramírez-Ojeda D. Zafra-Rojas Q.Y. contributed with reagents/materials/analysis tools and contributed to a valuable discussion; Hernández-Ávila J contributes with analysis and discussion of scanning electron microscopy.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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