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Influence of whole and fresh-cut mango intake on plasma lipids and antioxidant capacity of healthy adults

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ABSTRACT

The content of antioxidant compounds and antioxidant capacity of whole and fresh-cut mango, stored for 10 days at 12 °C and 5 °C, respectively and their influence on serum antioxidant capacity and lipid profile of normolipidemic humans were studied. Whole mango (WM) had a higher content of flavonoids, β-carotene and antioxidant capacity, determined by oxygen radical scavenging capacity, (ORAC) and 1,1-diphenyl-2-picrylhydrazyl (DPPH) assays, than the fresh-cut fruit (FCM). FCM presented higher amounts of total phenols. Thirty normolipidemic volunteers, ages 20–50 years, were randomly divided into two groups (WM and FCM) 15 persons each. During 30 consecutive days volunteers from groups 1 and 2, received daily 200 g of WM or FCM, respectively. Lipid levels and antioxidant capacity in plasma were determined at 0, 15 and 30 days of the experiment. Serum triglycerides were significantly reduced after 30 days of supplementation with WM and FCM (37 and 38% respectively); VLDL levels were reduced in a similar proportion. No significant changes in other plasma lipid levels were observed. Both treatments increased plasma antioxidant capacity measured by ORAC and TEAC methods. According to the results obtained in this study, we suggest that addition of mango fruit to generally accepted healthy diets could have a beneficial effect preventing hypertryglyceridemia, and that fresh-cut processing does not affect the beneficial properties of mango.

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1. Introduction

Epidemiological studies have shown that consumption of fruits and vegetables is associated with reduced risk of chronic diseases including coronary artery disease (CAD) (Lampe, 1999). Oxidative processes, in particular oxidation of low-density lipoprotein (LDL) cholesterol, are believed to be important etiologic factors in the development of CAD (Halliwell, 2001), and fruits and vegetables are rich in antioxidant phytochemicals (Gorinstein et al., 2011; Kim, Brecht, & Talcott, 2007). Therefore, the health protective effects of fruit and vegetable intake observed in epidemiological studies may be due, at least in part, to the presence of antioxidants in these foods (Liu, 2003).

Tropical fruits, particularly mango (Mangifera indica L.), have high content of antioxidant compounds, including phenolics (Vijaya Kumar Reddy, Sreeramulu, & Raghunath, 2010), carotenoids, and vitamin C (González-Aguilar et al., 2008). Mexico is one of the major producers and exporters of various mango cultivars, including the 'Ataulfo' variety, which is nowadays, the most popular mango cultivar of American and Mexican consumers. Due to its good texture and flavor this cultivar has attracted attention for minimal processing as a fresh-cut product (González-Aguilar et al., 2008). Previous work has demonstrated that fresh-cut 'Ataulfo' mango treated with antioxidant solutions conserves its sensorial and commercial quality, for more than 10 days of storage at 5 °C, although some loss in bioactive antioxidant compounds, such as β-carotene and vitamin C, occurred (González-Aguilar et al., 2008; Robles-Sánchez, Rojas-Graü, Odriozola-Serrano, González-Aguilar, & Martín-Belloso, 2009). It is not clear if those losses influence the beneficial effect of mango intake in the prevention of cardiovascular and other diseases. Mango extracts rich in antioxidant compounds have recently shown potent effects in promoting in vitro events associated with formation of new blood vessels

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(Daud et al., 2010) and inhibiting cancer cells proliferation (Noratto et al., 2010); however, the *in vivo* effects of mango consumption in humans have, to our knowledge, not been reported.

Since mango ranks among the fruits preferred by the Mexican population (Hervert-Hernández et al., 2011), it is rich in bioactive compounds and suitable for minimal processing, the objective of this work was to compare the *in vitro* antioxidant potential between whole and fresh-cut mango, and to assess *in vivo* their influence on plasma lipids and antioxidant activities in healthy human subjects.

2. Materials and methods

2.1. Reagents

Fluorescein (FL), 6-hydroxy-2,5,7,8-tetramethyl-chroman-2-carboxylic acid (Trolox) and 2,2-diphenyl-2-picrylhydrazyl hydrate (DPPH) were purchased from Aldrich (Milwaukee, WI); 2,2′-azobis(2-amidinopropane) dihydrochloride (AAPH) was obtained from Wako Chemicals USA (Richmond, VA); 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS), potassium persulfate, Folin–Ciocalteau reagent, butylhydroxytoluene (BHT), and hydroquinone (HQ) were obtained from Sigma Chemical Co. (St. Louis, MO, USA). All other standards and solvents were of analytical grade and commercially available from Sigma or Aldrich. Deionized and distilled water was used throughout the research.

2.2. Fruit samples

Mature green mangos (*Mangifera indica* L.) cv. 'Ataulfo' were harvested in Chiapas, Mexico and transported to the laboratory during March and April 2008. Fruits were selected to eliminate damaged, defective or ripe fruits, and, then stored at 15 °C until use. Mangos with flesh firmness between 15 and 27 N were used. Mangos were submerged in a solution containing 200 ppm sodium hypochlorite (6% NaClO) of a commercial bleach preparation (Cloralex™, NL, Mexico) for 3 min. Mangos were air-dried at room temperature. Fruits were peeled with a sharp vegetable peeler, and the flesh was sliced from the seed into halves with a sharp non-serrated knife. Mango slices were cut into 2×2×2 cm cubes and treated as follows.

2.3. Dipping treatment for fresh-cut mangos

The dipping treatment was similar to that reported in a previous work (González-Aguilar et al., 2008). Mango cubes were dipped in aqueous solution of 1% ascorbic acid (AA)+1% citric acid (CA)+1% $CaCl_2$ for 3 min and drained. The cubes were distributed in polypropylene plastic trays (200 g, each) and covered with lids of the same material. Trays containing the fresh-cut mangos were stored at 5 °C for 10 days. Parallel to this experiment, whole mangos were stored at 12 °C for 10 days. Antioxidant compounds content and antioxidant capacity for both fresh-cut and whole samples were evaluated at the end of the storage period (10 days).

2.4. Extraction of polyphenols

Methanolic extracts of samples were prepared according to Shivashankara, Isobe, Al-Haq, Takenaka, and Shiina (2004). Briefly, 20 g of fresh sample was mixed with 15 mL of 80% methanol (v/v), and homogenized with an Ultra-Turrax T 25 basic (IKA® WERKE, Germany); thereafter, the homogenate was sonicated for 15 min and centrifuged at 10,000 rpm at 5 °C for 15 min. The sample was vacuum-filtered through Whatman No. 1. This procedure was repeated twice to assure the maximum extraction of polyphenols. The extracts were collected and the volume adjusted to 50 mL with 80% methanol, further dilutions were made up with methanol 80%. The final concentration of the extract was 0.4 g/mL of the original mango pulp and was used for total phenols, flavonoids, ORAC, and DPPH assays.

2.5. Total polyphenols

Phenols were measured spectrophotometrically using the Folin–Ciocalteu reagent with gallic acid (GA) as standard. Briefly, 50 μL of mango extract was added to 3 mL of deionized water plus 250 μL of Folin–Ciocalteu reagent (diluted 2-fold before use), after 5 min, 250 μL of 7% Na_2CO_3 solution was added. The mixture was made up to 5 mL with deionized water and incubated for 90 min at room temperature. Absorbance was measured at 750 and results were reported as mg of gallic acid equivalents (GAE) per 100 g of fresh weight (FW).

2.6. Total flavonoids

Flavonoids were determined as previously described, using 5% $NaNO_2$, 10% $AlCl_3$ and 1 M NaOH. Absorbance was measured spectrophotometrically at 415 nm using quercetin as standard. The results were expressed as mg of quercetin equivalents (QE) per 100 g of FW (Dae-Ok, Seung, & Chang, 2003).

2.7. Total antioxidant capacity

2.7.1. ORAC assay

This assay measures the effect of antioxidant components in fruits and other foods on the decline in fluorescence of fluorescein induced by a peroxyl radical generator. The mango extracts were subjected to the ORAC assay as described by Alvarez-Parrilla et al. (2010) with minor modifications. Briefly, 20 μL of appropriately diluted sample or trolox standard was mixed with 120 μL fluoresceine (80 nM) and 60 μL AAPH (40 mM). Fluorescence was measured every 2 min for 60 min in a FLx800tbi plate reader (Bio-Tek Instruments, Winooski, VT, USA), with excitation and emission filters of 485/20 and 528/25, respectively. Results were expressed as micromoles of Trolox equivalent per 100 g of FW.

2.7.2. DPPH assay

This assay is based on the measurement of the scavenging ability of antioxidants towards the stable radical DPPH (Brand-Williams, Cuvelier, & Berset, 1995). Mango extracts were diluted to a final concentration of 0.06 mg/mL and 3.9 mL of a methanolic solution of DPPH (2.5 mg/100 mL MeOH) were mixed with 0.1 mL of each sample, and shaken vigorously. The tubes were allowed to stand at 27 °C for 20 min. The control was prepared as above without any extract, and MeOH was used for the baseline correction. Changes in the absorbance of the samples were measured at 515 nm. Radical scavenging activity (RSA) was expressed as the inhibition percentage and calculated as follows:

$$\%RSA = \frac{Abs_{control} - Abs_{sample}}{Abs_{control}} \times 100.$$

2.8. Vitamin C

This analysis was performed according to (González-Aguilar et al., 2008) with some modifications. Twenty five grams of fresh sample was added to 25 mL of a mixture of metaphosphoric: DL-1, 4-dithiotreitol (DTT) (4.5:0.72%/v) and homogenized with Ultra-Turrax T 25 basic S1 (IKA-Works Inc., Wilmington, NC 28405, USA). The sample was vacuum-filtered through Whatman No. 1. Then, an aliquot was passed through a 0.45 μm membrane filter and was ready to be injected in the HPLC system.

The HPLC system was equipped with a 600 Controller and a 486 Absorbance Detector (Waters, Milford, MA) working at 245 nm. Samples were introduced onto the column through a manual injector equipped with a sample loop (20 μL). The flow rate was fixed at 1.0 mL/min at room

temperature. A reverse-phase C18 Spherisorb ODS2 (5 μm) stainless steel column (4.6 mm × 250 mm) was used as stationary phase. The mobile phase was a 0.01% solution of sulphuric acid adjusted to pH 2.6. The concentration of vitamin C was calculated using ascorbic acid as external standard and expressed as mg ascorbic acid per 100 g of FW.

2.9. β-carotene

This determination was performed according to Mejía, Hudson, González, and Vázquez (1988). Five grams of fresh sample was added to 20 mL of tetrahydrofuran (THF) and homogenized with Ultra-Turrax T 25 basic S1 (IKA-Works Inc., Wilmington, NC 28405, USA). One aliquot was filtered through a 0.45 μm membrane and injected to a chromatographic system. The analysis was performed by HPLC (Varian 9012 solvent delivery system, California, USA), using an analytical column Microsorb RP-C18 (4.6 × 100 mm, 3 μm), 10 μL loop injector. The mobile phase was acetonitrile:methanol:THF (58:35:7 v/v), with isocratic flow at a rate of 1.5 mL/min. β-carotene content was detected by UV–Vis (Variable Wavelenght UV–Vis Detector, Varian 9050, California, U.S.A.) at 460 nm. The concentration of β-carotene was calculated using β-carotene as external standard and expressed as mg β-carotene per 100 g FW.

2.10. Vitamin E

Vitamin E was determined as α-tocopherol according to Hess, Keller, Oberlin, Bonfanti, and Schuep (1991). Six grams of fresh samples was weighed into glass tubes. Afterwards 5 mL of 13.8 M KOH solution, 16 mL of ethanol and 0.1 g of HQ were added. The mixture was homogenized with Ultra-Turrax T 25 basic S1 (IKA-Works Inc., Wilmington, NC 28405, USA) and maintained at 80 °C in a water bath for 30 min. After this period, were cooled in current water and 16 mL of diethyl ether was added. Tubes were shaken for 30 s to allow efficient extraction, thereafter placed in the dark during 10 min for phase separation. An aliquot of the upper layer was transferred and filtered through 0.45 μm filters into eppendorf tubes and injected to chromatographic system (Varian 9012 solvent delivery system, California, USA), using an analytical column Microsorb RP-C18 (4.6 × 100 mm, 3 μm) and 10 μL loop injector. The mobile phase was methanol:water (98:2 v/v), with isocratic flow at a rate of 1.0 mL/min. α-tocopherol content was detected at 290 nm using a UV–Vis detector (Varian 9050, California, U.S.A.). The concentration of Vitamin E was calculated using α-tocopherol as external standard and expressed as mg α-tocopherol per 100 g of FW.

2.11. Subjects and dietary intervention

Thirty volunteers (body mass index <26 kg/m^2) between 20 and 50 years of age were selected from the laboratory staff. All participants were considered in good health, based upon a medical history questionnaire. All subjects fulfilled the following eligibility criteria: 1) no history of cardiovascular, hepatic, gastrointestinal, or renal disease; 2) no alcoholism; 3) no antibiotic or supplemental vitamin and/or mineral use for at least 4 weeks before the start of the study, and 4) non smoking. The study protocol was approved by the Ethics Committee of the Centro de Investigación en Alimentación y Desarrollo (CIAD) of Hermosillo, Sonora, Mexico and written informed consent was signed by each person. The subjects were asked to maintain their normal diets constant as possible during the period of the study and avoid the intake of any drug or vitamin supplement.

Subjects were asked to eliminate mango and mango products from their diet, and consume only those mangos provided during the 30 days of the study. The subjects were then randomly assigned to either the whole mango (WM; n = 15) or the fresh-cut mango (FCM; n = 15) diet group for a period of 30 days. The experiment was designed to evaluate the effect of the consumption of fresh-cut or whole mango stored for 10 days. Therefore, both groups received daily mango servings with fruits that had been stored for this period of time, during the whole experiment (30 days).

Blood samples (5 mL) were collected at zero time (baseline sample); thereafter, all volunteers received 200 g of mango/day during 30 days. Additional blood samples were collected on days 15 and 30 of the dietary intervention.

2.12. Analysis of plasma samples

Baseline, 15 and 30-day blood samples were collected in tubes containing ethylenediamine tetraacetic acid (EDTA, 1.4 mg/mL), and plasma was immediately separated by centrifugation at 2500 rpm, 15 min, at 4 °C. Total cholesterol (TC), triacylglycerides (TG), and high-density lipoprotein cholesterol (HDL) were determined by enzymatic methods using commercial test kits. Very low density lipoprotein cholesterol (VLDL) was calculated dividing TG/5 while low density lipoprotein cholesterol (LDL) was calculated as:

$$LDL = TC - (HDL + VLDL).$$

2.12.1. Antioxidant capacity of plasma

To avoid protein interference in antioxidant capacity assays, the plasma was diluted with 0.5 mol/L perchloric acid (1:1, v/v). The samples were then centrifuged at 10,000 rpm for 10 min at 4 °C, and the supernatants were collected as protein-free plasma fractions. The plasma antioxidant capacity was determined by the trolox-equivalent antioxidant capacity test (TEAC) and ORAC assays.

ORAC assay was preformed as described for fruit samples only that standards and plasma samples were diluted with phosphate buffer instead of methanol (Alvarez-Parrilla et al., 2010). TEAC assay measures the scavenging ability of antioxidant compounds against ABTS•$^-$. Protein-free plasma was analyzed with the TEAC assay, according to Re et al. (1999), using Trolox as standard. For both assays, results were expressed as millimoles of Trolox equivalents per liter.

2.13. Statistical analysis

All analyses of bioactive compounds concentration, antioxidant capacity of fruits and plasma, and plasma lipids were repeated 5 times, means and standard deviations (means ± SD) were calculated. When appropriate, differences between fresh-cut or whole mango were tested by ANOVA ($p \leq 0.05$). Data of plasma lipids and antioxidant capacity were tested by ANOVA and Tukey's post-hoc test ($p \leq 0.05$) for differences between baseline, 15 and 30 days of supplementation for each dietary group, using the statistical software SAS version 8.0 (SAS Inst. Inc. Cary, NC, USA) . No gender and age related effects were noted in any of the variables examined, and, therefore, the analysis was conducted on the entire subject population. In order to eliminate variability between treatment groups, initial values for plasma lipids and antioxidant capacity were determined using the initial values of the 30 participants.

3. Results

3.1. Antioxidant compounds and antioxidant capacity of WM and FCM

Table 1 summarizes the bioactive compound contents of WM and FCM samples stored for 10 days at 12 °C and 5 °C, respectively. Concentration of total phenols in FCM was significantly higher than in WM (116.7 ± 1.2 mg·100 g^{-1} FW and 110.7 ± 1.1 mg·100 g^{-1} FW, respectively). However, WM contained higher flavonoids content than FCM.

The main carotene present in the 'Ataulfo' cultivar was β-carotene, whereas α-carotene was present only in small amounts (data not shown). The content of β-carotene was 4.47 ± 0.31 mg·100 g^{-1} FW and 3.03 ± 0.08 mg·100 g^{-1} FW for whole and fresh-cut fruit, respectively. Ascorbic acid content for WM was 93.59 ± 4.2 mg·100 g^{-1} FW, a lower

Table 1
Total phenols (TP), total flavonoids (TF), β-carotene, vitamin C, and vitamin E in whole (WM) and fresh-cut mango (FCM) stored for 10 days at 12 °C and 5 °C, respectively.

Samples	TP mgGAE·100 g^{-1} FW	TF mgQE·100 g^{-1} FW	β-carotene mg·100 g^{-1} FW	Vitamin C	Vitamin E
WM	110.7 ± 1.1[a]	16.9 ± 0.9[b]	4.47 ± 0.31[b]	93.5 ± 4.5[b]	0.92 ± 0.02[a]
FCM	116.0 ± 1.2[b]	11.2 ± 0.2[a]	3.03 ± 0.08[a]	86.7 ± 6.3[a]	0.93 ± 0.03[a]

mg/100 g FW; values are means ± SD of five measurements. Means in columns without letters in common differ significantly ($p \leq 0.05$).

level of this vitamin was observed in FCM (86.7 ± 6.3 mg·100 g^{-1} FW). Vitamin E content was 0.92 ± 0.02 and 0.93 ± 0.03 mg·100 g^{-1} FW for WM and FCM, respectively.

Table 2 shows the antioxidant capacity measured as DPPH (%RSA) and ORAC (μmol TE·100 g^{-1} FW) for WM and FCM stored 10 days at 12 °C and 5 °C, respectively. Significant differences in antioxidant capacity between WM and FCM for both DPPH and ORAC assays were observed. FCM had lower values than WM.

3.2. In vivo study

Table 3 summarizes the changes in fasting plasma lipids in response to dietary supplementation with WM and FCM during 30 days. All subjects had normolipidemic values, as expected. Lipid status was maintained stable in both groups, supplemented with either WM or FCM, except for triacylglycerides and VLDL levels, which were significantly reduced by both treatments. At 30 days of mango supplementation fasting plasma triacylglycerides were reduced by 37 and 38%, respectively in WM and FCM groups respectively. VLDL levels were reduced for both dietary groups in a similar proportion (34 and 35%, respectively).

A significant effect ($p \leq 0.05$) on fasting plasma antioxidant capacity levels measured as TEAC and ORAC was observed in both dietary groups (Table 4). At 15 days of dietary intervention, the values where highest for both groups and both methods, and at the end of the study (30 days), the plasma antioxidant capacity was slightly reduced but still higher than the baseline values, except when analyzed by TEAC in the WM group.

4. Discussion

Epidemiological studies have shown that high intake of fruits and vegetables is associated with reduced risk of cardiovascular diseases. Most fruits and vegetables contain significant quantities of polyphenolic compounds, in addition to variable amounts of antioxidant vitamins, including C, E, and β-carotene. The antioxidant capacity provided by whole fruits and vegetables in the diet is very important because the reactive oxygen species produced during oxidative processes are the key for the initiation of atherosclerosis (Steingerg, Parthasarathy, Carew, Khoo, & Witztum, 1989). Moreover some classes of polyphenolic compounds are believed to be effective in preventing cardiovascular disease by reducing chronic inflammation and improving endothelial function by up-regulating endothelial nitric oxide synthase (eNOS) expression and increasing production of endothelial cell nitric oxide (Erdman et al., 2007). In order to promote the intake of fresh-cut fruits like mangos, recently we evaluated the shelf-life and nutritional changes of whole and fresh-cut mangos, during storage (González-

Aguilar et al., 2008; Robles-Sánchez et al., 2009). In that study we observed that FCM had similar losses in antioxidant compounds content than WM. Losses in vitamins C, E and β-carotene were considerably higher in FCM than in WM; however, losses of phenolic compounds were lower, during the same period of storage. In that study we found that phenolic compounds appear to be the responsible of maintaining the antioxidant capacity in both, FCM and WM.

In the present study, we observed that concentration of phenolic compounds was higher in FCM, than in WM after 10 days of storage. In contrast, flavonoid, vitamin C and β-carotene concentrations were lower in FCM. Vitamin E was similar in both whole and fresh-cut fruits. Dipping treatments using antioxidants to preserve the commercial quality do not avoid losses of antioxidant compounds during storage, but help to hinder the oxidation of other components, such as phenols. DPPH and ORAC results showed that antioxidant capacity was lower in FCM, than in WM. These results could be due to the lower flavonoid and vitamin C content in FCM.

Antioxidant capacity measured as ORAC has been assessed in some tropical fruits such as pineapple (793 μmol TE per 100 g FW), banana (879 μmol TE per 100 g FW), papaya (384.8 μmol TE per 100 g FW), and mango cv. 'Kent' (256.2 μmol TE per 100 g FW) showing that whole 'Ataulfo' mango has higher antioxidant capacity than all these fruits, except banana (Rivera-Lopez, Vazquez-Ortiz, Ayala-Zavala, Sotelo-Mundo, & Gonzalez-Aguilar, 2005; Robles-Sánchez et al., 2009; Wu et al., 2004).

For the *in vivo* study, we decided to select samples of WM and FCM stored for 10 days at low temperature, based on our previous work, where we found that the FCM are microbiologically safe and accepted by more than 50% of consumers that tested mangos within this storage period (Robles-Sánchez et al., 2009).

The present study is to our knowledge, the first one to analyze the *in vivo* effect of whole or fresh-cut mango consumption by healthy normolipidemic subjects. We found that the dietary intervention significantly lowered fasting plasma triacylglycerides (TG). Reduction of plasma TG levels has also been observed in hyperlipidemic humans consuming diet containing red grape fruits (Gorinstein et al., 2006). Recent data has shown a strong association between serum triacylglycerides level and coronary atherosclerosis (Hamsten et al., 2005), This could indicate that 'Ataulfo' mango fruit could be considered as part of a healthy diet for hypertriacylglyceridemic prevention, however, further studies are needed to evaluate the effects of the consumption of this fruit in hyperlipidemic patients. It has been reported that mangiferin xanthone, a phenolic present in mango fruit, decreased triacylglycerides in an animal model of diabetes (Muraganadan, Srinivasan, Gupta, & Lal, 2005). Although mangiferin xanthone was not quantified in our samples, Schieber, Ullrich, and Carle (2000), detected mangiferin xanthone levels in flesh of about 4.4 mg/kg. Therefore, the presence of this compound could partially explain the large reduction of TG observed.

The dietary interventions had no significant effect on TC, HDL and LDL cholesterol fasting plasma concentrations; although a slight not-significant increase in TC and LDL was observed. Similar results have been found in other dietary interventions using fruits or vegetables in normolipidemic subjects (Alvarez-Parrilla et al., 2010; Ruel, Pomerleau, Couture, Lamarche, & Couillard, 2005).

Another relevant data was the increase of fasting plasma antioxidant capacity levels after 30 days of mango consumption. An increase in

Table 2
Antioxidant activity of whole (WM) and fresh-cut mango (FCM) stored for 10 days at 12 °C and 5 °C respectively.

Samples	DPPH %RSA	ORAC μmol TE·100 g^{-1} FW
WM	60.0 ± 2.0[b]	850.0 ± 1.7[b]
FCM	57.0 ± 1.2[a]	790.0 ± 0.2[a]

Values are means ± SD of five measurements. Means in columns without letters in common differ significantly ($p \leq 0.05$).

Table 3
Fasting plasma lipid concentrations of healthy human subjects before consumption of mango (FCM or WM) and after 15 and 30 days of dietary intervention.

Dietary group	Time	Plasma lipids (mg/dL)				
		TC	TG	HDL	VLDL	LDL
WM	0	152.2 ± 34.8^a	86.2 ± 40.7^b	47.0 ± 11.6^a	16.4 ± 6.8^b	86.9 ± 30.8^a
	15	165.9 ± 29.4^a	85.7 ± 37.8^b	45.7 ± 9.4^a	17.5 ± 7.5^b	103.0 ± 27.9^a
	30	149.7 ± 24.9^a	54.3 ± 32.5^a	44.9 ± 7.6^a	10.8 ± 6.5^a	93.7 ± 20.9^a
FCM	0	152.2 ± 34.8^a	86.2 ± 40.7^b	47.0 ± 11.6^a	16.4 ± 6.8^b	86.9 ± 30.8^a
	15	153.9 ± 36.2^a	58.0 ± 18.1^a	50.8 ± 10.2^a	11.6 ± 3.6^a	91.4 ± 32.3^a
	30	168.8 ± 29.6^a	53.5 ± 28.5^a	51.1 ± 12.1^a	10.7 ± 5.7^a	107.0 ± 26.6^a

Values are means $\pm$ SD of at least 15 subjects; initial values (time 0) were determined with the values from the 30 participants, values at days 15 and 30 were determined for each dietary group (15 participants). For each dietary intervention group, means in columns with different letters indicate statistically significant differences ($p \leq 0.05$). Abbreviations: WM, experimental group supplemented with 200 g of whole mango fruit; FCM, experimental group supplemented with 200 g of fresh-cut mango; TC, total cholesterol; TG, triacyglycerides; HDL, high density lipoprotein cholesterol; VLDL, very low density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol.

antioxidant capacity of plasma was also found in rats feed diets supplemented with mango juice for 4 months (García-Solís, Yahia, & Aceves, 2008). In another study, with human subjects supplemented during four weeks with 500 g of cactus pear pulp, a significant increase in plasma antioxidant capacity, vitamin C and E concentrations was observed (Tesoriere, Butera, Pintaudi, Allegra, & Livrea, 2004). Paiva, Yaum, Cao, Prior, and Russell (1998), showed that strawberry and red wine consumption significantly increased antioxidant capacity in serum. Alvarez-Parrilla et al. (2010) observed that fruit consumption for 4 weeks, increased plasma antioxidant capacity measured by ORAC and FRAP in healthy non-smoking adults. In agreement with the last study, in the present dietary intervention, an initial increase on the TAC measured by both methods, and followed by a slight decrease was observed.

The increased antioxidant capacity in plasma (ORAC and TEAC) following the consumption of whole and fresh-cut mango, could indicate a direct absorption of antioxidant phytochemicals and/or an enhanced production of antioxidants. On the other hand, because plasma proteins were removed in the ORAC and TEAC assays, the significant increase in serum antioxidant capacity, following these mango portions was mainly due to the non-protein antioxidants in plasma.

In conclusion, these results show that despite a decrease in flavonoids, vitamin C and β-carotene and antioxidant capacity found in FCM as compared to WM; daily consumption of both mango presentations for 30 days induced significant effects on plasma antioxidant capacity. This mango intake also decreased serum TG. With this background and the results presented here, it is possible to consider the mango cv. 'Ataulfo' a potential candidate to become part of a healthy diet in either whole or fresh-cut presentations. Future research should be focused on identifying the phenolic compounds in fresh-cut mangos and evaluating their bioavailability and health promoting properties.

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Table 4
Fasting plasma antioxidant capacity of healthy human subjects before consumption of mango (FCM or WM) and after 15 and 30 days of dietary intervention.

Dietary group	Time	Plasma antioxidant capacity (mmolTE/L)	
		TEAC	ORAC
WM	0	0.71 ± 0.07^a	0.31 ± 0.14^a
	15	0.78 ± 0.07^b	0.49 ± 0.18^b
	30	0.73 ± 0.08^a	0.46 ± 0.14^b
FCM	0	0.71 ± 0.07^a	0.31 ± 0.14^a
	15	0.85 ± 0.08^b	0.40 ± 0.15^a
	30	0.80 ± 0.10^b	0.37 ± 0.13^b

Values are means $\pm$ SD of at least 15 subjects; initial values (time 0) were determined with the values from the 30 participants, values at days 15 and 30 were determined for each dietary group (15 participants). For each dietary intervention group, means in columns with different letters indicate statistically significant differences ($p \leq 0.05$). ORAC, oxygen radical absorbance capacity; TEAC, trolox equivalent antioxidant capacity.

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