

Nutritional value and antioxidant activity of the maguey syrup (*Agave salmiana* and *A. mapisaga*) obtained through three treatments

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Abstract

During the Pre-Colombian period magueys were used in Mesoamerica for their sap, which is named “aguamiel” (literally “honey water” in Spanish). Aguamiel is then fermented into “pulque”, followed by (in order of importance): textiles, apparel, different thicknesses cords, food (sweetener, syrup, vinegar, flower buds, and cooked immature flowering stalks), firewood and construction materials. The maguey syrup is a product that is traditionally obtained by concentrating the aguamiel by means of an artisanal evaporation treatment (high temperatures, atmospheric pressure and prolonged times). The nutritional and nutraceutical value of this concentrate is unknown despite its wide consumption since pre-Hispanic times in various regions of Mexico. The objective of this work was to evaluate the nutritional value and the content of antioxidant compounds of the maguey syrup obtained from the aguamiel (*Agave salmiana* and *A. mapisaga*) through three elaboration treatments (artisanal evaporation, evaporation under reduced pressure and lyophilization). The best species for the production of maguey syrup turned out to be the aguamiel of the *A. salmiana* due to its nutritional and nutraceutical attributes, higher content of reducing sugars and lower sucrose compared to that of *A. mapisaga*. The maguey syrup is a sweetener with a higher content of protein (3320 mg 100⁻¹) in comparison to bee honey (152.7 mg 100 g⁻¹). The maguey syrup obtained by lyophilization (LYT) retained the nutraceutical value; but its antioxidant activity was statistically equal to the syrup obtained by evaporation under reduced pressure (RPT), and the artisanal evaporation treatment (AET) had a decrease in vitamin C content in comparison to LYT and RPT. The syrups obtained by RPT and AET presented different degrees of non-enzymatic darkening, possibly due to the formation of melanoidins (dark pigments). The darkest syrup obtained by AET had the highest antioxidant capacity (987.24 μM TE 100 g⁻¹) associated to a higher content of phenolic compounds (593.74 mg GAE 100 g⁻¹).

Keywords: aguamiel; antioxidants; melanoidins; non-enzymatic darkening; syrups

Abbreviations: Artisanal evaporation treatment (AET); Reduced pressure treatment (RPT); Lyophilization treatment (LYT); Fructooligosaccharides (FOS)

Introduction

The genus *Agave* is the largest and most diverse of the Agavaceae family; 159 species (75%) are distributed in Mexican territory, of the 211 species that comprises this genus. For this reason, Mexico is considered the centre of origin of agaves distributed in the arid and semi-arid regions of the country (García-Mendoza, 2011; Narvaez *et al.*, 2016; Colunga, 2018). These plants with crassulacean acid metabolism (CAM) have a special importance for water-use-efficiency, this behaviour favours their development in arid environments. Some species of agave, also called magueys, associated with the goddess Mayahuel for the culture of the Nahuas, are widely used as a source of food and hard fibres, in regional herbalism and in the production of fermented and/or distilled alcoholic beverages (Lappe-Oliveras *et al.*, 2008). There are several pulqueras species: *A. americana*, *A. atrovirens*, *A. ferox*, *A. mapisaga* and *A. salmiana* (Enriquez-Salazar *et al.*, 2017). The richness of the variability of the maguey mainly to the *A. salmiana* (more abundant taxon) is known as ayoteco, chalqueño, chino, manso, mutha, púa larga, verde, xamini (Chávez-Güitrón *et al.*, 2019) and *A. mapisaga* species as well as the various common names (carrizo, maye, morado, mexicano, penca larga, liso charcas, manso ahualalco, sabililla (Mora-López *et al.*, 2011; Reyes-Agüero *et al.*, 2019) due to the diversity of uses since pre-hispanic times and for the regions where it is cultivated.

The species *A. tequilana* Weber stands out for its use in tequila elaboration. By contrast, *A. mapisaga* and *A. salmiana* are the main species used in the production of pulque, an alcoholic beverage with the greatest ancestral tradition of Mexico, obtained through the fermentation of aguamiel (Lappe-Oliveras *et al.*, 2008). Aguamiel is the main product of the maguey (*A. mapisaga* and *A. salmiana*) that is produced with the removal (trimming) of the floral bud of the agave to leave a central cavity (hole) where the sap accumulates; after a time of maturation (aging) it is culturally known as aguamiel (Lappe-Oliveras *et al.*, 2008). Aguamiel has been used since pre-Hispanic times to produce pulque; it has been considered a food alternative due to its nutritional attributes (proteins, amino acids, sugars, minerals, saponins and fructooligosaccharides) and its antioxidant potential attributed mainly to the presence of phenolic compounds and vitamin C (Ortiz-Basurto *et al.*, 2008; Tovar-Robles *et al.*, 2011; Guzman-Pedraza y Contreras-Esquivel, 2018). Another alternative for the use of aguamiel has been the obtention of agave syrup by its moisture content, a product obtained ancestrally by an artisanal process (conventional evaporation at high temperatures), where the time and temperature of evaporation contribute to the flavour and colour of the syrup (brown to black by non-enzymatic darkening reactions, Maillard reaction) (Wang *et al.*, 2011; Santos-Zea *et al.*, 2016). However, the impact on nutritional and nutraceutical quality due to the elaboration treatment is unknown. Based on the above, the objective was to evaluate the effect of three syrup elaboration treatments: artisanal evaporation (AET), reduced pressure evaporation (RPT) and lyophilization (LYT) from the aguamiel of two species of agave (*A. salmiana* and *A. mapisaga*) in their nutritional and nutraceutical properties, in order to identify the best agro-industrial use of the product.

Materials and Methods

Aguamiel harvest

Aguamiel samples from two species of maguey harvested from two pulque-producing regions were used: *Agave mapisaga* Trel cv. 'carrizo of Texcoco' (19° 20' 190 N, 98° 55.67' W, 2365 m altitude) and *A. salmiana* Otto ex Salm-Dyck cv. 'manso of Axapusco' (19° 52.027' N, 98° 44.252' W, 2361 m altitude), harvest temperature between 12 and 15 °C, respectively, communities of the State of Mexico, Mexico. Aguamiel was extracted from 8-year-old agaves. All of these plants were at two months of the harvest period. Five different samples were collected in this period. The sap was removed by oral suction, through a dried gourd (*Lagenaria siceraria*) called an acocote. The aguamiel of each species was found at 10 ± 2 °C when it was harvested at 7:00 in the morning and kept refrigerated (2 °C) during its transfer to the laboratory, to avoid fermentation.

Subsequently, it was stored at -20 °C until the syrup was obtained and analyzed. Herbarium specimens were prepared for taxonomic identification. The species *A. salmiana* was identified in the MEXU Herbarium of the Institute of Biology at Universidad Nacional Autónoma de México (UNAM) (registration numbers 1388320 and 1388345), and that of *A. mapisaga* in the "JES" Herbarium of the Universidad Autónoma Chapingo, México (UACH) (registration number 30189).

Maguey syrup elaboration treatments

Three treatments for obtaining syrup were applied within these characteristics (75-85 °Brix and 16-25% moisture), similar to those described in commercial agave, corn and bee honey syrups (74-80 °Brix and 19-25% moisture) (Mellado-Mojica and Lopez-Perez, 2013).

Artisanal evaporation (AET)

The aguamiel was concentrated in a stainless-steel container by evaporation using an electric grill (SP46925, Thermolyne, USA). The treatment was carried out approximately between 90-93 °C at an atmospheric pressure of 780 mbar for 75 min.

Evaporation under reduced pressure (RPT)

The aguamiel was concentrated under reduced pressure at a vaporization temperature of 55-58 °C and a vacuum pressure of 157 mbar for 25 min in a rotary evaporator (Laborota 4003 Control, Heidolph Instruments, Germany).

Lyophilization (LYT)

The aguamiel was frozen by immersion in liquid nitrogen and was stored at -20 °C until treatment. The frozen samples were lyophilized (Labconco, Kansas, USA) at -48 °C and 0.20 mbar for 26 h.

Nutritional analysis

The contents of Fe, Ca, Mg, K and Na were quantified by atomic absorption spectrophotometry (700 Analyst, PerkinElmer, USA). The pH, content of total soluble solids (TSS), moisture, ash, protein, total carbohydrates (TC), total sugars (TS) and reducing sugars (RS) of the samples were determined according to the methodologies of the AOAC (2000).

Determination of colour parameters

The colour of the syrup was expressed as lightness (*L*), tone angle (*hue*), and chromaticity index (*chroma*), and it was evaluated with a Hunter Lab colorimeter (Mini Scan XE Plus 45/0-L, RestonVa, USA).

Determination of viscosity and water activity (w_a)

The determination of viscosity was done at room temperature with a digital viscometer (RV-DV II Pro, Brookfield, USA). The water activity (w_a) of the samples was determined at 25 °C by means of a dew point sensor: Aqualab Series 3 TE model (Decagon Devices, Washington, USA).

Quantification of antioxidant components

Ascorbic acid

For its determination, the method of indophenol-xylene extraction was used (Burdurlu *et al.*, 2006), the absorbance reading was performed at a wavelength of 520 nm in a spectrophotometer (Genesys 10s, Thermo Scientific, USA). Concentrations were calculated using a standard curve of ascorbic acid ($y = -2.666x + 0.567$; $R^2 = 0.995$). The results were expressed in mg equivalent of ascorbic acid per 100 g of syrup (mg AAE 100 g⁻¹).

Total phenolic compounds

Quantification was performed according to the Folin-Ciocalteu method (Singleton and Rossi, 1965), the absorbance reading was performed at a wavelength of 760 nm. Concentrations were calculated using a standard curve of gallic acid ($y = 5.9332x - 0.0375$; $R^2 = 0.995$). The results were expressed in mg equivalent of gallic acid per 100 g of syrup (mg GAE 100 g⁻¹).

Flavonoids

For its evaluation, the Dowd method adapted by Arvouet-Grand *et al.* (1994) was used. The absorbance reading was performed at a wavelength of 425 nm. The standard curve was built using quercetin as a reference ($y = 5.4696x + 0.0018$; $R^2 = 0.996$). The results were expressed in mg equivalent of quercetin in 100 g of syrup (mg QE 100 g⁻¹).

Quantification of total melanoidins

The degree of darkening was obtained indirectly by measuring the content of total melanoidins, pigments resulting from temperature treatments and their interaction with the chemical components of the food matrix, in this case aguamiel (non-enzymatic Maillard reaction) (Wang *et al.*, 2011). The melanoidin content was analyzed by the method described by Turkmen *et al.* (2006). A syrup sample was diluted with distilled water until a total soluble solid's concentration of 4 °Bx was reached. Subsequently, the absorbance of the mixture at a wavelength of 420 nm was read (Turkmen *et al.*, 2006; Wang *et al.*, 2011) in a spectrophotometer. The results were expressed as absorbance units (AU) since due to the structural complexity of the melanoidins a commercial standard for direct quantification was not found.

Determination of antioxidant activity

The antioxidant activity was measured using the DPPH free radical method (2,2-diphenyl-1-picrylhydrazyl) (Brand-Williams *et al.*, 1995). The absorbance reading was performed at a wavelength of 517 nm. The antioxidant activity was calculated by a standard curve based on trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) ($y = 76.889x + 2.2556$; $R^2 = 0.997$). The results were expressed in μM equivalent of trolox per 100 g of syrup (μM TE 100 g⁻¹).

Statistical analysis

All results were expressed as the mean ± standard deviation of the average of five repetitions. An analysis of variance was performed with a comparison of means using the minimum honest significant difference method (Tukey, 0.01), a Pearson correlation analysis with the support of software SAS.

Results and Discussion

Nutritional composition

No significant differences ($p < 0.01$) were observed in the content of K in the syrup between species and between the AET and LYT treatments. The exception was in the RPT treatment in *A. salmiana*. It was the element that was found in the highest concentration in all the samples analyzed (Table 1), higher than that reported on bee honey (152.7 ± 76.1 mg 100 g⁻¹ fresh weight) (Escuredo *et al.*, 2013a). The *A. salmiana* syrup had the highest Fe values in all treatments while that of the *A. mapisaga* was statistically higher in sodium content (Table 1) even though the daily intake of *A. mapisaga* syrup would contribute a lower than recommended amount of sodium (1.0 to 1.5 g day⁻¹) in children and adults (Brown, 2011). The differences observed in the concentrations of some elements present in the syrup of the different treatments could be due to the physical-chemical characteristics of the aguamiel, the mineral profile of the soil of each agave-growing region, and/or the genetic variability between species (Gonzalez-Miret *et al.*, 2005).

On the other hand, the syrups obtained by the three treatments showed moisture contents (17.0 and 24.8%) in a similar range (15-25% moisture) to those reported for other commercial agave, corn and bee honey syrups (Mellado-Mojica and Lopez-Perez, 2013). It is an important quality parameter because a low moisture content could favor crystallization or otherwise, the development of microorganisms (Yanniotis *et al.*, 2006). Other components in the syrup were the protein and ash contents in the three treatments (Table 1) which exceeded what was reported on bee honey (0.59-1.0% and 0.18% fresh weight, respectively) (Gupta and Sharma, 2009; Escuredo *et al.*, 2013a).

Regarding the total carbohydrate and total sugar contents, there were no significant differences ($p < 0.01$) between treatments and between species. The total carbohydrate and total sugar contents found in the syrups of the three treatments, approximately 89% of the total carbohydrates could be simple carbohydrates (monosaccharides and disaccharides), therefore, the remaining 11% could be attributed to the presence of complex carbohydrates mainly fructooligosaccharides (FOS). Ortiz-Basurto *et al.* (2008) highlight that aguamiel from the *Agave mapisaga* is a source of FOS (10.2% in dry weight). Other authors report in the processed sap of the head of the *A. salmiana* a high content of these fruit trees (80% in dry weight) and Godinez-Hernandez *et al.* (2016) in the sap of the *A. tequilana*. These reserve carbohydrates in vegetables of a lower molecular weight than inulin are resistant to hydrolysis by human digestive enzymes, so they are non-digestible fructose oligomers with prebiotic activity that lower blood cholesterol levels, favor the absorption of calcium by the bones and a low glycemic index (Alves Filho *et al.*, 2016; Martinez-Gutierrez *et al.*, 2017). The conditions of the process for the obtention of syrup can also influence its quality, mainly by the type of sugar obtained. In this regard, Gonzalez-Ponce *et al.* (2016) report that the production of syrup of *A. tequilana* Weber Blue by an acid-thermal hydrolysis treatment produces a high content of fructose compared to fructooligosaccharides (Michel-Cuello *et al.*, 2015).

In this research, syrup of the species *A. salmiana* had a higher content of reducing sugars and a lower content of sucrose, an opposite effect to that observed in the syrup of *A. mapisaga* independently of the treatments (AET and RPT) (Table 1). Therefore, these variations could be explained by the variability between species, the period of accumulation of the sap in the cavity (hole), and the period of aging or harvest of the aguamiel (Lappe-Oliveras *et al.*, 2008; Ortiz-Basurto *et al.*, 2008).

Physical-chemical characterization

The values of *hue* and *chroma* in the syrups obtained by the three treatments of both species presented similar saturation and colour tone (Table 1). These were darker compared to those reported on bee honey according to the criteria proposed by Gonzalez-Miret *et al.* (2005): clear honey, $L^* > 50$; dark honey, $L^* < 50$.

The lowest luminosity values (L) were observed in the darkest syrups of the two species obtained by the AET treatment compared to the remaining treatments (Table 1), since the high temperature (90 to 93 °C) produced non-enzymatic darkening reactions (Maillard reaction) due to the formation of dark pigments. This syrup also presented the highest levels of melanoidins. The Maillard reaction favours the formation of these pigments in some foods during the coffee roasting process, as well as in the obtention of aguamiel syrup by the interaction of functional groups present in some of its components (proteins and reducing sugars) (Turkmen *et al.*, 2006; Ortiz-Basurto *et al.*, 2008; Wang *et al.*, 2011). The formation of these dark pigments was also strongly correlated with the antioxidant activity (0.76) and with the content of the phenolic compounds (0.83) in the syrups (Table 2) of both species.

Table 1. Physical-chemical characterization and nutritional value of maguey syrup (*Agave salmiana* and *A. mapisaga*) obtained through three treatments (artisanal evaporation, evaporation under reduced pressure and lyophilization)

Variable	Maguey syrup (<i>A. salmiana</i>)			Maguey syrup (<i>A. mapisaga</i>)		
	Artisanal	Lyophilization	Reduced pressure	Artisanal	Lyophilization	Reduced pressure
Fe (mg 100 g ⁻¹)	9.60±0.35 a	10.19±0.70 a	8.93±0.34 a	3.35±1.28 a	3.20±1.47 a	3.19±1.17 a
Mg (mg 100 g ⁻¹)	88.90±4.71 a	86.72±9.09 ab	70.08±2.53 b	73.48±7.63 a	76.13±11.82 a	71.24±3.69 a
K (mg 100 g ⁻¹)	1101.00±62.60 a	1053.96±52.77 ab	921.98±46.78 b	1113.05±171.07 a	813.90±357.99 a	957.11±102.47 a
Ca (mg 100 g ⁻¹)	41.50±2.11 a	43.88±2.85 a	31.27±1.46 b	38.45±2.69 a	37.81±5.02 a	43.25±7.29 a
Na (mg 100 g ⁻¹)	76.15±4.13 a	81.90±4.00 a	70.26±12.42 a	98.161±2.67 a	120.28±27.25 a	123.34±17.68 a
Moisture (%)	16.99±2.79 b	19.40±4.00 b	24.80±2.40 a	20.97±5.27 a	20.78± 6.78 a	20.52±3.00 a
Proteins (g 100 g ⁻¹)	3.85±0.27 a	3.61±0.22 a	3.60±0.59 a	3.12±0.34 a	2.76±0.38 a	3.02±0.07 a
Ashes (g 100 g ⁻¹)	3.06±0.87 a	3.05±0.77 a	3.07±1.09 a	2.00±0.68 a	2.85±0.77 a	2.40±0.19 a
TC (g 100 g ⁻¹)	76.10±1.05 a	73.94±0.97 a	68.53±1.56 b	73.91±0.50 a	73.62±0.71 a	74.06±0.21 a
RS (g 100 g ⁻¹)	55.47±2.74 a	55.69±5.49 a	52.58±1.77 a	14.44±3.15 b	23.21±4.78 a	9.57±2.79 b
TS (g 100 g ⁻¹)	69.42±3.45 a	61.18±4.70 ab	54.03±1.59 b	75.00±7.04 a	63.89±5.39 a	69.20±5.01 a
Sucrose (g 100 g ⁻¹)	13.25±4.44 a	5.22±1.32 b	1.53±0.82 b	57.56±8.82 a	38.56±8.76 b	56.40±6.31 ab
L* (%)	9.74±2.88 b	30.13±5.38 a	20.61±0.59 a	8.64±3.86 b	23.53±3.22 a	16.99±1.98 a
Hue	68.76±12.23 a	74.84±13.04 a	85.69±1.45 a	64.52±16.96 a	79.73±5.80 a	84.85±3.85 a
Chroma	4.77±2.15 ab	4.52±2.64 b	12.84±3.13 a	5.00±1.84 a	4.53±1.77 a	6.71±1.52 a
Melanoidins (AU)	2.413±0.97 a	0.554±0.08 b	0.922±0.17 b	1.840±0.79 a	0.577±0.19 b	1.050±0.14 b
w _a	0.62±0.62 a	0.605±0.08 a	0.73±0.03 a	0.67±0.05 a	0.71±0.13 a	0.72±0.06 a
pH	5.26±0.22 a	5.47±0.06 a	5.49±0.08 a	5.34±0.45 a	5.45±0.55 a	5.78±0.73 a
TSS (°Brix)	83.88±5.64 a	79.10±3.24 a	73.54±2.59 a	79.48±2.71 a	78.16±9.20 a	76.50±3.88 a
Viscosity (Pa·s)	15.98±3.46 a	7.34±3.93 b	2.05±1.33 b	15.68±2.34 a	7.90±2.30 b	7.50±3.16 b

Data are expressed as mean ± standard deviation. Different letters in the same line and species indicate significant difference by Tukey's test ($p < 0.01$). L*: lightness, W_a: water activity, TSS: total soluble solids, TC: total carbohydrates, RS: reducing sugars, TS: total sugars. All values are reported on the fresh weight basis.

On the other hand, no significant differences were observed in the water activity (w_a), the TSS and the pH values in the syrup between species and between treatments. The exception was the viscosity (Table 1). The higher content of melanoidins in the syrups of the two species that were obtained by the AET treatment presented a higher viscosity (Table 1). Viscosity is an important characteristic in syrups, a rheological property that influences the sensory quality related to the consistency and structure of the product; a quality attribute that varies with the temperature of the process of obtention, with the content of water and the crystallization of sugars (Yanniotis *et al.*, 2006; Ren *et al.*, 2010).

Antioxidant components and antioxidant activity

The contents of phenolic compounds and ascorbic acid observed in the syrup were similar between species (Table 2). Only significant differences ($p < 0.01$) were found between the elaboration treatments. The content of ascorbic acid present in the syrup obtained by the three treatments exceeded what was reported on

bee honey (4.2-14.50 mg AAE 100 g⁻¹) (Ferreira *et al.*, 2009; Escuredo *et al.*, 2013b). There are no reports of ascorbic acid degradation during the obtention of the agave syrups by heat treatments. In this research it was found that the highest content of ascorbic acid was found in the syrup obtained by lyophilization due to the low dehydration temperature compared to the thermal treatments (AET and RPT), possibly due to the temperature of the treatment in the reported interval for the degradation (40 to 100 °C) (Herbig and Renard, 2017). A series of oxide-reduction reactions by temperature degrade the ascorbic acid to dehydroascorbic acid and finally to catalyzed oxalic acid (Dhuique-Mayer *et al.*, 2007; Herbig and Renard, 2017).

Table 2. Antioxidant activity and content of phytochemicals in maguey syrup (*Agave salmiana* and *A. mapisaga*) obtained through three treatments (artisanal evaporation, evaporation under reduced pressure and lyophilization)

Variable	Maguey syrup (<i>A. salmiana</i>)			Maguey syrup (<i>A. mapisaga</i>)		
	AET	LYT	RPT	AET	LYT	RPT
Total phenolic compounds (mg GAE 100 g ⁻¹)	593.74±250.06 a	186.73±23.63 ab	136.69±11.75 b	480.17±306.38 a	191.54±65.76 a	146.54±14.68 a
Ascorbic acid (mg AAE 100 g ⁻¹)	ND±0 b	197.05±40.44 a	171.55±41.60 a	6.03±12.06 c	226.07±55.03 a	108.39±22.24 b
Flavonoids (mg QE 100 g ⁻¹)	1.00±0.19 b	0.70±0.09 a	0.57±0.21 a	0.65±0.10 b	1.49±0.18 a	1.16±0.22 ab
Antioxidant activity (μM TE 100 g ⁻¹)	987.24±155.58 a	610.99±12.99 a	573.00±55.98 a	882.75±208.20 a	429.31±82.26 b	419.31±63.36 b
DPPH inhibition (%)	79.62±12.73 a	48.83±1.06 b	45.72±4.58b	71.07±17.04 b	33.96±7.06 a	33.14±5.19 a

Data are expressed as mean ± standard deviation. Different letters in the same line and species indicate significant difference by Tukey's test ($p < 0.01$). AET: artisanal evaporation treatment, LYT: lyophilization treatment, RPT: reduced pressure treatment, QE: quercetin equivalents, GAE: gallic acid equivalents, AAE: ascorbic acid equivalents, TE: trolox equivalents, DPPH: 2,2-diphe-nyl-1-picrylhydrazyl, ND: value not detected. All values are reported on fresh weight basis.

The content of phenolic compounds in the syrup was higher than what was reported for bee honey and *Agave tequilana* syrup (35.91-108.81 and 22.42-300.09 mg GAE 100 g⁻¹, respectively) (Rodríguez *et al.*, 2012; Velazquez-Rios *et al.*, 2019). The content of these metabolites between the RPT and LYT treatments was similar, but lower than that of the syrup obtained by AET, this due to the possible formation of melanoidins (Wang *et al.*, 2011). The chemical complexity of melanoidins has hindered the purification and structural identification of these pigments; they consist of high and low molecular weight complexes (antioxidants) formed by the interaction with proteins, polyphenolic compounds and carbohydrates. These pigments are formed during the heat treatment of the food matrix in association with amino groups of proteins, with simple sugar carbonyls and with phenolic compounds. They can also react with the Folin-Ciocalteu reagent as well as free phenolic compounds, which could increase the content of these antioxidants when analyzed with this reagent, as found in this research (Brudzynski and Miotto, 2011; Pastoriza and Rufian-Henares, 2014). Some research also reports the formation of melanoidins present in bee honey and coffee beans produced by a heat treatment (Wang *et al.*, 2011; Santos-Zea *et al.*, 2016).

Flavonoids are the most abundant group of phenolic compounds studied in products of plant origin. The syrup had a lower concentration of flavonoids (0.927 mg QE 100 g⁻¹ fresh weight) in relation to that reported on bee honey (12.36-58.74 mg QE 100 g⁻¹) (Ferreira *et al.*, 2009), possibly due to the low levels reported in some agave species (Ahumada-Santosa *et al.*, 2013). In contrast, some authors state that other species of the genus (*A. lechuguilla* and *A. striata*) are an important source of flavonoids and phenolic acids (Almaraz-Abarca *et al.*, 2013).

The maguery syrup obtained by the three treatments showed a greater antioxidant activity compared to that reported by Tenore *et al.* (2012) and Rodríguez *et al.* (2012) on bee honey (130-460 and $81.9-255.0 \pm 3.4$ $\mu\text{M TE kg}^{-1}$, respectively). Significant differences ($P \leq 0.01$) of the antioxidant activity were observed between the treatments for the obtention of syrup (Table 2). The AET allowed the obtention of a syrup with a higher antioxidant capacity, possibly due to the higher content of melanoidins. The Pearson correlation analysis showed a highly significant correlation between the content of phenolic compounds (0.78) and the formation of dark pigments (0.76) with antioxidant activity, mainly in the darkest syrup (AET). The antioxidant activity of the syrup derived from *A. salmiana* was statistically superior to the one found in that of *A. mapisaga* (Table 2), possibly due to the genetic variety between species (Al-Mamarya *et al.*, 2002).

Conclusions

The maguery syrup is a product with greater nutritional and nutraceutical attributes than bee honey. The best species for the production of maguery syrup turned out to be the aguamiel of the *Agave salmiana* due to its nutritional and nutraceutical attributes, higher content of reducing sugars and lower sucrose compared to that of *A. mapisaga*, which is a very little studied species. The maguery syrup elaboration treatment influenced the nutraceutical potential. The syrup obtained by the conventional treatment was darker and with a greater antioxidant activity, associated with a high content of phenolic compounds and the presence of dark pigments (melanoidins). This research will contribute to revalue the maguery for its multiple uses; as well as, improving the process of obtaining maguery syrup and recognizing its nutraceutical quality for generate demand of the use of aguamiel, an ancient drink with high cultural potential.

Authors' Contributions

Investigation HR and GM; Project administration: GM; Software: YM; Supervision: GM; Visualization: CL; Writing - original draft: HR; Writing - review and editing: GM and HR. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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