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Valorization of mango (*Mangifera indica* L.) pericarp powders as an alternative for the generation of functional foods

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Abstract

Mango pericarp powders (*Mangifera indica* L.) of Ataulfo, Keitt and Tommy Atkins cultivars were obtained by dehydration and grinding. The content of moisture, ash, fat, dietary fiber, antioxidant capacity and total phenols was evaluated. The cultivar with functional ingredient potential was Ataulfo with antioxidant capacity of 34,811 μmol ET g^{-1} and 7578 mg EAG 100 g^{-1} total phenol, and dietary fiber ≈ 20 %. All three cultivars can be considered as ingredients for adding or enriching fiber in food formulations.

Key Words: mango, pericarp, nutritional, functional, powder.

Valoración de polvos de cáscara de mango (*Mangifera indica* L.) como una alternativa para la generación de alimentos funcionales

Resumen

Los polvos de pericarpio de mango (*Mangifera indica* L.) de los cultivares Ataulfo, Keitt y Tommy Atkins se obtuvieron por deshidratación y molienda. Se evaluó el contenido de humedad, ceniza, grasa, fibra, capacidad antioxidante y fenoles totales. El cultivar con potencial de ingrediente funcional fue Ataulfo, en el que el polvo del pericarpio mostró una capacidad antioxidante de 34,811 μmol ET g^{-1} y 7578 mg de EAG 100 g^{-1} de fenoles totales. Los tres cultivares evaluados pueden considerarse como ingredientes para agregar o enriquecer la fibra en formulaciones de alimentos.

Palabras Clave: mango, pericarpio, nutricional, funcional, polvo.

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Introduction

The mango production in Mexico (*Mangifera indica* L.) has managed to stay at one million tons per year for the last decade. Among the cultivars with the largest cultivated areas are Ataulfo, Manila, Tommy Atkins, Haden, Kent, Keitt and Criollo (SIAP, 2017). The mango consumption is mainly as fresh fruit, but also is processed into value-added products such as juices, jams, candies, frozen and dried, among others (Siddiq, Sogi & Roidoung, 2017). However, the industrial processing generates waste by-products, which are not commercially exploited. These wastes, composed primarily of pericarp, endocarp and cotyledon, represent 28 to 38 % of the total content of the fruit (Sumaya-Martínez, Sánchez-Herrera, Torres-García & García-Paredes, 2012) and when not used, generate environmental problems due to microbial development and unpleasant odors formed by their decomposition (Jahurul *et al*., 2015). Furthermore, the consumption of functional foods has become popular in recent years and is defined by the Functional Food Center (FFC) "*as natural or processed foods that contains known or unknown biologically-active compounds; the foods, in defined, effective, and non-toxic amounts, provide a clinically proven and documented health benefit for the prevention, management, or treatment of chronic disease*" (Martirosyan & Singh, 2015). Mango peel contains antioxidants and dietary fiber and can be used in food preparations for the health benefits (Serna-Cook, García-Gonzales & Torres-León, 2016; Ajila, Aalami, Leelavathi & Rao, 2010). For those reasons, the aim of this study was to characterize the nutritional content and antioxidant capacity of pericarp powders of Ataulfo mango, Keitt and Tommy Atkins cultivars for possible applications in value-added products.

Materials and methods

Mangos of Ataulfo, Keitt and Tommy Atkins cultivars in state of maturity for consumption produced in Escuinapa, Sinaloa, were collected from June to September 2017 at harvest maturity. The pericarp was manually separated at the Laboratory of Protected Agriculture and Postharvest CIAD Culiacán and stored at -20 °C until use. Subsequently, it was dehydrated for five hours at 80 ºC (Excalibur® dehydrator, model Comm 2). The particle size was reduced using a Pulvex 200® mill (ø 2 mm) and stored in Ziploc® bags at room temperature. The powders obtained were characterized with the protocols of the AOAC (AOAC, 1998) in moisture content (920.39), ash (942.05), protein (988.05), fat (920.39), and minerals (955.06). The total dietary fiber, soluble and insoluble, was determined using the method 32-05.01 of the AACC (McCleary, Sloane, Draga & Lazewska, 2013). Finally, the proximal carbohydrate content was calculated by difference*: % carbohydrates = [100 – (% ash + % moisture + % fat + % protein)].*

Total phenols

The phenolic compounds were extracted according to Adom & Liu (2002) and Vázquez-Olivo, López-Martínez, Contreras-Angulo & Heredia (2017) with modifications. Briefly, samples of pericarp powder (2.5 g) were mixed with 10 mL of 80 % ethanol (v v^{-1}), homogenized 10 s (Ultra-Turrax, homogenizer) and incubated for two hours with shaking at 200 rpm at room temperature (25 °C). Then, they were centrifuged (10, 000 rpm) (Thermo Fisher Scientific®, Sorvall Legend XTR) for 15 minutes at 4 ºC. In a 96-well microplate, 10 µL extract, 10 µl of blank (ethanol 80 %) and standard curve of gallic acid in concentrations of 0 to 0.4 mg mL^{-1} (10 µL per concentration) diluted in ethanol 80 % (v v^{-1}) were separately distributed. To each treatment, 230 µL of distilled water and 10 µL de of Folin-Ciocalteu reagent (2 N) were added and incubated for three minutes at 25 °C in the absence of light. Then 25 µL of Na_2CO_3 (4 N) was added, incubated for 2 h at 25 °C and the absorbance measured at 725 nm in microplate reader (Synergy HT, BioTek®, Co. EUA). The content of total phenols was determined from the standard curve of gallic acid, and the results were expressed in mg equivalent of gallic acid per 100 g (mg EAG 100 g^{-1}).

Antioxidant Capacity

The antioxidant capacity was quantified by the ORAC method (Oxygen Radical Aborbance Capacity), as reported by Huang, Ou, Hampsch-Woodill, Flanagan & Prior (2002), and modified by Vázquez-Olivo, López-Martínez, Contreras-Angulo & Heredia (2017). AAPH (2,2-azo-bis-2-methylpropanamide dihydrochloride, Sigma-Aldrich®) and fluorescein (Sigma-Aldrich®) were used. The standard Trolox curve was prepared with the concentrations: 6.25, 12.5, 25, 50, 75, 100 y 125 µM. The measurements were performed in 96-wells plates with a Synergy HT microplate reader (BioTek®, Co. EUA) at 37 ºC. The results were expressed in µmol equivalents of Trolox per 100 g (µmol ET 100 g^{-1}).

Experiment design and statistical analysis

The design of the experiment was completely random of one factor (cultivar). Mean (n=3) and standard deviations of the response variables were obtained and an analysis of variance (ANOVA) was performed with subsequent comparisons of statistical groups with the Tukey test ($p \leq 0.05$) utilizing the statistical program JMP V5. 5.0 (USA).

Results and discussion

The proximal analysis of the mango pericarp powders of Ataulfo, Keitt and Tommy Atkins is shown in Table I. In percentage of moisture, significant differences were found in ethereal extract and carbohydrates ($p \leq 0.05$) between cultivars. The pericarp powder Tommy Atkins contains higher moisture (8.57 %) compared to Keitt and Ataulfo. The lower content of water in pericarp powders of the Keitt and Ataulfo cultivars may be due to the differences in composition of the ethereal extract content, as having a higher concentration of hydrophobic compounds, and the hydrophobic repulsion with water eases its evaporation in the dehydrator. Regarding the percentage of moisture values, <6 % is suitable to maintain stability in food (Barbosa, Fontana, Schmidt & Labuza, 2007). In the mango pericarp powders of this study, the moisture contents were higher than 6 % and lower than 9 %; however, it could be reduced to the ideal percentage if the dehydration times are extended. Moreover, Ajila, Leelavathi & Rao (2008) report percentages of ethereal extract, ash and total protein in 2.2 %, 3.0 % and 3.6 %, respectively, for ripe mango dehydrated for 18 hours at 50 °C. Although the evaluated cultivar was not reported, its proximal composition is similar to the one obtained in this investigation. Also, similar results were found to those reported by Serna-Cock, Torres-León & Ayala-Aponte (2015a) where they report ethereal extracts of 1.87 % and 1.78 % for mango Keitt and Tommy Atkins, respectively.

The Table II shows the mineral content. Significant differences were obtained ($p \leq 0.05$) between cultivars. In Ataulfo, the minerals manganese (Mn), zinc (Zn), copper (Cu) and potassium (K) were higher than Keitt and Tommy Atkins cultivars. The content of potassium, calcium, magnesium (Mg) and manganese found in Ataulfo, Keitt and Tommy Atkins mango powders can be an alternative source of the micronutrients in food formulations (Araújo *et al*, 2014).

In antioxidant capacity and total phenols (Table III), the pericarp powder of Ataulfo cultivar showed significant differences ($p \leq 0.05$) with respect to Keitt and Tommy Atkins cultivars. The mango pericarp is a product with potential as an antioxidant. Among the phenolic compounds that can be found in this tissue are quercetin and its derivatives, ellagic acid, mangiferin and derivatives, carotenoids, tocopherols, and sterols, among others (Dorta, Lobo & González, 2012). García, García, Bello-Pérez, Sáyago-Ayerdi & Oca (2013) reported that the lyophilized pericarp of the Ataulfo mango resulted in a higher phenolic content (6813 mg EAG 100 g^{-1}**),** as well as greater antioxidant capacity (1276 µmol ET 100 g^{-1}) when compared to the pericarp of the Tommy Atkins cultivar.The results obtained in this study were higher in antioxidant capacity and phenol content (Table III).

The composition of antioxidants is of interest because there is a reduction of antioxidant compounds in dehydrated with the application of forced heat with temperature over 70 °C (Dorta, Lobo & González, 2012). However, the concentration of antioxidants obtained after dehydrated (80 °C) in mango pericarp powders does not affect the possible use for antioxidant properties.

The dietary fiber content obtained for mango pericarp powders can be considered as an ingredient for functional foods. This is because the total dietary fiber content of mango pericarps is superior to other commercial products considered high in dietary fiber, such as bread whole wheat and rye bread (Serna-Cock *et al*., 2015a; Serna-Cock *et al*., 2015b). The soluble

Cultivar	Moisture	Ethereal extract	Protein	Ashes	Carbohydrates
Ataulfo	6.96±0.43^{b}	1.866±0.080^{b}	2.573±0.899^{a}	2.133± 0.038 ^{a}	92.95±0.797^{ab}
Keitt	6.68±0.0.10^{b}	2.27±0.048^{a}	2.707±0.163^{a}	2.074±0.113 ^{a}	92.955±0.105^{b}
Tommy Atkins	8.57±0.09^{a}	1.33±0.049^{c}	1.980±0.477^{a}	2.165±0.111 ^{a}	93.955±0.281^{a}
Average percentages (n=3) and standard deviation expressed in a dry weigh basis. Means with different letter in columns are statistically different (Tukey, $p \leq 0.05$).					

Table I. Proximal analysis of mango pericarp powder.

Mineral (ppm)	Mango cultivar		
	Ataulfo	Keitt	Tommy Atkins
Fe	16.49±2.47^{a}	13.69±0.49^{a}	17.16±2.93^{a}
Mn	33.32±0.95^{a}	18.92±0.56^{b}	20.19±0.15^{b}
Zn	7.98±0.09^{a}	5.07±0.93^{b}	6.02±0.11^{b}
Cu	4.60±0.26^{a}	2.10±0.14^{b}	3.28±0.14^{c}
K	8363.94±622.56^{a}	6643±415.12^{b}	6986±137.73^{b}
Ca	3917.79±13.53^{a}	2361.11±239.26^{b}	3639.42±20.10^{a}
Mg	1232.33±2.78^{a}	949.42±99.9470^{b}	1144.95±12.91^{a}
Average concentrations (n=3) and standard deviation expressed in dry weight basis. Means with same letter in files are not statistically different (Tukey, $p \leq 0.05$).			

Table II. Mineral content of mango pericarp powder.

and insoluble fiber contents in mango pericarp powders was higher than 19 % and 9 %, respectively for the three cultivars (Table IV). Serna-Cock, Torres-León & Ayala-Aponte (2015b) reported total fiber content (soluble and insoluble) for lyophilized powders of Keitt mango above 22 %. The pericarp powders of Ataulfo, Keitt and Tommy Atkins samples in this study contain 38, 28, and 39 %, respectively, of total fiber. However, Hincapíe, Vásquez, Galicia & Hincapíe (2014) reported the total dietary fiber content higher than 60 % for mangoes commercially obtained and crude fiber of 18 %, higher values to those obtained in this study. The differences in fiber content may be due to the process of water elimination, pre-harvest conditions and state of maturity of the mango, although in all cases, the fiber content can be considered high. Therefore, if the interest of obtaining pericarp powders is the use of total dietary fiber, the method used in this study may be acceptable.

With respect to its use as an ingredient in food, functions due to its composition Serna-Cock, Torres-León & Ayala-Aponte (2015b) recommend the use of pericarp powders of Keitt and Tommy Atkins cultivars as emulsifying agents in the food industry, as well as constituents in the functional food formulation. In macaroni, Ajila, Aalami, Leelavathi & Rao (2010) incorporated mango peel and obtained major properties functional because an increase in antioxidant properties and dietary fiber from mango peel.

Conclusions

The mango pericarp powders of the Ataulfo, Keiit and Tommy Atkins cultivars can complement the nutritional and functional content in the food formulation due to their antioxidant capacity and fiber content. Future studies focusing on assessing the shelf life and use as an ingredient in functional foods could be carried in order to evaluate the potential of this ingredients as functional foods.

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Cultivar	Antioxidant capacity (μmol ET 100 g^{-1})	Phenol content (mg EAG 100 g^{-1})
Ataulfo	34811±2.96^{a}	7578±10.09^{a}
Keitt	27256±50.77^{b}	5228±8.24^{b}
Tommy Atkins	23270±9.38^{b}	3857±5.35^{b}

Average concentrations (n=3) and standard deviation expressed in dry weight basis. Means with different letter in columns are statistically different (Tukey, p ≤ 0.05).

Table III. Antioxidant capacity and phenol content of mango pericarp powders.

Cultivar	Soluble fiber	Insoluble fiber
Ataulfo	23.84±4.61^{a}	15.16±3.24^{a}
Keitt	19.18±1.09^{a}	9.73±4.89^{a}
Tommy	23.31±4.16^{a}	16.53±0.26^{a}

Average concentrations (n=3) and standard deviation expressed in dry weight basis. Means with same letter in columns are not statistically different (Tukey, p ≤ 0.05).

Table IV. Dietary fiber content of mango pericarp powder.

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