Arabian Journal of Chemistry (2016) 9, S1010–S1018

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

REVIEW

Evaluation of nutritional value and antioxidant activity of tomato peel extracts

Elsayed Elbadrawy [a,*], Amany Sello [b]

[a] Medical Biochemistry Dept., Faculty of Medicine, Taif University, Taif, Saudi Arabia
[b] Home Economics Dept., Faculty of Specific Education, Mansoura University, Mansoura, Egypt

Received 23 July 2011; accepted 22 November 2011
Available online 29 November 2011

KEYWORDS

Tomato peel;
Minerals;
Amino acids;
Phenolic acids;
Antioxidant activity

Abstract The objective of this work was to study the nutritional composition and the antioxidant activity of some tomato peel extracts. Preliminary chemical composition, minerals content, amino acids, fatty acids and phenolic compounds of the peels were determined. The extracts which had been obtained by using different solvents; petroleum ether, chloroform, ethyl acetate and methanol were assayed for their antioxidant activity. Antioxidant activities of the extracts were evaluated by the determination of peroxide, malondialdehyde (MDA), P-anisidine and total carbonyl values during four weeks storage of cottonseed oil at 60 °C. Also, the 1,1-diphenyl-2-picrylhydrazine (DPPH) radical scavenging was carried out. The results revealed that most of the extracts showed significant increases in DPPH scavenging activity as compared to butylated hydroxy toluene (BHT), an artificial antioxidant. On the other hand, significant decreases in peroxide, P-anisidine, malondialdehyde and carbonyl values were observed in the oil samples treated with the extracts in comparing with the untreated sample (control). Due to tomato peel content of many nutrients and its antioxidant activities, tomato peel or its extracts can be used as a food supplement.

* Corresponding author. Tel.: +96656339953.
E-mail address: s.elbadrawy@hotmail.com (E. Elbadrawy).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.arabjc.2011.11.011

Contents

1. Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the world's major vegetable with a worldwide production of 126 million tons in 2005 (FAOSTAT, 2007). It is an excellent source of many nutrients and secondary metabolities that are important for human health; mineral matter, vitamins C and E, B-carotene, lycopene, flavonoids, organic acids, phenolics and chlorophyll (Giovanelli and Paradise, 2002).

Tomatoes are widely consumed either raw or after processing and can provide a significant proportion of the total antioxidants in the diet (Martinez-Valvercle et al., 2002). Tomatoes constitute the predominant source of lycopene and phenols in the Egyptian diet because of their year-round availability, high utility in Egyptian culinary preparations and their cheap price. However when tomatoes are processed into products like Catsup, salsa and sauces, 10–30% of their weight becomes waste or pomace (King and Zeidler, 2004). Food by-products usually represent an environmental problem for the industry, and many studies have been carried out about the potential utilization of several vegetable origin by-products for their inclusion in the human diet, which could reduce industrial costs and justify new investments in equipment, providing a correct solution for the pollution problem connected with food processing (Lario et al., 2004). These new ingredients could be of great interest for food and pharmaceutical industries. Al-Wandawi et al. (1985) reported that tomato peel contains high levels of lycopene compared to the pulp and seeds. In addition, tomato skin and seeds were reported to contain essential amino acids and the tomato seeds had higher amounts of minerals (Fe, Mn, Zn and Cu). They also have monounsaturated fatty acids especially oleic acid and linolenic acid. However, they did not measure the other antioxidant compounds in their study. In most of the previous studies, antioxidants have been measured, mainly in, whole tomatoes or processed tomato products (Lavelli et al., 2000; Martinez-Valvercle et al., 2002; Raffo et al., 2002). Stewart et al. (2000) reported that the majority of the flavonols in tomatoes are present in the skin. Similarly, Sharma and Le Maguer (1996) observed that most of the lycopene was associated with the skin and water insoluble fraction of the tomato pulp. George et al. (2004) studied antioxidant compounds in 12 field grown tomato genotypes and reported that on average, the tomato skin had 2.5 times higher lycopene levels than the pulp. The skin of fruits and vegetables is commonly removed because they are thought to be indigestible and contain low levels of nutrients, furthermore, approximately one third of total weight of tomatoes in the form of skin and seeds is discarded during processing of tomatoes into paste (Al-Wandawi et al., 1985). In general, there is a lack of information on the levels of antioxidants in the peel fraction of tomatoes, and this could be an important contributor to the antioxidant activity of

tomatoes. So, in this work we aimed to benefit from tomato peel which is a by-product by studying its nutritional value by the determination of its content of total protein, total lipids, total carbohydrates, minerals, fatty acids, amino acids and phenolic acids. In addition its antioxidant activity was also studied in vitro against hot cotton seed oil by the determination of peroxide value, malondialdhyde, DPPH, P-anisidine value, TBA and Carbonyl content.

2. Materials and methods

2.1. Samples preparation

Tomato peels were obtained from Best Factory, EL-Dakahlia Governorate, Egypt at the end of September 2008. The peels were cleaned, dried in the air, ground and kept under freezing.

2.2. Gross chemical composition

Moisture, ash, crude protein, crude lipids, and total carbohydrates of tomato peels were estimated in plant samples according to the methods of AOAC (2000).

2.3. Determination of minerals

The ash samples were dissolved in 1% hydrochloric acid and the solutions were used for the determination of the following minerals: Iron, zinc, sodium, calcium, manganese, magnesium, selenium, cobalt, chromium, potassium, cadmium, lead, nickel and copper by using Atomic Absorption Spectrometry according to Luten et al. (1996).

2.4. Oil extraction

Tomato peels powder was treated with hexane (one part powder to 10 parts hexane, w/v). The mixture was shaken for 10 min and left at room temperature over night, then filtered and the residue was re-extracted with the same solvent four times. The solvent was removed under reduced pressure and the obtained oil was flushed with a stream of nitrogen and stored in sealed tubes prior to analyses.

2.5. Extraction of the hydro-alcoholic extract

The extraction procedure for the hydro-alcoholic extract was carried out according to Charles et al. (1993) which was modified by EI-Badrawy (1996). About 250 g of the milled plant sample were macerated in 500 ml of methanol over night at room temperature, then filtered and the methanolic crude extract was collected. Another portion of 500 ml of methanol was added to the plant residue and boiled for 2 h under reflux condenser in a water bath and then filtered. The filtrate was collected to the previous crude extract. In the same manner 500 ml portion of water were added to the residue plant and left at room temperature over night, then filtered. The filtrate was added to the previous crude extract. Another volume of water was added to the residue, boiled for two hours under reflux condenser and filtered. The hot water filtrate and the methanolic crude extract obtained previously were gathered to form the hydro-alcoholic crude extract. The solvents were evaporated under vacuum using rotary evaporator. The crude extract was obtained, kept in dark bottles and stored in a deep freezer until use.

2.6. Successive extraction of the hydro-alcoholic extract with organic solvents

The obtained hydro-alcoholic extract was subjected to sequence successive extractions by using selective organic solvents according to their polarity as follows; petroleum ether, chloroform, ethyl acetate and methanol. The residue after each extraction was re-extracted with the next solvent. Each solvent was removed by using rotary evaporator and the residue was dried and kept for studying its antioxidant activity.

2.7. Fractionation and identification of phenolic acids of tomato peels

Phenolic acids were estimated in Central Laboratory of Food Tech. Res. Inst., Agric. Res. Center, Giza, Egypt. An HP 1100 HPLC system equipped with an alpha Bond C18 125A column (4.6×250 mm, particle size 5 μm) and coupled with Agilent 1100 series Chem Station software was used for quantifying the individual phenolic acids. The mobile phases consisted of 2.0% acetic acid in distilled water (A) and acetonitrile (B). The column was eluted at 1.0 ml/min under a linear gradient from 5% mobile phase B to 75% over 20 min, to 100% over 5 min, isocratic for 5 min, to 25% over 5 min and to 5% over 5 min. Sample injection volumes were 20 μl. Compounds were detected at 280 nm with an HP 1100 series ultraviolet (UV) Diode Array Detector. Standards of ellagic, catechin, caffeic, protocatchioc, syrengic, furan, vanillic, gallic and coumarin were injected for identification at 280 nm.

2.8. Fatty acids composition

Methyl esters of fatty acids found in the oil of tomato peel were determined according to Radwan (1978) at the unit of analysis and scientific services of Agriculture Faculty, Alexandria, University Alexandria, Egypt. By using GC model, shimadzu-8A, equipped with FID detector and glass column $2.5\ m \times 3$ mm i.d, under the following circumstances, column: 5%DEGS on 80/100 chromo Q; column temp.: 140–180 °C at rate 5 °C/min; Detector temp.: 270 °C; N2 flow rate: 20 ml/min; H2 flow rate:75 ml/min. Air flow rate: 0.5 ml/min; sensitivity 16×102; chart speed: 2.5 mm/min.

2.9. Antioxidant activity

Different methods have been adopted to assess antioxidative potential of the tomato peel extracts as follows.

2.9.1. Scavenging effect on DPPH

The DPPH assay constitutes a quick and low cost method, which has frequently been used for the evaluation of the anti-oxidative potential of various natural products (Soler-Rivas et al., 2000). Due to its odd electron, DPPH gives a strong absorption band at 516 nm (deep violet color). In the presence of a free radical scavenger, this electron becomes paired, resulting in the absorption loss and consecutive stoichiometric decolorization with respect to the number of electron acquired. The absorbance change produced by this reaction is assessed to evaluate the antioxidant potential of the test

sample. Scavenging effect on DPPH radical was determined by the method reported earlier by some authors (Miller et al., 1997; Sanchez and Calixto, 1998) with minor modifications. The extracts (100, 200, 250, 500 and 100 in methanol (1 ml) were mixed with 4 ml of 0.004% methanolic solution of DPPH. The mixture was shaken vigorously and left to stand for 30 min in dark at 30 °C, and the absorbance was then measured at 517 nm against the corresponding control.

The percent of DPPH decolorization of the samples was calculated according to the formula

$$\text{Antiradical activity} = \frac{(\text{absorbance of control} - \text{absorbance of sample})}{\text{absorbance of control}} \times 100$$

2.9.2. Evaluation of antioxidant activity for cottonseed oil

To assess the antioxidant activities of peel extracts, crude cotton seed oil obtained from local oil mill, having initial peroxide value of 2–3 meq/g, was taken for present investigation. This oil is the most frequently used edible oil. Six petri dishes were used in this experiment to study the antioxidant activity of the peel extracts. 100 g of cotton seed oil were put in each petri dish. One dish containing cotton seed oil only was used as a control, another one was treated by BHT with a concentration of 0.04 g/100 ml. 0.1 g of each peel extract were added to each of the rest dishes. All the dishes were incubated at 60 °C for 28 days. Peroxide, TBA, P-anisidine and total carbonyl values were determined in all incubated dishes at intervals of 7 days during the incubation period. The antioxidant activity of extracts was evaluated by comparing with the control and the activity of the artificial antioxidant; BHT.

2.9.2.1. Peroxide value. Peroxide value was determined in each oil sample according to the method described in AOAC (2000).

2.9.2.2. Thiobarbituric acid value (TBA). The test was performed according to the methods previously stated by some authors (Ottolenghi, 1959; Kikuzaki and Nakatani, 1993), with small changes. The same samples prepared previously were used. To 10 g sample of each dish, 0.67% aqueous thiobarbituric acid (20 ml) and benzene (25 ml) were added. This mixture was shaken continuously for 2 h using mechanical shaker. After 2 h, supernatant was taken and placed into boiling water bath for 1 h. After cooling, absorbance of supernatant was measured at 540 nm with Hitachi-U 2000 spectrophotometer.

The TBA value was expressed as mg. malondialdhyde/kg sample using the following equation:

$$\text{TBA} = 7.8 \times \text{O.D.}$$

where O.D. is the absorbance at 540 nm.

2.9.2.3. P-Anisidine value. The test was performed according to the methods of AOCS (1998). The same samples prepared previously were used. In a 25-ml volumetric flask, 0.6 g sample was taken, and the volume was made using isooctane solvent. The absorbance (Ab) of the solution was measured at 350 nm using the reference cuvette filled with solvent as a blank. Exactly 5 ml of the fat solution were transferred into one test tube and exactly 5 ml from the solvent into a second test tube. One ml of the P-anisidine reagent (0.25% in glacial acetic acid) was added exactly to each tube and shaked, kept in dark for 10 min, and absorbance (As) was measured at 350 nm using the solution from the second test tube as a blank using a UV–VIS spectrophotometer.

The P-anisidine value (P-A.V.) is given by the formula

$$\text{P} - \text{A.V.} = 25 \times (1.2\text{As} - \text{Ab})/m$$

where As = absorbance of the fat solution after reaction with P-anisidine reagent; Ab = absorbance of the fat solution; m = mass of the test portion in grams.

2.9.2.4. Total carbonyl value. Carbonyl value was evaluated according to the methods reported earlier (Franken, 1998). The same samples as prepared for the peroxide value method were used. About 4 g sample was taken in a 50-ml volumetric flask, and the volume was made up using carbonyl free benzene. Out of this, 5 ml was pipetted out and mixed with 3 ml 4.3% trichloroacetic acid and 5 ml 2.4-dinitrophenyl hydrazine (0.05% in benzene) in 50-ml volumetric flasks. The mixture was incubated at 60 °C for half an hour to convert free carbonyls into hydrazones. After cooling 10 ml KOH solution (4% in ethanol) was added and the volume was made up with ethanol. After 10 min, absorbance was measured at 480 nm using UV–VIS spectrophotometer Blank was prepared in the same manner substituting 5 ml benzene instead of sample. A standard curve was drawn using valeraldehyde (50–250 μg) in 5 ml benzene instead of sample. The total carbonyl was calculated with the help of the standard curve and expressed as mg of valeraldehyde per 100 g of sample.

2.10. Statistical analysis

The experimental data were statistically analyzed using the analysis of variance by the factorial design method (SAS, 2001).

3. Results and discussion

During tomato paste manufacture, two different by-products are produced. One is the outer skin of the fruit (peel), while the other results from removing the seeds. In this work, the nutritional value of the peel was studied in addition to studying the antioxidant activities of some peel extracts.

Table 1 Chemical composition, minerals content and fatty acids of tomato peel.

Chemical composition (g/100 g)		Minerals content (mg/100 g)	
Protein	10.50	Ca	160
Fat	4.04	Mg	149
Ash	5.90	Fe	1.50
Carbohydrates	78.56	Cu	1.10
Fatty acids (%)		Cr	0.06
Myristic acid	0.34	Co	0.01
Palmitic acid	15.19	Ni	0.66
Stearic acid	6.84	Zn	3.12
Total Saturated	22.37	Mn	1.40
Palmitoleic acid	1.82	Na	73.6
Oleic acid	19.14	Se	0.01
Linoleic acid	52.41	Pb	0.05
Linolenic acid	4.26	Cd	0.02
Total Unsaturated	77.63	K	1097

Results expressed as mean values (n = 3).

3.1. Nutritional value

Nutritional value of the peel was studied by the determination of its content of protein, oil, ash, carbohydrates and minerals. In addition, fatty acids of the peels oil and amino acids of peel protein were identified. Data in Table 1 summarize the proximate composition, fatty acids percentages, and mineral content of the tomato peels.

3.1.1. Proximate chemical composition

The proximate composition revealed that tomato peel contained 10.5 g protein, 5.9 g ash, 4.04 g oil and 78.56 g carbohydrates per 100 g on dry weight basis (Table 1). These results are not in accordance with that of González et al. (2011) who stated that tomato peel has higher amounts of protein (13.3%) and lipid (6%) and lower content of ash (3%).

3.1.2. Minerals content of tomato peel

The results in Table 1 showed that tomato peel has high levels of K (1097) Na (73.6), Ca (160), Mg (149), Zn (3.12) and Fe (1.5) mg/100 g. In addition, it contains Mn (1.4), Cu (1.1), Cr (0.06), Ni (0.66), Se (0.01) and Co (0.01) mg/100 g. On the other hand, some heavy metals namely Lead and Cadmium are found in concentrations of 0.05, 0.02 mg/100 g, respectively. These results agree to a less extent with that of González et al. (2011) who reported that the major elements in tomato peel are K, Mg, Ca, and Na. These results indicate that tomato peels contain most of the antioxidant minerals especially Ca, Cu, Zn, Mn and Se which are important for antioxidant enzymes in vivo and hence protect the body from cancer. In addition, tomato peel could be considered a good food supplement because of its high content of K, Ca, and Mg and low content of Na. Because of its low Na/K ratio, it could be used as a protective agent for cardiovascular diseases.

3.1.3. Fatty acids

The obtained results in Table 1 illustrated the fatty acids identified in tomato peel oil. It is clear that linoleic acid (ω6) represents the main fatty acid with a percentage of 52.41% of the total fatty acids followed by oleic acid (19.14%), whereas linolenic acid (ω3) was 4.26% and palmitoleic acid was 1.82. The four mentioned fatty acids which are known as unsaturated fatty acids constitute about 77.6% of the total fatty acids. The saturated fatty acids found in tomato peel oil were myristic (0.34%), palmitic (15.19%) and stearic acid (6.84%) with a total percentage of 22.37%. Although the amount of peel oil is small, it contains high level of unsaturated fatty acids especially linoleic acid (ω6) and linolenic acid (ω3) which are essential fatty acids that protect the body from cardiovascular disease (CVD).

Table 2 Amino acids content (g/100 g protein) of tomato peel.

Essential amino acids	g/100 g Protein	Nonessential amino acids	g/100 g Protein
Threonine	2.34	Aspartic	0.70
Valine	4.58	Serine	3.08
Methionine	1.02	Glutamic	14.56
Isoleucine	3.86	Proline	2.78
Leucine	5.07	Glycine	4.29
Phenylalanine	3.12	Alanine	5.02
Histidine	3.64	Cystine	0.39
Lysine	4.40	Tyrosine	3.42
Arginine	4.34	Ammonia	1.42

Results expressed as mean values ($n = 3$).

3.1.4. Amino acids

Amino acids were determined in tomato peel by using HPLC and their concentrations were registered in Table 2. It is obvious that the estimated amino acids constitute about 66.62% of the total protein. The abundant amino acid was glutamic acid which represents 14.56 g/100 g protein. The results also revealed that tomato peel protein contains nine essential amino acids with a total percentage of 47.57% whereas tryptophan has not been determined. The non essential amino acids represent about 52.41% of total amino acids. Concerning essential amino acids, leucine, valine, lysine, argnine, isoleucine and phenylalanine had the highest values whereas methionine had the lowest. On the other hand, the non essential amino acids with high values were glutamic, alanine, glycine and tyrosine whereas cysteine and aspartic acid were the lowest among all the amino acids.

3.1.5. Phenolic acids of tomato peel

The main phenolic acids identified in tomato peel are presented in Table 3. These are caffeic, procatchoic, vanillic, catechein and gallic acid. Their corresponding concentrations were 0.50, 5.52, 3.31, 2.98 and 3.85 mg/100 g, respectively. It was clear that procatchoic was the abundant phenolic acid followed by gallic, vanillic and catechein acids whereas caffeic was the least one. Phenols are very important plant constituents because of their scavenging ability on free radicals due to their hydroxyl groups (Hemi et al., 2002). Several studies showed good correlation between the phenols and antioxidant activity (Haung et al., 2005; Silva et al., 2006). González et al. (2011) found that tomato peel contains several flavonoids with beneficial effects for human health such as rutin, naringenin and quercetin. Rutin has been associated with markedly decreased hepatic and cardiac levels of triglycerides (Fernandez et al., 2010), and it has been suggested that it has anti-inflammatory properties (Guardia et al., 2001). Naringenin has been suggested as an antioxidant, an anti-inflammatory, and a regulator of fat metabolism and sex hormone metabolism. Finally, quercetin has been reported to exhibit antioxidative, anticarcinogenic, anti-inflammatory, anti-aggregation, and vasodilating effects (Erlund, 2004).

3.2. Antioxidant activity of tomato peel extracts

Four tomato peel extracts namely; petroleum ether, chloroform, ethyl acetate and methanol were used to study their antioxidant activity as follows:

Table 3 Phenolic acids of tomato peels.

Phenolic acids	(mg/100 g)
Caffeic	0.50
Procatchoic	5.52
Vanillic	3.31
Catechein	2.98
Gallic	3.85

Results expressed as mean values ($n = 3$).

Table 4 Scavenging effect (%) of tomato peel extracts on (DPPH) radical.

Extract	Concentration	
	100 μg/ml	200 μg/ml
BHT	48.53 ± 6.5c	72.53 ± 6.1[c]
Petroleum ether	75.40 ± 1.34[a]	97.32 ± 0.64[a]
Chloroform	81.03 ± 1.0[a]	96.30 ± 1.1[a]
Ethyl acetate	69.19 ± 3.9 [b]	86.40 ± 3.6[b]
Methanol	44.30 ± 0.88[c]	97.07 ± 0.97[a]

Each value is the Mean ± SD.
*The values having different superscripts in the same column are significantly different at $p \leqslant 0.05$.

3.2.1. Scavenging effect on DPPH radicals

Scavenging the stable DPPH radical model is a widely used method to evaluate antioxidant activity. DPPH is a stable free radical with characteristic absorption at 517 nm and antioxidant react with DPPH and convert it to 2.2-diphenyl-1-picrylhydrazine. The degree of discoloration indicates the scavenging potential of the antioxidant extract, which is due to the hydrogen donating ability (Van Gadow et al., 1997). DPPH radical-scavenging abilities of the four tomato peel extracts along with the reference antioxidant BHT (butylated hydroxy toluene) are shown in Table 4. All tested extracts showed high scavenging activity with a concentration of 200 μg/mg where petroleum ether and methanol extracts were the best ones followed by chloroform and ethylacetate extracts. Their scavenging activities were, 97.32%, 97.07%, 96.30% and 86.4%, respectively, which were significantly higher than that of BHT (72.53%). It has also been shown that there were no significant differences between the extracts of petroleum ether, chloroform and methanol which exhibited the highest activities. These results indicate that tomato peel has a noticeable effect on scavenging free radicals. This could be attributed to its high content of lycopene and phenolic compounds. It has been documented that antiradical scavenging activity is related to substitution of hydroxyl groups in the aromatic rings of phenolics, thus contributing to their hydrogen-denoting ability (Brand-Williams et al., 1995; Yen et al., 2005).

3.2.2. Inhibitory effect of tomato peel extracts on peroxide value

Peroxide value (PV) is a measure of the concentration of peroxides and hydroperoxides formed in the initial stages of lipid oxidation. As it is known, peroxide value is one of the most tests used for the measurement of primary oxidation in oils and fats. In this work, oxidation degree on cotton seed oil samples was determined by measuring peroxide value in the absence and presence of extracts and BHT at 60 °C for 28 days of storage. The effect of tomato peel extracts during storage period on PV in the cotton seed oil samples is shown in Table 5.The results revealed that PV increased linearly with storage time. Cotton seed oil samples without the antioxidant (control) reached a maximum PV of 60.0 + 1.75 meq/kg after 28 days of storage. A significant difference ($P < 0.05$) in PV was observed between the control and cotton seed oil samples containing tomato peel extracts and synthetic antioxidant (BHT). After 28 days of storage, the PV of cotton seed oil samples treated with petroleum ether, chloroform, ethyl acetate and methanol extracts and BHT were 34.5, 36.5, 43.15, 43.5 and 42.0 meq/kg, respectively. Their corresponding inhibition rates were 42.5%, 39.16%, 28.08%, 27.5% and 30%, respectively after 28 days under storage conditions compared to the control. However, the antioxidant effects of petroleum ether and chloroform extracts were better than that of BHT.

Table 5 Inhibitory effect of tomato peel extracts on the primary oxidation of cotton seed oil as measured by using peroxide value.

Extract	Days				
	Zero time	7 days	14 days	21 days	28 days
Oil (control)	2.31 ± 0.41	10.92 ± 0.11[a]	20.40 ± 1.05[a]	40.80 ± 2.70[a]	60.00 ± 1.75[a]
Oil + BHT	2.31 ± 0.41	4.80 ± 0.87[c]	12.30 ± 0.43[c]	29.12 ± 0.25[b]	42.0 ± 0.36[b]
Petroleum ether	2.31 ± 0.41	6.80 ± 0.69[bc]	14.40 ± 0.72[bc]	20.21 ± 0.85[b]	34.50 ± 0.85[b]
Chloroform	2.31 ± 0.41	6.70 ± 1.34[c]	16.80 ± 0.60[ab]	25.60 ± 1.50[b]	36.5 ± 0.43[b]
Ethyl acetate	2.31 ± 0.41	6.80 ± 0.52[bc]	16.59 ± 0.97[ab]	28.80 ± 1.31[b]	43.15 ± 0.51[b]
Methanol	2.31 ± 0.41	9.60 ± 0.85[ab]	18.36 ± 1.06[ab]	28.00 ± 1.60[b]	43.5 ± 1.21[b]

Each value is the Mean ± SD.
*The values having different superscripts in the same column are significantly different at $p \leqslant 0.05$.

Table 6 Inhibitory effect of tomato peel extracts on the malondialdhyde formation in cotton seed oil as measured by using TBA.

Extract	Days				
	Zero time	7 days	14 days	21 days	28 days
Oil (control)	0.44 ± 0.01	1.7 ± 0.01[a]	4.86 ± 0.20[a]	6.77 ± 0.21[a]	6.09 ± 1.88[a]
Oil + BHT	0.44 ± 0.01	0.82 ± 0.16[b]	1.26 ± 0.50[cd]	2.90 ± 0.01[c]	3.80 ± 0.10[b]
Petroleum ether	0.44 ± 0.01	0.63 ± 0.10[b]	1.00 ± 0.17[d]	2.10 ± 0.80[d]	3.40 ± 0.10[b]
Chloroform	0.44 ± 0.01	0.61 ± 0.11[b]	2.79 ± 0.38[b]	3.02 ± 0.10[c]	4.06 ± 0.43[b]
Ethyl acetate	0.44 ± 0.01	0.70 ± 0.28[b]	2.30 ± 1.30[c]	3.70 ± 0.10[b]	4.56 ± 0.23[b]
Methanol	0.44 ± 0.01	1.7 ± 0.70[a]	3.60 ± 0.45[b]	3.40 ± 0.10[c]	4.29 ± 0.39[b]

Each value is the Mean ± SD.
*The values having different superscripts in the same column are significantly different at $p \leqslant 0.05$.

Table 7 Inhibitory effect of tomato peel extracts on the formation of 2-alkenals in cotton seed oil as measured by using P-anisidine method.

Extract	Days				
	Zero time	7 days	14 days	21 days	28 days
Oil (control)	13.63 ± 0.11	37.36 ± 0.82^{a}	47.10 ± 2.6^{a}	53.33 ± 3.1^{a}	72.30 ± 2.6^{a}
Oil + BHT	13.63 ± 0.11	22.83 ± 0.25^{b}	25.80 ± 3.0^{b}	29.30 ± 3.08^{b}	34.06 ± 0.55^{b}
Petroleum ether	13.63 ± 0.11	12.16 ± 3.05^{d}	19.30 ± 1.04^{cd}	22.10 ± 1.82^{cd}	24.80 ± 9.1^{cd}
Chloroform	13.63 ± 0.11	15.06 ± 2.53^{cd}	16.26 ± 5.0^{d}	19.30 ± 0.79^{d}	21.30 ± 5.5^{d}
Ethyl acetate	13.63 ± 0.11	18.06 ± 4.82^{bc}	21.70 ± 2.36^{bc}	24.0 ± 3.50^{c}	26.06 ± 1.27^{cd}
Methanol	13.63 ± 0.11	16.40 ± 1.47^{cd}	26.06 ± 2.21^{b}	30.40 ± 0.96^{b}	32.00 ± 1.68^{b}

*Each value is the Mean ± SD.
*The values having different superscripts in the same column are significantly different at $p \leqslant 0.05$.

Table 8 Inhibitory effect of tomato peel extracts on total carbonyls (mg/100 g) present in cotton seed oil.

Extract	Days			
	7 days	14 days	21 days	28 days
Oil (control)	25.26 ± 0.83^{a}	42.46 ± 4.35^{a}	48.10 ± 3.82^{a}	60.53 ± 1.25^{a}
Oil + BHT	13.10 ± 0.60^{d}	14.05 ± 0.95^{d}	23.60 ± 1.05^{bc}	32.66 ± 5.82^{b}
Petroleum ether	12.86 ± 1.28^{d}	8.73 ± 1.25^{e}	18.06 ± 1.64^{c}	25.06 ± 0.98^{c}
Chloroform	14.93 ± 0.65^{c}	17.46 ± 1.25^{c}	20.90 ± 3.34^{bc}	28.36 ± 5.20^{bc}
Ethyl acetate	17.46 ± 1.25^{b}	19.00 ± 0.30^{c}	25.26 ± 0.83^{b}	40.20 ± 2.52^{d}
Methanol	23.83 ± 0.75^{a}	30.90 ± 0.30^{b}	48.50 ± 6.18^{a}	50.40 ± 5.01^{e}

*Each value is the Mean ± SD.
*The values having different superscripts in the same column are significantly different at $p \leqslant 0.05$.

3.2.3. Inhibitory effect of tomato peel extracts on malondialdehyde formation (TBA value)

Malondialdehyde (MDA) is a degradation product generated from lipid peroxidation (oxidative degradation of polyunsaturated fatty acids in cell membrane). MDA has been extensively used as an index for lipid peroxidation and as a marker for oxidative stress (Kubow, 1992). The reaction of MDA with TBA has been widely adopted as a sensitive assay method for lipid peroxidation (Ohkawa et al., 1978). The data in Table 6 showed that petroleum ether, chloroform, and ethyl acetate extracts in addition to BHT caused significant decreases in TBA values after 7 days of storage. After 14 and 28 days, all the extracts including methanol extract beside BHT revealed significant decreases in TBA values as compared to the control. The most effective extract was petroleum ether followed by chloroform.

3.2.4. Inhibitory effect of tomato peel extracts on the formation of 2-alkenals in cotton seed oil as measured by P-anisidine method

P-Anisidine value is extensively used to measure the secondary oxidation products mainly non-volatile carbonyls, formed during lipid oxidative degradation. P-Anisidine values, which reflect the inhibitory effect of the tomato peel extracts on the formation of 2-alkenals in cotton seed oil, were determined every 7 days and recorded in Table 7. The results revealed that alkenals formation increased by increasing storage period in control, BHT and extract samples. The increase was significantly lower in the samples treated with tomato peel extracts than control. However, chloroform and petroleum ether extracts were the best among the four extracts where they caused significant decrease in P-anisidine values as compared to control and their activities in this respect were better than that of BHT (the artificial antioxidant).

3.2.5. Inhibitory effect of tomato peel extracts on total carbonyls present in cotton seed oil during storage period

Carbonyl value is widely used as a measure of the secondary lipid oxidation indicating the amount of carbonyl formed in fats and oils during oxidation. Data in Table 8 shows total carbonyl value changes during 28 days of storage which measured every 7 days. It is clear that petroleum ether, chloroform and ethyl acetate extracts caused significant decreases in carbonyl content in all the investigated samples during storage period as compared to control. The best one among them was petroleum ether extract which reduced carbonyl content more than that of BHT (the artificial antioxidant).

On the other hand, methanol extract exhibited the lowest antioxidant activity in this respect. Regarding the antioxidant activity of tomato peel, it could be noticed that tomato peel contains high levels of antioxidants and the extracts of petroleum ether and chloroform have the majority of antioxidants found in tomato peels such as phenolic compounds and lycopene. Martinez-Valvercle et al. (2002) reported that tomato can provide the diet with a significant proportion of the total antioxidants. This is largely in the form of carotene (Nguyen and Schwartz, 1999). Al-Wandawi et al. (1985) reported that tomato skin contains high levels of lycopene compared to the pulp and seeds. Stewart et al. (2000) reported that the majority of the flavonoids in tomatoes are present in the skin. Sanchez et al. (2003) separated the tomato peel from the tomato

slurry and modified it by passing through the homogenizer and then added it to the tomato juice. The prepared tomato paste was reported to have improved rheological properties than the paste prepared without the addition of tomato slurry. The authors suggested that the addition of modified tomato slurry could lead to a significant cost saving by reducing the quantity of thickeners added to the paste.

4. Conclusion

From these results it can be concluded that tomato peel has a good nutritional value because of its content of essential amino acids and fatty acids besides its high content of antioxidants such as flavonoids, phenolic acids, lycopene, ascorbic acid and minerals (Ca, Cu, Mn, Zn, and Se). Therefore, the peel fraction of tomatoes could be used as a value added ingredient in other food products where it could play an important role in improving antioxidant intake in the human diet. However, removal of this fraction during home cooking or processing results in a loss of their potential health benefits. Consumer demand for healthy food products provides an opportunity to develop foods rich in antioxidants as new functional foods. Further research would be desirable, to assess the physiological effects of the main components of petroleum ether and chloroform extracts separated from tomato peels in the human body, as well as the possibility of using them in pharmaceutical industry as antioxidant supplements.

References

Al-Wandawi, H., Abdul Rehman, M.H., Al shaikhly, K.A., 1985. Tomato processing wastes as essential raw materials source. Journal of Agriculture and Food Chemistry 33, 804–807.

A.O.A.C. (2000). Association of Official Analytical chemists, 17th Ed. Official Methods of Analysis, Washington, DC, USA.

AOCS American Oil Chemists Society, 1998. Official methods P-anisidine value In Official methods and recommended practices of the American Oil Chemists Society, fifth ed., pp. 18–90.

Brand-Williams, B., Cuvelier, M.E., Berset, C., 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Science and Technology 28, 25–30.

Charles, D.J., Morales, R., Simon, E., 1993. Essential oil content and chemical composition of hydroalcoholic extract of fennel. New Crops, 570–573.

EI-Badrawy, E. E.Y. 1996. Biochemical Studies on Some Natural Plant Products. Ph.D. Thesis. Fac. of Agric., Mansoura, Univ., Egypt.

Erlund, Iris, 2004. Review of the flavonoids quercetin, hesperetin, and naringenin. Dietary sources, bioactivities, bioavailability, and epidemiology. Nutrition Research, 24, 851–874.

FAOSTAT, 2007. FAOSTAT agriculture production database. <http:llfaostat.fao.org/site/336/default.aspx> (accessed 11.07).

Fernandez, A.A.H., Novelli, E.L.B., Okoshi, K., Okoshi, M.P., Di Muzio, B.P., Guimarães, J.F.C., 2010. Influence of rutin treatment on biochemical alterations in experimental diabetes. Biomedicine and Pharmacotherapy 64, 214–219.

Franken, E.N., 1998. Lipid Oxidation Dundee. The Oily Press, UK, p. 301.

George, B., Kaur, C., Khurdiya, D.S., Kapper, H.C., 2004. Antioxidants in tomato (*Lycopersicon esculentum*) as a function of genotype. Food Chemistry 84, 45–51.

Giovanelli, G., Paradise, A., 2002. Stability of dried and intermediate moisture tomato pulp during storage. Journal of Agriculture and Food Chemistry 50, 7277–7281.

González, I.N., Valverde, V.G., Alonso, J.G., Periago, M.G., 2011. Chemical profile, functional and antioxidant properties of tomato peel fiber. Food Research International 44, 1528–1535.

Guardia, T., Rotelli, A.E., Juarez, A.O., Pelzer, L.E., 2001. Anti-inflammatory properties of plant flavonoids. Effects of rutin, quercetin and hesperidin on adjuvant arthritis in rat. IL Farmaco 56, 683–687.

Haung, D., Ou, B., Prior, R.L., 2005. The chemistry behind antioxidant capacity assays. Journal of Agriculture and Food Chemistry 53, 1841–1856.

Hemi, K.E., Taigliaferro, A.R., Bobilya, D.J., 2002. Flavonoids antioxidant chemistry, metabolism and structure activity relationship. The Journal of Nutrition Biochemistry 13, 572–584.

Kikuzaki, H., Nakatani, O., 1993. Antioxidant effect of some ginger constituents. Journal of Food Science 58, 1407–1410.

King, A.J., Zeidler, G., 2004. Tomato pomace may be a good source of vitamin E in broiler diets. Californiea Agriculture 58, 59–62.

Kubow, S., 1992. Routes of formation of toxic consequences of lipid oxidation products in foods. Free Radical Biological Medicines, 1263–1281.

Lario, Y., Sendra, E., García-Pérez, J., Fuentes, C., Sayas-Barberá, E., Fernández López, J., et al., 2004. Preparation of high dietary fiber powder from lemon juice by-products. Innovative Food Science and Emerging Technologies 5 (1), 113–117.

Lavelli, V., Peri, C., Rizzolo, A., 2000. Antioxidant activity of tomato products as studied by model reactions using xanthine oxidase, myelperoxidase, and copper-induced lipid peroxidation. Journal of Agricultural and Food Chemistry 48, 1442–1448.

Luten, J., Crews, E., Flynn, A., Van, D.P., Hurrell, R., Deelstra, H., Shen, L., Fairweather-Talt, S., Hickson, K., Faire, R., Schleminer, U., Frochlich, W., 1996. Interlaboratory trial on the determination of the in vitro iron dialysabilily from Food. Journal of the Science of Food and Agriculture 72, 415–424.

Martinez-Valvercle, I., Periage, M.J., Provan, G., Chesson, A., 2002. Phenolic compounds, Lycopene and antioxidant activities in commercial varieties of tomato (lycopersicon esculentum). Journal of the Science of Food and Agriculture 82, 323–330.

Miller, N., Rice, D., Evans, E., 1997. Factors influencing the antioxidant activity determined by ABTS. Radical Cation Assay 26, 195–199.

Nguyen, M.L., Schwartz, S.J., 1999. Lycopene: chemical and biological properties. Food Technology 53, 38–53.

Ohkawa, H., Ohishi, N., Yagi, K., 1978. Assay for lipid peroxides in animal tissue by thiobarbituric acid reaction. Analytical Biochemistry 95, 351–358.

Ottolenghi, A., 1959. Interaction of ascorbic acid and mitochondrial lipids. Archives Biochemistry Biophysics 79, 355–358.

Radwan, S.S., 1978. Coupling of tow dimension thin layer chromatograph with gas chromatography for the quantitative analysis of lipids classes and their constituent fatty acid. Journal of Chromatographic Science 16, 538–542.

Raffo, A., Leonardi, C., Fogliano, V., Ambrosino, P., Salucci, M., Gennaro, L., et al., 2002. Nutritional Value of Cherry tomatoes (*Lycopersicon esculentum* CvNaomi F1) harvested at different ripening stages. Journal of Agricultural and Food Chemistry 50, 6550–6556.

Sanchez, M., Calixto, F., 1998. A procedure to measure the antiradical efficiency of polyphenols. Journal of the Science of Food and Agriculture 76, 270–276.

Sanchez, M.C., Valencia, C., Ciruelos, A., Latorre, A., Gallegos, C., 2003. Rheological properties of tomato paste: Influence of the addition of tomato slurry. Journal of Food Science 68, 551–554.

SAS, 2001. SAS Users Guide: Statistics (8th ed.) SAS Institute Inc., Gary, NC Soler-Rivas, C.; Espin, I. C. and Wichers, I. (2000). An easy and fast to compare total free radical scavenger capacity of food studys. Phytochemical Analysis 11, 330–338.

Sharma, S.K., Le Maguer, M., 1996. Lycopene in tomatoes and tomato pulp fractions. Italian Journal of Food Science 2, 107–113.

Silva, E.M., Souza, J.N.S., Rogez, H., Rees, J.F., Larondella, Y., 2006. Antioxidant activities and polyphenolic contents of fifteen selected plant species from the Amazonian region. Food Chemistry 101 (3), 1012–1018.

Soler-Rivas, C., Espin, I.C., Wichers, I., 2000. An easy and fast to compare total free radical scavenger capacity of food studys. Phytochemical Analysis 11, 330–338.

Stewart, A.J., Bozonnet, S., Mulluen, W., Jenkis, G.I., Lean, M.E.J., Crozier, A., 2000. Occurrence of flavonols in tomato and tomato-based products. Journal of Agriculture and Food Chemistry 48, 2663–2669.

Van Gadow, A., Joubert, E., Hannsman, C.T., 1997. Compression of the antioxidant activity of aspalathin with that of other plant phenols of roolobs tea (*Aspalanthus Linearis*), α-tocoferol BHT, and BHA. Journal of Agriculture and Food Chemistry 45, 632–638.

Yen, W.J., Change, L.W., Duh, P.D., 2005. Antioxidant activities of peanut seed test and its antioxidative component. Ethyl protocatechuate. Lebensmittel-Wissenschaft and Technologie 38, 193–200.