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RESEARCH ARTICLE

Pre-meal tomato (*Lycopersicon esculentum*) intake can have anti-obesity effects in young women?

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Abstract

The effect of pre-meal tomato intake in the anthropometric indices and blood levels of triglycerides, cholesterol, glucose, and uric acid of a young women population ($n = 35$, 19.6 ± 1.3 years) was evaluated. During 4 weeks, daily, participants ingested a raw ripe tomato ($\sim$90 g) before lunch. Their anthropometric and biochemical parameters were measured repeatedly during the follow-up time. At the end of the 4 weeks, significant reductions were observed on body weight (-1.09 ± 0.12 kg on average), % fat (-1.54 ± 0.52%), fasting blood glucose (-5.29 ± 0.80 mg/dl), triglycerides (-8.31 ± 1.34 mg/dl), cholesterol (-10.17 ± 1.21 mg/dl), and uric acid (-0.16 ± 0.04 mg/dl) of the participants. The tomato pre-meal ingestion seemed to interfere positively in body weight, fat percentage, and blood levels of glucose, triglycerides, cholesterol, and uric acid of the young adult women that participated in this study.

Keywords

Anti-obesity, blood lipids, glucose, tomato (*Lycopersicon esculentum*), uric acid

History

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Introduction

Intensive research efforts and nation level intervention programmes have been recently undertaken, in order to find solutions to reverse, or at least mitigate, the continuous increase of obesity worldwide (De Sa & Lock, 2008; Gordon-Larsen et al., 2010; Ogden et al., 2012). Growing evidence has been gathered indicating that antioxidant compounds may play a role in the prevention of obesity and related diseases (Peairs & Abbey, 2013). Vitamins and phenolic compounds, including flavonols and flavanones, have been suggested as having anti-obese and anti-diabetic effects (Hsu & Yen, 2008; Jeyakumar et al., 2008; Kaya et al., 2009; Renzaho et al., 2011). Although the precise function and metabolism in the human organism still remain relatively obscure for several of these compounds. An increasing number of authors argue that they play a major role in oxidative stress combat and, thereby, in metabolic syndrome and degenerative diseases prevention (Willcox et al., 2004). This has led to a rising interest in antioxidant supplements, with several studies reporting the potential of dietary antioxidant supplementation in the reduction of body weight and its beneficial effect on several obesity-related disorders (Valdecantos et al., 2009). There are even studies suggesting that women who consume high amounts of antioxidants before and during their pregnancies may be protecting their children against diabetes and obesity (Sen & Simmons, 2010).

Fruits and vegetables are naturally rich in antioxidant compounds thus supplying by ingestion these molecules to the organism. Furthermore, fruits and vegetables generally present a high water content, relatively low energy density, and relatively high content of dietary fibers. Indeed, several studies have reported that fruit and vegetable consumption increases postprandial satiety, subsequently decreasing hunger, which may lead to a decrease on the energy intake and, thereby, in body weight, as the theories behind satiety and weight loss advocate (Hetherington et al., 2013).

The aim of this study was to evaluate the short-term effect of pre-meal ingestion of a Portuguese tomato cultivar (*rama*) on glucose, triglycerides, cholesterol, and uric acid blood levels, and body weight and fat mass of a young adult women population. This tomato cultivar was chemically characterized with a special emphasis on bioactive compounds levels, and *in vitro* antioxidant activity, in order to find in this fruit composition the rationale for the potential role of tomato intake on the prevention of obesity, diabetes, and hyperuricemia, conditions with an increasing tendency worldwide (De Sa & Lock, 2008; Gordon-Larsen et al., 2010; Ogden et al., 2012; Roddy et al., 2007).

Subjects and methods

Study population

The sample population used in this study was exclusively composed by Caucasian women aged between 18 and 25 years (19.6 ± 1.3 years). All the study subjects were recruited from the student population of CESPU (*Cooperativa de Ensino Superior, Politécnico e Universitário, Famalicão*, Portugal) during the period from September to January. Volunteers signed a consent form after the approval of the Ethics Committee and had to fill out an anonymous survey on issues related to dietary habits, personal and direct relative's clinical history and use of

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medications. Individuals with smoking and alcohol drinking habits were excluded as well as those under medication (except birth control pill), suffering from some disease and with a family history of hypertension, coronary heart disease, and diabetes. The final sample size was 35. The participants had to eat a tomato (cv. *rama*) with an average mass of ~90 g per day before lunch, during 4 weeks. The ingested tomatoes presented similar weight and epidermal hue angle. The participants were encouraged to maintain their eating habits.

Anthropometric measures

The body weight and the percentages of body fat, fluid, and muscle were determined using a digital bio-impedance scale (BF 18, BG 34, Beurer, Ulm, Germany).

Biochemical blood analysis

Blood was collected by an analyst at the Clinical Analysis Laboratory of CESPU. At the time of blood sampling, the subjects were required to be fasting. During the follow-up time, three blood collections for each individual were carried out: the first sampling occurred on the beginning of the study, the second, 15 d after, and the third, 30 d after, in the end of the study. Blood was collected in evacuated tubes containing ethylenediaminetetraacetic acid to obtain the plasma for further analysis. The plasma concentrations of total cholesterol, glucose, triglycerides, and uric acid were assessed using CELM biochemical kits in an automated analyzer (Tokyo Boeki Prestige 24i, Tokyo Boeki Medisys Inc., Tokyo, Japan).

Tomato fruits

Tomato fruits from a Portuguese cultivar (*Lycopersicon esculentum* L. cv. *rama*) were conventionally produced in the North of Portugal (latitude: 41.3826, longitude: −8.76279 41°22′ 57″ North, 8° 45′ 46″ West). Fruits in pink maturity stage were randomly harvested from 10 different tomato plants located in the same plantation area.

Chemical characterization of the tomato fruits

Chemicals and methods

2,6-Dichlorophenol (Tillmans reagent), sodium carbonate, *n*-hexane, acetone, *b*-carotene, chloroform, Tween 40 emulsifier, ascorbic acid, and 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•) were obtained from Sigma-Aldrich (St. Louis, MO). Methanol, Folin–Ciocalteu reagent, sodium hydroxide, linoleic acid, and gallic acid were purchased from Panreac Química S.L.U. (Barcelona, Spain). All aqueous solutions were prepared with Milli Q filtered water (resistivity >18 MΩ.cm) (Millipore, Bedford, MA).

Samples preparation

Tomato samples were prepared by homogenizing (MX-291-N, National, Osaka, Japan) four freshly collected washed fruits. Samples were then transferred into an amber air-tight container, flushed with nitrogen, and stored at −20 °C. All analyses were performed within two weeks after sample preparation.

Phytochemicals composition

Ascorbic acid was determined, in triplicate, according to Vinha et al. (2014). Very briefly, samples were mixed with metaphosphoric acid (0.1 mg/ml) and 1 ml of filtrate was mixed with a 2,6-dichlorophenolindophenol solution. Quantification was performed spectrophotometrically at 515 nm using an ascorbic acid standard.

β-Carotene and lycopene were determined, in triplicate, according to Nagata & Yamashita (1992). Briefly, samples were extracted with acetone/hexane (2:3, v/v), and supernatants absorbance were measured at 453, 505, 645, and 663 nm. The contents of β-carotene and lycopene were calculated according to the following equations: β-carotene $(\text{mg}/100\,\text{ml}) = 0.216 \times A_{663} - 1.220 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}$; lycopene $(\text{mg}/100\,\text{ml}) = -0.0458 \times A_{663} + 0.204 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}$, and expressed in mg per 100 g of sample.

Total phenolics content was determined, in triplicate, according to Jang et al. (2007). Very briefly, samples were subjected to extraction with 80% methanol for 1 h. After filtration, an extract aliquot was added to 0.5 ml of the Folin–Ciocalteu reagent (1:10), and after 3 min, saturated sodium carbonate solution was added. After standing at room temperature for 120 min, absorbance readings were performed at 725 nm. As ascorbic acid also reacts with the Folin–Ciocalteu reagent, total phenolic contents were corrected for the ascorbic acid interference, according to Asami et al. (2003).

Phenolic compounds analysis by HPLC/DAD

Qualitative and quantitative analyses of phenolic compounds were performed according to the methodology described by Vinha et al. (2002) with minor modifications. Briefly, each sample (~1.5 g) was thoroughly mixed with methanol (80% v/v) until complete extraction of compounds (negative reaction to NaOH 20%). The extract was filtered, evaporated to dryness under reduced pressure (40 °C), and redissolved in methanol (5 ml). Chromatographic analysis was carried out on an HPLC unit (Gilson International, Villiers-Le-Bel, France), using a Spherisorb ODS2 column (250 × 4.6 mm, 5 µm) from Waters (Milford, MA). The solvent system used was a gradient of water–formic acid (19:1) (A) and methanol (B): 0′ – 5% B, 3′ – 15% B, 13′ – 25% B, 25′ – 30% B, 35′ – 35% B, 39′ – 40% B, 42′ – 45% B, 45′ – 45% B, 50′ – 47% B, 50′ – 47% B, 60′ – 48% B, 64′ – 50% B, 66′ – 100% B. The flow rate was 0.9 ml/min, and the injection volume was 20 µl. Chromatograms were recorded at 280 and 320 nm. Analyses were performed in triplicate. The compounds were identified based on their retention times and UV spectra compared with those of standards. Data were processed on the Unipoint® system software (UniPoint System, Middleton, WI). Results were expressed in mg/100 g of tomato sample.

Antioxidant activity

The antioxidant activity of tomato fruits was evaluated in methanolic and aqueous extracts obtained by mixing ~5 g of the homogenized tomato with 50 ml of methanol or water under constant stirring (1 h). All experimental steps were carried out under dim light and controlled temperature (21 °C).

Two methods were performed to evaluate antioxidant activity of samples: the 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•) inhibition and β-carotene linoleate model system assays. The scavenging ability of sample extracts against DPPH• was evaluated according to Vinha et al. (2014). The radical scavenging activity (RSA) was calculated as a percentage of DPPH• inhibition using the equation: $\%RSA = [(A_{DPPH} - A_S)/A_{DPPH}] \times 100$, where A_{DPPH} is the absorbance of the DPPH solution and A_S represents the absorbance of the sample extract with DPPH.

The β-carotene linoleate model system was performed according to the methodology described by Vinha et al. (2014). Briefly, 2 ml of a β-carotene solution (1 mg/5 ml chloroform) were pipetted into a 100 ml round-bottom flask. After the

chloroform was removed under vacuum, 40 mg of linoleic acid, 400 mg of Tween 40 emulsifier, and 100 ml of aerated distilled water were added with vigorous shaking. Aliquots of this emulsion (5 ml) were then transferred into different test tubes containing 1 ml of tomato extract. As soon as the emulsion was added to each tube, the zero time absorbance was read at 470 nm. The tubes were placed at 50 °C in a water bath. Measurement of absorbance was continued until the color of β-carotene disappeared; a blank, devoid of β-carotene, was prepared for background subtraction. Antioxidant activity percentage (%) was calculated using the following equation: antioxidant activity = (β-carotene content after 2 h of assay/initial β-carotene content) × 100.

Statistical analysis

Statistical analysis was performed using the program SPSS V.21.0® (SPSS Inc., Chicago, IL). ANOVA was used to assess significant changes in the dependent variables during the follow-up time. Every time the overall ANOVA result was significant, the Bonferroni post-hoc test was employed to make pairwise comparisons among means. Before applying the ANOVA analysis, the Kolmogorov–Smirnov test was used to test for data normality and the Mauchly's Test for sphericity. Every time data violated the assumption of sphericity, conclusions relied on the Greenhouse–Geisser statistic. Pearson correlation tests were used to ascertain the existence of linear relationships between the biochemical parameters and anthropometric variables. The level of significance for all hypothesis tests (p) was 0.05.

Results

The chemical analysis of the *rama* tomatoes (Tables 1 and 2) showed a fruit containing different classes of bioactive compounds: carotenoids (β-carotene and lycopene), flavanones (naringenin), flavonols (kaempferol), flavonols glycosides (rutin, quercitrin), hydroxycinnamic acids (neochlorogenic acid), and ascorbic acid. This composition makes tomato an interesting fruit taking into account the potential benefits for human health. Although the energy content has not been determined in this study it is known that tomatoes are very low in calories ~0.18 kcal/g (USDA, National Nutrient Database for Standard Reference, Release 26;http://ndb.nal.usda.gov/ndb/foods/show/3270)

Table 1. Chemical characterization of the *rama* tomatoes considered in this study[a].

Bioactive compounds (mg per 100 g fresh weight of edible portion)	
Ascorbic acid	44.2 ± 0.3
Total phenolics	54.2 ± 0.5
Carotenoids	
β-Carotene	0.9 ± 0.1
Lycopene	10.7 ± 0.5

[a]All values expressed as mean ± standard deviation obtained from three measurements per replicate.

Table 2. Phenolic compounds of the *rama* tomatoes considered in this study[a].

Phenolic compounds (mg per 100 g fresh weight of edible portion)	
Neochlorogenic acid	0.12 ± 0.02
Rutin	5.30 ± 0.06
Quercitrin	0.14 ± 0.04
Naringenin	0.14 ± 0.02
Kaempferol	1.71 ± 0.41

[a]All values expressed as mean ± standard deviation obtained from three measurements per replicate.

The antioxidant potential of this tomato cultivar was confirmed *in vitro* by two methods: the DPPH• inhibition and the β-carotene linoleate model (Figure 1). The results obtained for both types of extracts (aqueous and methanolic) reveal the antioxidant capacity of *rama* tomato, a reflex of the content in bioactive compounds (with different polarities) able to prevent oxidation via complementary mechanisms. Tomato intake is, therefore, a way of increasing total dietary antioxidant capacity, which has been recently described as a potential indicator of the risk to develop obesity-related features (Puchau et al., 2010). The anthropometric and biochemical characterization of the young women enrolled in the study, before and after 4 weeks of pre-meal *rama* tomato ingestion, is presented in Table 3 and the results of the statistical treatment of the data are presented in Figure 2 and Table 4. Repeated measures ANOVA with a Greenhouse–Geisser correction determined that mean values for weight, BMI, and fat differed significantly between time points (Table 4). The variations detected reached ~−1 kg (on an average) of body weight and −1.54% of fat mass (%), after 4 weeks. Additionally, post hoc tests using the Bonferroni correction revealed that the pre-meal ingestion of the *rama* tomato by the young women elicited a reduction in their body weight and BMI that is statistically significant after 2 weeks, and between these and the values obtained after 4 weeks. Although a mean slight reduction in the fat% was noticed from 2 weeks to 4 weeks (27.03 ± 0.93 versus 26.83 ± 1.03, respectively), the difference between these values was not statistically significant. The body fluid, muscle, and bone mass, in contrast, remained statistically unaltered even after 4 weeks of pre-meal ingestion of the *rama* tomato.

Blood tests, shown in Figure 2, revealed that pre-meal ingestion of the *rama* tomato caused a statistically significant reduction in the levels of glucose, triglycerides, cholesterol, and uric acid after 2 weeks of study, and between 2 weeks and 4 weeks. On an average, and after 4 weeks, the fasting blood glucose concentration of the participants was reduced in 5.29 ± 0.80 mg/dl, that of triglycerides in 8.31 ± 1.34 mg/dl, the cholesterol in 10.17 ± 1.21 mg/dl and uric acid in 0.16 ± 0.04 mg/dl. In terms of percentage, the largest variations were found in the levels of cholesterol and triglycerides (−7.7 and 7.0%, respectively). The fairly statistically significant correlations found between anthropometric variables (body weight and BMI) and the blood levels of triglycerides and cholesterol (Table 5)

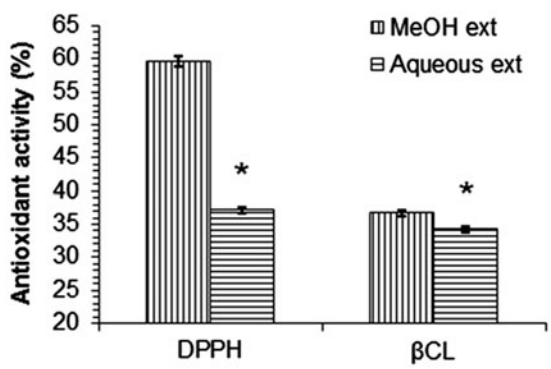

Figure 1. Antioxidant activity of methanolic (MeOH) and aqueous extracts from *rama* tomato fruits on 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) and by the β-carotene linoleate model system (βCL). *Statistically different (95% significance) from the antioxidant activity exhibited by the MeOH extract.

Table 3. Parameters for the individual subjects enrolled in the study at the beginning and after 4 weeks of pre-meal *rama* tomato ingestion.

Subject	Age	Glucose (mg/dl)	Triglycerides (mg/dl)	Cholesterol (mg/dl)	Uric acid (mg/dl)	Weight (kg)	Height (m)
				Day 1			
1	18	74	110	137	3.65	59.8	1.69
2	18	85	123	165	3.98	62.5	1.65
3	19	91	145	160	2.97	64.3	1.69
4	18	74	106	119	3.55	55.1	1.71
5	20	86	127	101	2.87	54.9	1.73
6	19	92	132	147	3.69	57.5	1.65
7	21	90	101	129	3.47	60.1	1.62
8	18	87	95	120	2.94	56.2	1.70
9	18	95	104	158	2.66	58.3	1.67
10	22	89	128	118	3.61	60.8	1.65
11	21	110	102	147	2.87	58.5	1.71
12	20	75	97	129	3.48	54.0	1.68
13	19	89	95	116	2.91	56.7	1.64
14	19	104	110	147	3.55	62.7	1.70
15	18	118	93	128	3.62	59.4	1.75
16	22	95	147	131	3.80	66.8	1.64
17	21	93	163	127	2.88	64.1	1.60
18	21	99	103	111	2.91	56.3	1.67
19	22	102	97	100	2.62	55.3	1.69
20	20	111	107	110	3.27	58.6	1.70
21	20	85	98	76	2.05	54.5	1.69
22	21	97	126	112	2.38	56.1	1.70
23	19	102	117	124	2.49	57.6	1.69
24	18	74	98	101	2.34	55.5	1.70
25	19	69	108	127	2.56	58.7	1.69
26	20	104	129	185	4.80	57.9	1.71
27	21	67	137	129	3.70	62.8	1.68
28	18	75	124	191	4.69	60.4	1.70
29	20	84	148	137	2.91	57.6	1.69
30	20	93	135	105	5.82	55.1	1.66
31	18	106	128	137	4.96	63.0	1.72
32	21	82	105	149	6.12	59.9	1.67
33	19	97	139	158	3.41	58.3	1.65
34	19	91	147	123	3.99	55.7	1.71
35	20	74	119	147	4.51	61.8	1.69
				Day 30			
1	18	68	101	124	3.40	57.3	1.69
2	18	81	120	158	3.73	61.6	1.65
3	19	89	142.1	156	2.97	63.5	1.69
4	18	75	103	115	3.52	54.0	1.71
5	20	76	122	97	2.87	54.1	1.73
6	19	91	132	130	3.68	57.3	1.65
7	21	85	100	129	3.45	59.5	1.62
8	18	85	92	117	2.94	56.1	1.70
9	18	92	102	145	2.65	58.0	1.67
10	22	86	119	109	3.60	59.3	1.65
11	21	101	97	137	2.83	58.0	1.71
12	20	73	96	121	3.47	54.0	1.68
13	19	84	90	98	2.87	56.0	1.64
14	19	100	93	138	3.40	59.0	1.75
15	18	102	90	121	3.47	58.6	1.75
16	22	95	138	124	3.64	65.0	1.64
17	21	91	142	102	2.85	63.2	1.60
18	21	85	94	92	2.87	55.2	1.67
19	22	91	94	90	2.60	54.6	1.69
20	20	98	99	101	3.14	57.6	1.70
21	20	84	98	86	2.10	54.1	1.69
22	21	91	118	103	2.37	55.0	1.70
23	19	95	100	114	2.35	56.9	1.69
24	18	70	92	98	2.25	54.1	1.70
25	19	67	100	122	2.51	57.8	1.69
26	20	96	120	169	4.53	56.5	1.70
27	21	68	120	115	3.45	60.8	1.68
28	18	70	118	169	4.22	59.2	1.70
29	20	80	133	129	2.80	56.8	1.69

(*continued*)

Table 3. Continued

Subject	Age	Glucose (mg/dl)	Triglycerides (mg/dl)	Cholesterol (mg/dl)	Uric acid (mg/dl)	Weight (kg)	Height (m)
30	20	82	97	99	5.10	54.6	1.66
31	18	90	111	125	4.08	61.0	1.72
32	21	84	102	124	5.51	58.1	1.67
33	19	93	130	139	3.32	57.2	1.65
34	19	85	127	115	3.58	54.0	1.71
35	20	71	120	134	4.42	60.8	1.69

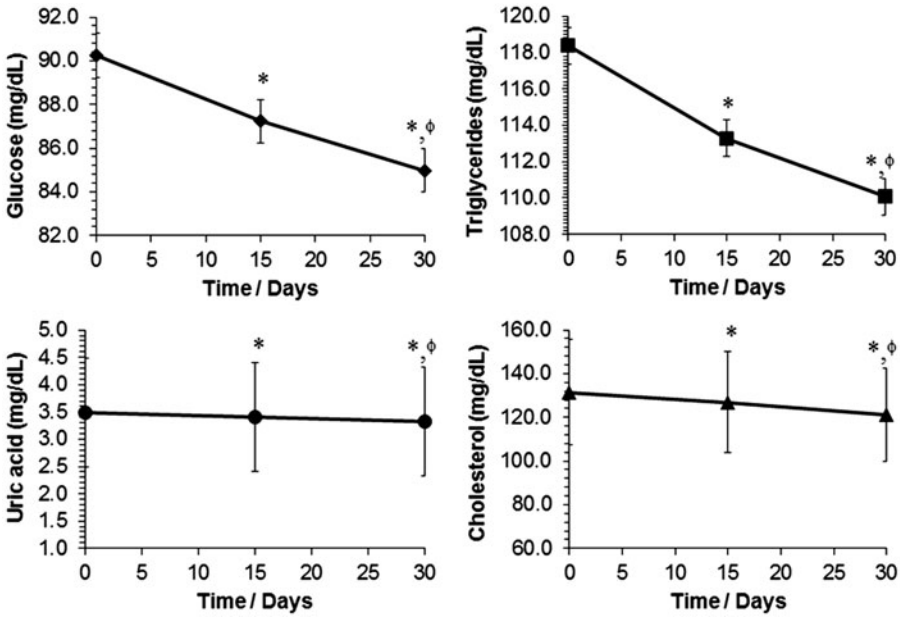

Figure 2. Change in the biochemical parameters during the follow-up time. *The mean difference relative to the initial value is significant at the 0.05 level. $^{\phi}$The mean difference relative to the 2 value is significant at the 0.05 level.

Table 4. Change in the anthropometric indices during the follow-up time.

	Initial values	Mean change after 2 weeks	Mean change after 4 weeks
Weight (kg)	58.77 ± 0.54	−0.55 ± 0.09[a]	−1.09 ± 0.12[a,b]
BMI/(kg/m^2)	20.79 ± 0.27	−0.21 ± 0.06[a]	−0.41 ± 0.07[a,b]
Fat (%)	28.37 ± 0.89	−1.34 ± 0.32[a]	−1.54 ± 0.52[a,b]
Body fluid (%)	54.60 ± 3.48	−0.09 ± 0.01	−0.30 ± 0.03
Muscle mass (%)	37.30 ± 0.45	0.06 ± 0.01	0.10 ± 0.01
Bone mass (%)	6.23 ± 0.48	0.00 ± 0.00	0.01 ± 0.01

[a]The mean difference relative to the initial value is significant at $p < 0.05$.
[b]The mean difference relative to the 2nd week value is significant at $p < 0.05$.

suggest that their simultaneous decrease during the follow-up time were associated.

Discussion

Numerous studies suggest that fruit consumption is correlated with body weight maintenance or reduction. For instance, Oliveira et al. (2003) reported that the intake of three apples or pears per day for 12 weeks reduced the weight (−1.22 kg) of hypercholesterolemic overweight women (30–50 years old) and lowered their blood glucose levels in 5.2 mg/dl. In addition, Duttaroy & Jørgensen (2004) reported that consumption of 2–3 kiwi fruit per day for 28 d lowered blood triglycerides levels by 15%. Muraki et al. (2013), using data from three prospective cohort studies performed in US adults, also concluded that a greater consumption of whole fruits, particularly blueberries, grapes, and apples, was significantly associated with a lower risk of type 2 diabetes. For such, the reason most often given (particularly in early studies) is that an increase on fruit consumption decreases postprandial hunger. In the long term, replacement of caloric foods by fruits (low energy density foods) may lead to a significant decrease in energy intake and, thereby, in body weight (Ello-Martin et al., 2007; Rolls et al., 2005). The regular pre-meal intake of fresh tomatoes examined in this study is expected to have the same effect on satiety and there are studies which reported so. For example, George et al. (2010) observed that tomato-enriched bread significantly decreased the desire to eat over the 4 h postprandial period compared with simple bread and carrot-enriched bread. A growing number of studies also showed that the amount of antioxidants in the daily diet plays an essential role in the prevention and control of obesity (Mangge et al., 2013; Puchau et al., 2010) since this injury has been described as a state of chronic oxidative stress (Fernández-Sánchez et al., 2011). Indeed, oxidative stress has been defined as the link between obesity and its major associated disorders such as insulin resistance and hypertension (Savini et al., 2013). The *rama* tomato, besides having high content of water and relatively low energy density, is a fruit particularly rich in antioxidants, having a very high antioxidants amount/caloric content ratio. Moreover, the antioxidant molecules found in the composition of the *rama* tomato have already been reported individually as having hypolipidemic, hypoglycemic, and hypouricemic actions, notably the phenolic compounds. For example, orally administered extracts from several plants rich in caffeoylquinic acids have been shown to have hypoglycemic and anti-obese effects in rats, being able to lower the plasma glucose levels

Table 5. Correlations between the biochemical parameters and anthropometric variables.

	Glucose	Triglycerides	Cholesterol	Uric acid	Weight	Fat%	BMI
Glucose	1.00						
Triglycerides	0.033	1.00					
Cholesterol	0.098	0.258[b]	1.00				
Uric acid	−0.036	0.116	0.405[b]	1.00			
Weight	0.148	0.325[b]	0.489[b]	0.244[a]	1.00		
Fat%	0.244[a]	0.170	0.212[a]	−0.054	0.370[b]	1.00	
BMI	0.057	0.346[b]	0.344[b]	0.189	0.872[b]	0.399[b]	1.00

[a]Correlation is significant at $p < 0.05$.
[b]Correlation is significant at $p < 0.01$.

and decrease rat body weight and abdominal fat pad weight (Andrade-Cetto & Vázquez, 2010; Kim et al., 2011; Muthusamy et al., 2010). Feeding rats with foods rich in the flavonol glycoside rutin decreased their weight, number of fat cells, insulin, leptin, hepatic triacylglycerol, cholesterol, with an improved overall serum lipid profile (Hsu et al., 2009; Rickman et al., 2010). Moreover, the consumption of rutin reduced oxidative stress and suppressed adipogenesis in 3T3-L1 adipocytes (Panchal et al., 2011). Quercitrin (quercetin 3-*O*-a-L-rhamnoside) is converted to quercetin in the digestive tract. Among other effects, quercetin has also been shown to prevent oxidative injury and in parallel, it has a fat-lowering effect, improve diabetes-related impairments, and damp postprandial hyperglycemia in type 2 diabetes patients (Fiorani et al., 2010; Hussain et al., 2012; Kobori et al., 2009). The protective effect of dietary quercetin has been related with the inhibition of liver and pancreas CDKN1A gene expression (Kobori et al., 2009). Naringenin has been reported to correct triacylglycerides and cholesterol high levels, prevent the development of insulin resistance, and normalize glucose metabolism in mice fed with high-fat diet (Mulvihill et al., 2009). Another study demonstrated that naringenin was able to inhibit TLR2 expression and block the lipolitic actions of tumor necrosis factor-α (TNF- α) in adipocytes (Yoshida et al., 2013). Annadurai et al. (2012) further reported that following oral administration of naringenin (50 mg/kg a day) to diabetic rats for 21 d results were similar to those produced by glyclazide, a standard drug for therapy of diabetes *mellitus*. The intake of the flavonoid kaempferol in turn has been shown to increase cellular energy expenditure and thyroid hormone activation and by these means confer resistance to diet-induced obesity, which has been attributed to the alteration of the expression of a set of metabolically important genes (Da Silva et al., 2007). Additionally kaempferol was suggested to prevent the onset of diabetes by preventing oxidative damage in pancreatic β cells (Lee et al., 2010). It has also been suggested that kaempferol and some of its glycosides decrease triglycerides and cholesterol levels, and reduce body weight. Park et al. (2012) argued that kaempferol reduces adipogenesis and balances lipid homeostasis partly through the down-regulation of the expression of adipogenic transcription factors and genes involved in triglyceride biosynthesis while increasing lipolysis-related genes.

Besides phenolic compounds, tomatoes are rich in ascorbic acid (vitamin C), reported as an appetite suppressant. For example, it has been observed that vitamin C dose-dependently inhibits leptin secretion in primary rat adipocytes (Garcia-Diaz et al., 2010), and lower vitamin C levels were associated to higher leptin concentrations in morbidly obese patients (Aasheim et al., 2008). Vitamin C supplementation has proven to reduce the gene expression of apelin, an adipokine associated with insulin resistance, obesity, and increased inflammation in animal models (Garcia-Diaz et al., 2010).

Although lycopene and β-carotene are molecules with antioxidant activity, the direct effect on obesity and diabetes is not yet clarified. Recent findings in animal models revealed that lycopene supplementation did not affect body weight or adiposity, nevertheless it significantly decreased leptin, resistin, and IL-6 gene expression in epididymal adipose tissue and plasma (Luvizotto et al., 2013). No evidence for the association between lycopene intake and the risk for diabetes developing has been found (Valero et al., 2011). Serum β-carotene concentration has been reported to be not significantly associated with obesity (Wallström et al., 2001), but recent findings identified β-carotene as a critical physiological precursor for retinoic acid production in adipocytes and implicated provitamin A as a dietary regulator of body fat reserves (Lobo et al., 2010).

Considering the above information, two orders of factors may, in our view, underlie the reduction observed for the different parameters (weight, BMI, fat percentage, glucose, triglycerides, and cholesterol) evaluated in the young women population enrolled in this study, associated with the ingestion of a tomato before lunch. First, its effect on promoting satiety with the consequent reduction of dietary energy density; and second, the biochemical effect of the phenolic and flavonoid compounds present in its composition. In fact, it has been shown that neochlorogenic acid, rutin, naringenin, quercitrin, and kaempferol have hypolipidemic and hypoglycemic effects. Furthermore, the effects of these compounds should be synergistic and may far exceed the sum of those for any compound individually. The reduction in blood levels of uric acid can also be accounted for by the action of these compounds since studies indicate that oral administration of quercetin, naringenin or kaempferol (50 mg/kg for 3 d) was able to elicit hypouricemic actions in hyperuricemic mice (Mo et al., 2007). Oral doses of 100 mg/kg of rutin had also a similar effect (Zhu et al., 2004). According to these studies, it seems to be likely that these flavonoids reduce serum urate levels by mainly inhibiting the xanthine oxidase activity.

Conclusion

The results of this study demonstrate that the daily pre-meal ingestion of a *rama* tomato (∼90 g) by young women is associated, after 4 weeks, to significant reduction in body weight, BMI, and serum levels of glucose, triglycerides, cholesterol, and uric acid. The reduction in body weight reached on average 1.09 ± 0.12 kg. In our point of view, the effect of tomato intake in the studied variables is due (i) to satiety promotion, leading to a reduction in the ingestion of more caloric food: tomatoes, due to their moisture content, are quite filling and at the same time have less than 20 calories; (ii) to the synergistic antioxidant activity of flavonoids, phenolic compounds, and vitamins present in *rama* tomatoes at significant levels. These molecules among other actions have been reported to reduce the oxidative stress and the production of appetite hormones, modulate gene expression, and increase energy expenditure.

The intake of fresh tomatoes, in addition to the already proven benefits in the prevention of several diseases, appears also as a

natural way to prevent obesity, diabetes, and gout. These effects can be due to their exceptional high content in lycopene and other bioactive compounds with hypolipidemic, hypoglycemic, and hypouricemic effects.

Declaration of interest

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