J. Food and Dairy Sci., Mansoura Univ., Vol. 5 (4): 247 - 263, 2014

ANTIOXIDANT PROPERTIES OF SOME EXTRACTS FROM GAMMA IRRADIATED TOMATO (*Lycopersicon esculentum* L.) POMACE

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ABSTRACT

In this study, the gamma radiation processing of tomato pomace samples was carried out at dose levels of 0, 1, 3 and 5 kGy. The total phenolic content, total flavonoids content and antioxidant activity properties of both non-irradiated and irradiated samples extracted in acetone 70%, methanol and chloroform: ethyl acetate (1:1) were assessed. The obtained data showed that, the total phenolic content increased with an increase in radiation dose for all extractions. Extracted Phenolic content from tomato pomace by using acetone (70%) was higher than those extracted by other solvents, whereas the phenolic content in acetone extract was increased from 182.579 mg GAE/100 g^{-1} for the control sample to 191.445 mg GAE/100 g^{-1} for the 3 kGy radiation-processed samples. Three methods were carried out to determine the antioxidant activity of tomato pomace, the first method was the radical scavenging activity against 2, 2′-diphenyl-1-picrylhydrazyl (DPPH), acetone extract exhibited greater scavenging activity than those extracted by other solvents. The same trend was also observed by using the second method of β- carotene bleaching assay and third method of ferric reducing antioxidant power (FRAP). The Highest ratio of β-carotene reducing power was achieved with acetone extract at 3 kGy whereas reached to 61.14%. Twelve phenolic acids component were identified in both non-irradiated and irradiated at 3kGy tomato pomace extracts by HPLC. Acetone extract of gamma irradiated and non-irradiated tomato pomace was tested for this antioxidant activity against oxidative stability of sunflower oil. The overall results indicated that, the highest oxidative stability (10.6 hr.) was obtained by using gamma irradiated tomato pomace at 3 kGy extract compared with those of the other doses. Finally, the obtained data showed that, tomato pomace is a very promising source of bioactive compounds and it is a very potential natural source of antioxidant compounds.

Keyword: Tomato pomace- gamma irradiation - phenolic compounds – Flavonoid compounds-Antioxidant activity -High performance liquid chromatography (HPLC).

INTRODUCTION

Tomato is one of the world's major vegetable with a worldwide and Egypt production of 161.8 and 8.6 million tons, respectively (FAOSTAT, 2012**)**. It is an excellent source of many nutrients and secondary metabolities that are

important for human health; minerals, vitamin C and E, ß-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, tomato paste and sauces, 10–30% of their weight becomes waste or pomace (King and Zeidler, 2004). The pomace consists of the crushed skins and seeds of the fruit. It is rich in protein (20–23% on dry basis) and fat (12–18%, mostly located in the seeds), while crude fibers comprise the third main component (12–30%) (Liadakis, 1999). 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).

Several other organic micronutrients, such as carotenoids and polyphenols, impart health benefits. Carotenoids are mostly used as natural food colorants, but also some of them (ß-carotene, apocarotenal) have a vitamin A activity as well as antioxidant activity in vitro and in vivo (Kiokias and Gordon 2004). Polyphenols also act as antioxidants; they scavenge free radicals which are responsible for serious diseases and for the oxidation of lipids, proteins, and DNA. Several studies have revealed their antimicrobial, antithrombotic, antimutagenic, and anticarcinogenic activities (Kandaswami and Middleton, 1997and Sahu and Green, 1997). In addition to health benefits, the supplementation of food products with antioxidants delays the formation of off-flavors and rancidity and extends the shelf life of the product. Carotenoids and polyphenols are extensively distributed in several plant by-products. Thus most fruit and vegetable by-products could serve as raw materials for their recovery. Moreover, these antioxidants or colorants would have a natural origin, which is in accordance with the demands of consumers for ‘‘all natural’’ because of the possible toxicity of synthetic additives. 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). Stewart *et al.* (2000) reported that the majority of the flavonoids 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 that 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 are discarded during processing of tomatoes into paste (Al-Wandawi *et al.*, 1985).

The antioxidants are isolated by solvent extraction and both extraction yield and antioxidant activity of the extracts are strongly dependent on the solvent, due to the variant antioxidant potential of compounds with different polarity. Nonpolar solvents (hexane and petroleum ether) can be used for the recovery of tocopherols and certain phenolic terpenes. Ethyl ether and ethyl acetate are very efficient for the recovery of flavonoid aglycons, low-molecular-weight phenols, and phenolic acids. Solvents of higher polarity (ethanol or ethanol–water mixtures) additionally can extract flavonoid glycosides and higher molecular weight phenols, resulting higher yields of total extracted polyphenols. However, that can range in size from monomers to long-chain polymers such as tannins, and usually exist bound to carbohydrates or as part of repeating subunits of high molecular weight polymers. Acetone results were the highest yield compared to ethanol, petroleum ether, and hexane (Aravantinos-Zafiris *et al.*, 1992).

On the other hand gamma irradiation is approved by the Food and Drug Administration and the United States Department of Agriculture to preserve various food products. The U.S. Food and Drug Administration (1981) concluded that food irradiated at 50 kGy or less can be considered safe for human consumption. Various forms of Irradiation have been shown to influence the phenolic content of foods and their by-products. Far-infrared has also been used to release low-molecular- weight phenolics with antioxidant activity from food by-products for instance rice hulls and sesame meal extracts (Lee *et al.,* 2003 and 2005). Gamma irradiation (10 kGy) increased phenolic acid content in cinnamon and clove, while phenolic content in nutmeg remained unaltered (Variyar *et al.,* 1998 and Cantos *et al.,* 2000). Additionally, new trials for increasing biological activities of natural product by gamma irradiation showed advantage in increasing yields, improved the color and antioxidant activity (Byun *et al.*, 1999; Jo *et al.*, 2003 and Kim *et al.*, 2006). There is a growing scientific interest in the influence of irradiation processes on antioxidant activity and the compounds responsible for such activity. Several studies on plant materials showed that gamma irradiation does maintain or enhance antioxidant properties (Byun *et al.*, 2002). However, some studies have shown that gamma irradiation decreased the antioxidant properties in plant materials (Ahn *et al.*, 2004 and Lampart-Szczapa *et al.*, 2003).

In general, the present study was undertaken to investigate the effect of gamma irradiation at various doses level on the antioxidant activity properties and total phenolic and flavonoids contents extracted with different solvents of tomato pomace.

MATERIALS AND METHODS

Materials:

Tomato pomace was obtained from Qaha Egypt For Food DevelopmentCompany,Egypt, Butylatedhydroxytuluen (BHT) 1, 1-Diphenyl-2-picrylhydrazyl (DPPH), β-carotene, gallic acid, quercetin, iron (III) chloride

and aluminum chloride were purchased from Sigma (St. Louis, MO, USA), Folin- Ciocalteu reagent was purchased from LOBA Chemie, india. All other chemicals used were analytical reagent grade.

Methods:

Preparation of plant extract:

Tomato pomace was dried in oven drier at 45 ºC for 72 hr and grounded. The dried pomace was packed in polyethylene bag each bag was contained 250 g of dried pomace. Irradiation treatment were carried out at doses of 1, 3 and 5 kGy using a ^{60}Co Russian gamma chamber, (dose rate 1.3 kGy/h), belonging to Cyclotron Project, Nuclear Research Center, Atomic Energy Authority, Cairo, Egypt.

Dried pomace powder (10g) was extracted individually into 100 ml of chloroform: ethyl acetate (1: 1), methanol and acetone: water: glacial acetic acid (70: 29.5: 0.5) separately after soaking in hexane to remove fatty materials (1: 5). All the extracts were subjected to shaking at room temperature overnight at a speed of 200 vib. /min. The extracts were filtered through Whatman No. 42 filter paper and the residue was again extracted with 100 ml of respective solvent to ensure the complete extraction of phenolic compounds. Then, the filtrate was subjected to rotary evaporator at 45ºC under reduced pressure for the removal of solvent. The extracts were stored at -18ºC until analyses.

Determination of total phenolic content (TPC):

Total phenolic content was determined by the Folin–Ciocalteu method according to Arabshahi-Delouee and Urooj (2007).

Determination of total flavonoids content (TFC):

Total flavonoids content was determined by the method according to Ordon*et al.* (2006**)**.

Antioxidant activity of extracts:

Because of the differences among the various test systems available, the results of a single method can provide only a limited assessment of the antioxidant properties of a substance (Giann*et al.*, 2005). For that reason, in this study the antioxidant capacity of each extract was determined through three complementary assay procedures.

DPPH radical-scavenging activity:

The electron donation ability of the obtained extracts was measured by bleaching of the purple colored solution of DPPH according to the method of Hanato*et al.*, 1988 and Gülçin*et al.*, 2004. Percentage of antioxidant activity of free radical DPPH was calculated as follow:

β-Carotene/linoleic acid bleaching (βCB):

The ability of extracts and synthetic antioxidants to prevent the bleaching of β-carotene was assessed as described by **Keyvan*et al.* (2007)**.

Ferric reducing antioxidant power (FRAP):

Reducing power of all extracts was measured by the method of Oyaizu (1986).

High performance liquid chromatography (HPLC) analysis:

Fractionation and identification of phenolic compounds in extracts:

Phenolic compounds of unirradiated and irradiated with 3 kGy tomato pomace extracts were estimated in Central Laboratory of Food Tech. Res. Inst., Agric.Res.Center, Giza, Egypt. Phenolic compounds of each sample were identified by comparing their relative retention times with those of the standard mixture chromatogram (Elbadrawy and Sello, 2011). The concentration of an individual compounds was calculated on the basis of peak area measurement , then converted to mg phenolic / 100 g dry matter .

Fractionation and identification of flavonoide compounds in acetone extract:

Flavonoide compounds of unirradiated and irradiated with 3 kGy tomato pomace acetone extract were determined by HPLC. The quantification was made with an external standard (Skerget *et al.*, 2005).

Determination of antioxidant activity of acetone extract by the rancimat method:

One ml of condensed acetone extract of unirradiated and irradiated at 1, 3 and 5 kGy tomato pomace mixed well with sunflower oil using a magnetic stirrer to complete dispersion in the oil. Sunflower oil sample without any addition was kept as a control. The antioxidant activity was determined by the Rancimat method using Rancimat Metrohm 679 as described by Hasenhuttle and Wan (1992) and the induction period (I.P.) was conducted with Rancimat at 100ºC and calculated at 25ºC using the temperature coefficient of 2.2 for induction period according to the method reported by Hadron and Zurcher (1974) and 2.5 for expired period. The antioxidant activity and increasing index were calculated using the following equations:

$$\text{Antioxidant activity} = \frac{\text{Induction period of sample}}{\text{Induction period of control}} \quad \textbf{(1)}$$

$$\text{Increasing index} = \frac{\text{Induction period of sample} - \text{Induction period of control}}{\text{Induction period of control}} \times 100 \quad \textbf{(2)}$$

RESULTS AND DISCUSSION

Total phenolic compounds (TPC):

Phenolic compounds are hydroxylated derivatives of benzoic and cinnamic acids and contribute to overall antioxidant activities in the plants. Data inTable(1)indicate that, thesolvent extractionswere affected the concentration of total phenols in irradiated and non-irradiated samples of tomato pomace. The phenolic contents of the control (non-irradiated) samples were found to be 182.58, 134.11 and 78.38 mg GAE/100 g^{-1}DW for acetone 70%, methanoland Chloroform: ethyl acetate (1:1) extracts, respectively. It can be inferred from these results that acetone 70% is the most efficient solvent for extracting phenolic compounds from tomato pomace.This may be attributed to higher polarity and good solubility of acetone (70%) for phenolic components extraction from plant materials (Wieland *et al.*, 2006).

Table (1): Total Phenolic and Flavonoide contents of gamma irradiated and non-irradiated tomato pomace extracted by different solvents.

Gamma irradiation doses (kGy)	Solvents					
	Chloroform: ethyl acetate (1:1)		Methanol		Acetone (70%)	
	TPC	TFC	TPC	TFC	TPC	TFC
0	78.38	50.16	134.11	62.25	182.58	72.90
1	85.05	55.77	137.44	70.74	188.57	89.59
3	100.37	56.71	142.40	65.70	191.45	90.60
5	80.22	51.38	134.80	72.90	185.34	85.71

Data in the same table show that, the total phenolic contents of irradiated acetone extracts, was 191.45 mg GAE/100 g^{-1}DW for a gamma radiation at 3 kGy. It seems that 1-5 kGy of irradiation might induce some chemical reactions in components of tomato pomace, which possibly degrade or decompose large molecules into small phenolic molecules, which are readily soluble in acetone and may also be beneficial for the antioxidant properties of tomato pomace. The phenolic and flavonoids contents depend on the cultivar, growing region, climate, maturity, cultivation practice, storage conditions (Poyrazoglu*et al.*, 2002) and the methods ofextractions. These compounds are known for their properties to scavenge free radicals and to inhibit lipid oxidation in vitro (Noda*et al.*, 2002). On the other hand, irradiation treatment at 3 kGy in the same solvent had an increasing in TPC of all extracts particular compared to other treatments at 0, 1 and 5 kGy.Variya*et al.* (1998) found increased the amounts of phenolic acids in irradiated cloves and nutmeg. Harrison and Were (2007) also reported increases in total phenolic content of gamma-irradiated almond skin extract, as compared to the control samples. These increases in phenolic contents were associated with the degradation of tannins (Variya*et al.*, 1998) and changes in the conformation of the molecules (Topuz and Ozdemir, 2004), as a result of the irradiation treatment. In contrast, Kosek*iet al.*, (2002) reported a decrease in the amount of total phenolic compounds in dehydrated rosemary after irradiation doses of between 10 and 30 kGy, with respect to control samples. The difference in the effect of radiation on total phenolic content may be due to plant type, geographical and environmental conditions, state of the sample (solid or dry), phenolic content composition, extraction solvent, extraction procedures, temperature, dose of gamma irradiation.Bhatt *et al.* (2007) observed that, except for 2.5 kGy, the other doses showed a significant dose-dependent increase in total phenolics to higher extractability by depolymerization and dissolution of cell wall polysaccharides by irradiation, which was known to increase the activity of phenylalanine ammonialyase, responsible for the synthesis of phenolic compounds.

Total flavonoids content (TFC):

Flavonoids, which are the major components of the total phenolic content of tomato pomace, were also quantified in different solvent extracts (Table.1).Data in Table (1) indicate that, theacetone extract of tomato pomace had the highest total flavonoids contents in all extracts of non-irradiated samples. The hightotalcontent of flavonoids (90.60mg QE /100g^{-1}DW) was observed with acetone extract of irradiated tomato pomace(3kGy) gamma irradiation, while the lowest level was found in chloroform extract of tomato pomace which exhibited 50.16 mg QE/ 100g^{-1}DW. The results confirmed a previous report that flavonoids represent the main group of phenolic compounds in white onion (Yang *et al.*, 2004). In spite of gamma irradiation, it can be observed that 3kGy enhanced TFC compared to 0, 1 and 5 kGy; this may be due to the same effects of irradiation on TPC mentioned before.

Antioxidant activity of extracts:

All plant phenolic classes have the structural requirements of free radical scavengers and have potential as food antioxidants (Jayathilankan*et al.* 2007). The antioxidant activity of phenolic compounds may result from the neutralization of free radicals initiating oxidation processes or from the termination of radical chain reactions. Also the antioxidant activity of phenolic compounds is due to their high tendency to chelate metals. Phenols are very important plant constituents because of their scavenging ability on free radicals due to their hydroxyl groups (Heim*et al.*, 2002). Several studies showed good correlation between the phenols and antioxidant activity. As mentioned by Frankel and Meyer (2000) and Huang *et al.* (2005) no single method is adequate for evaluating the antioxidant capacity of foods or extracts, since different methods can yield widely diverging results. Thus, several methods based on different mechanisms should be used. Here we applied the DPPH radical-scavenging activity, β-carotene/linoleic acid bleaching test and the ferric reducing antioxidant power (FRAP) to each extract.

DPPH radical-scavenging activity:

The effect of antioxidants on DPPH radical-scavenging is thought to be due to their hydrogen-donating ability, $DPPH^{\bullet}$ is a stable free radical and accepts an electron or hydrogen radical to become a stable molecule (Gülçin*et al.*,2004).The obtained data in Table (2) indicate that,the antioxidant activity with different solvents varied from 35.53 to 69.08 % after 120 min for non-irradiated samples. On the other side, the highest antioxidant activity was observed with acetone extract (74.05 % after 120 min) of irradiated tomato pomace at 3kGy compared withBHT value (74.05 % after 120 min). So, the high scavenging ability of acetone extract of irradiated tomato pomace at 3kGy can be correlated to the highest phenolic content. The enhanced antioxidant capacity /activity of a plant after irradiation is mainly attributed either to increased enzyme activity (e.g. phenyl alanine ammonialyase and peroxidase activity) or to the increased extractability from the tissues extractability by depolymerization and dissolution of cell wall polysaccharides by irradiation (Alothman *et al.*, 2009).

T2

β-Carotene/linoleic acid bleaching (BCB):

Data in Table (3) show that, all extracts were capable of inhibiting the bleaching of β-carotene by scavenging linoleate-derived free radicals. The order of decreasing efficacy of irradiated and non-irradiated tomato pomace extracts was acetone> methanolic > (chloroform: ethyl acetate). The results reveal that, the scavenging ability of acetone extract (58.50%) was the highest one compared with the other extracts of non-irradiated tomato pomace. On the other hand, the irradiation treatment at 3 kGy was enhanced the scavenging ability of all extracts which achieved to 38.42%, 53.52% and 6`1.14% for chloroform: ethyl acetate, methanol and acetone extracts, respectively. Data in the same table showed that, the acetone extract of irradiated tomato pomace at 3 kGy was the highest extract in β-carotene/ linoleic acid bleaching (βCB) system compared to other extracts and synthetic antioxidants (BHT).Kumari*et al.* (2009) also showed similar results with triphala, wherein they have found out an increase in gallic acid concentration and total phenolics in the water extract due to irradiation that leads to increase in antioxidant property. On the other hand the decrease in antioxidants caused in extracts of irradiated tomato pomace at 5 kGy compared to 3 kGy could be attributed in general, to the formation of radiation-induced degradation products or the formation of free radicals (Sajilata and Singhal, 2006). Breitfellner*et al.* (2002) have reported that γ-irradiation (1-10 kGy) of strawberries lead to the degradation of phenolic acids like cinnamic, p-coumaric, gallic, and hydroxybenzoic acids. The hydroxylation (decomposition) of these phenolic acids has been attributed to the formation of free hydroxyl (OH^-) radicals during the treatment.

Ferric reducing antioxidant power (FRAP):

An irradiation dose-dependent increase in the ferric reducing power value was observed in the tomato pomace extracts (Table, 3). An increasing in the ferric reducing power was observed in 1 and 3 kGy compared to with 0 and 5 kGy doses in all extracts. However, the results revealed that the ferric reducing power value of acetone extract (1.745) was the highest one compared with the other investigated extracts of non-irradiated tomato pomace. On the other hand, the irradiation treatment at 3 kGy was enhanced ferric reducing power value of all extracts which achieved to 1.580, 1.780 and 1.900 for Chloroform: ethyl acetate, Methanol and Acetone extracts, respectively. From these results, overall, the acetone extract of irradiated tomato pomace at 3 kGy was the highest extract in ferric reducing power value compared to the other extracts and synthetic antioxidants (BHT). Total phenolic content and ferric reducing power are related with each other. Fe (III) reduction is often used as an indicator of electron-donating activity, which is an important mechanism of phenolic antioxidant action (Dorman *et al.*, 2003). The FRAP (ferrous reducing antioxidant power) assay is commonly used for assessing antioxidant activity, since it has high sensitivity, and is rapid and inexpensive. In the present investigation, there was a significant and/or negligible increase in the FRAP of all irradiated tomato pomace when compared to non-irradiated tomato pomace extracts.

Table (3): β-carotene/ linoleic acid bleaching (βCB) system and absorbance of ferric reducing power (FRAP) of gamma irradiated and non-irradiated tomato pomace extracted by different solvents compared with BHT.

Gamma irradiation doses (kGy)	Solvents					
	Chloroform : ethyl acetate (1:1)		Methanol		Acetone (70%)	
	ß-carotene	FRAP	ß-carotene	FRAP	ß-carotene	FRAP
0	35.04	1.373	50.44	1.632	58.50	1.745
1	37.98	1.516	52.2	1.668	59.24	1.863
3	38.42	1.580	53.52	1.780	61.14	1.900
5	36.51	1.420	51.76	1.889	58.80	1.815
BHT (200ppm)	60.85	1.019	60.85	1.019	60.85	1.019

Fractionation and identification of phenolic compounds in extracts:

The non-irradiated and gamma irradiated tomato pomace with 3 kGy doses and extracted by different solvents were subjected to HPLC. Data in Table (4) show the separation a large number of compounds of which twelve phenolic acids were identified. The phenolic acids were identified according to their retention time in comparison with authentic samples. The irradiation treatment with 3kGy of tomato pomace led to phenolics content increasing. For example, the cholorogenic acid, this corresponding concentration was 2.661, 2.625 and 1.680 mg/100 g of non-irradiated tomato pomace in chloroform: ethyl acetate, methanol and acetone extracts, respectively. While, the concentration of cholorogenic acid was increased to 9.395, 12.301 and 2.411 mg/100 g in gamma irradiated (3kGy) tomato pomace of the same extracts, respectively. Phenols are very important plant constituents because of their scavenging ability on free radicals due to their hydroxyl groups (Heim *et al.*, 2002). Several studies showed good correlation between the phenols and antioxidant activity (Haung *et al.*, 2005 and Silva *et al.*, 2006).

Table 4. Identified phenolic compounds (mg/100gm) of non-irradiated and gamma irradiated tomato pomace with 3 kGy extracted by different solvents.

Phenolic compounds	Phenolic compounds (mg /100gm)					
	Chloroform : ethyl acetate (1:1)		Methanol		Acetone :water : glacial acetic acid (70:29.5:0.5)	
	0 kGy	3 kGy	0 kGy	3 kGy	0 kGy	3 kGy
Protocatechuic	7.277	5.088	7.609	16.402	3.953	3.543
Catechein	1.645	1.397	1.201	1.394	5.566	-
Catechol	0.973	5.996	1.148	5.102	3.037	-
Chlorogenic	2.661	9.395	2.625	12.301	1.680	2.411
Caffeic	7.795	5.171	1.105	0.909	0.448	2.383
Vanillic	2.726	2.162	0.684	25.532	2.745	0.454
Caffeine	0.589	3.190	0.529	1.431	0.894	2.705
Ferulic	4.252	0.891	3.645	1.895	36.078	2.192
Salicylic	5.933	5.164	17.024	13.38	1.774	18.364
Ellagic	2.242	6.731	4.084	2.958	2.118	9.947
Coumarin	1.633	0.846	0.612	1.009	-	-
Cinnamic	1.505	1.616	0.819	1.020	-	1.988

Fractionation and identification of flavonoid compounds in acetone extract:

The non-irradiated and gamma irradiated tomato pomace with 3 kGyand extracted by the acetone(70%)solvent was subjected to HPLC. Data in Table (5)show the separation of eight flavonoids compounds were identified. TheFlavonoid compounds were identified according to theirretention time in comparison with authentic samples.It wasclear that Rutin was the abundant flavonoid compound followed by Rosmarinic, Luteolin, Quercitrin, Hespertin,NarengininandQuerctin,whereasKampferolwas the least one. The irradiation treatment with 3 kGy of tomato pomace led to flavonoids content increasing. For example, the concentration of Rutinincreased from 9.55 to 11.43 mg/100 gof non-irradiated and gamma irradiated tomato pomace (3 kGy) acetone extract, respectively. In the same idea, Gonzalez*et al.*(2011) found that tomato *peel* contains several flavonoids withbeneficial effects for human health such as rutin, naringeninand quercetin. Rutin has been associated with markedly decreasedhepatic and cardiac levels of triglycerides (Fernandez *et al.*,2010), and it has been suggested that it has anti-inflammatoryproperties (Guardia *et al.*, 2001). Naringenin has beensuggested as an antioxidant, an anti-inflammatory, and a regulatorof fat metabolism and sex hormone metabolism. Finally,quercetin has been reported to exhibit antioxidative,anticarcinogenic, anti-inflammatory, anti-aggregation, andvasodilating effects (Erlund, 2004).

Table5. Identified flavonoide compounds (mg/100g) of non-irradiated and gamma irradiated tomato pomace at 3 kGy of acetone extract.

Flavonoide compounds	Flavonoids compounds (mg /100g)	
	Acetone (70%)	
	0kGy	3kGy
Rosmarinic	5.02	5.93
Rutin	9.55	11.43
Quercitrin	2.76	3.30
Narenginin	2.25	1.50
Querctin	1.34	1.40
Hespertin	2.28	2.42
Kampferol	1.04	-
Luteolin	3.38	-

Effect of gamma irradiated and non-irradiated tomato pomace acetone extracts on oxidative stability of sunflower oil.

Lipid oxidation is one of the major deteriorative reactions especially, in highly processed foods such as margarines, butters and other fats. Accordingly, it is important to predict the oxidative stability of given food byrapid and reliable methods in order to determine shelf life and evaluate the effectof protective antioxidants (Thomsen*et al.*,2000).The induction period is determined at the time whichthe conductivity exponentially increases. The induction period has been definedas the length of time until progressive

oxidation exponentially accelerates thegeneration of oil degradation compounds (Kristott, 2000). Therefore, forcedoxidative conditions were used to determine the effect of addition of acetone extracts of gamma irradiated and non-irradiated tomato pomace on shelf life or oxidative stability of sunflower oil.

Data in Table (6) notice that, the induction period at 100˚C of sunflower oil was increased to 10.5 hr. as a result of addition BHT (200 ppm) compared with that of control sample (8.38hr.). Also, it is clear that, the oxidative stability (10.6 hr.) was obtained using addition of acetone extract of gamma irradiated tomato pomace at 3 kGy which increased the shelf life from 12.43 to 15.73 month. From the aforementioned data, it could be concluded that, the addition of acetone extract of gamma irradiated tomato pomace at 3 kGy improved the antioxidant activity and increasing index (1.26 and 26.49 %, respectively). As well as, it can be used as a new source of natural antioxidants to improve the oxidative stability of sunflower oil. These results are in accordance with those obtained byHemeda (1994).

Table (6): Effect of gamma irradiated and non-irradiated tomato pomace acetone extracton oxidative stability of sunflower oil.

Gamma irradiation doses (kGy)	Oxidative stability			
	Induction periodat (100ºC)	Shelf life at 25ºC (month)	Antioxidant activity	Increasing index (%)
Control	8.38	12.43	0	0
(0kGy)	10	14.83	1.19	19.33
(1kGy)	10.4	15.43	1.24	24.11
(3kGy)	10.6	15.73	1.26	26.49
(5kGy)	10.2	15.13	1.21	21.71
BHT (200ppm)	10.5	15.58	1.25	25.30

CONCLUSION

Generally, this study concluded that gamma radiation dose up to 3 kGy can improve the antioxidant activity of tomato pomace extracts, in addition to the enhancement of scavenging activity and increase in the phenolic and flavonoid contents. This study therefore, supports the use of gamma radiation as a phytosanitary treatment for tomato pomace and calls for further investigations to elucidate its effect on the other biological activities and constituents of the plant.

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الخواص المضادة للأكسدة لبعض مستخلصات تفل الطماطم المعامل بأشعة جاما

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تم في هذه الدراسة معاملة تفل الطماطم بجرعات صفر، ١، ٣ و٥ كيلو جراى بأشعة جاما. ثم تم تقدير المحتوى الكلى من الفينولات والفلافونيدات والنشاط المضاد للأكسدة لمستخلصات تفل الطماطم غير المعامل والمعامل بأشعة جاما والمستخلص بالأسيتون (٧٠%) ،الميثانول والكلورفورم : الإيثيل أسيتات (١:١). وقد أظهرت النتائج المتحصل عليها زيادة المحتوى الكلى من الفينولات لجميع المستخلصات بزيادة الجرعة الإشعاعية. وكان المحتوى الفينولى لتفل الطماطم المستخلص بالأسيتون (٧٠%) أعلى من المستخلصات بالمذيبات الأخرى، حيث زاد المحتوى الفينولى للمستخلص الأسيتونى من ١٨٢,٥٨ ملجم GAE /١٠٠جم من تفل الطماطم غير المعامل إلى ١٩١,٤٥ ملجم GAE /١٠٠جم من تفل الطماطم المعامل بجرعة ٣ كيلو جراى من أشعة جاما . تم تقييم النشاط المضاد للأكسدة لتفل الطماطم بثلاثة طرق، الطريقة الأولى وهى معرفة القدرة الإختزالية للشقوق الحرة (DPPH) ، حيث حقق المستخلص الأسيتونى اعلى قدرة إختزالية عن غيره من المستخلصات الأخرى. وقد لوحظ نفس الإتجاه مع الطريقة الثانية وهى قصر لون مستحلب البيتا كاروتين واللينوليك ومع الطريقة الثالثة أيضا وهى القدرة الإختزالية للحديديك (FRAP) . وقد حقق المستخلص الأسيتونى لتفل الطماطم المعامل بجرعة ٣ كيلو جراي بأشعة جاما أعلى مستوى من القدرة الإختزالية للبيتا كاروتين حيث وصل إلى ٦١,١٤%. تم التعرف بجهازالكروماتوجرافيا السائلة عالية الكفاءة (HPLC) على اثنى عشر حامض فينولى من المركبات الفينولية لمستخلصات تفل الطماطم غير المعامل والمعامل بجرعة ٣ كيلو جراى بأشعة جاما. تم إختبار فاعلية النشاط المضاد للأكسدة للمستخلص الأسيتونى لتفل الطماطم غير المعامل والمعامل بأشعة جاما بالجرعات المختلفة فى منع أكسدة زيت دوار الشمس. أظهرت النتائج المتحصل عليها ان اعلى ثبات لزيت دوار الشمس (١٠,٦ ساعة) كان بإستخدام المستخلص الأسيتونى لتفل الطماطم المعامل بأشعة جاما بجرعة ٣ كيلوجراى. ويتضح من النتائج المتحصل عليها ان تفل الطماطم مصدر هام للمركبات ذات النشاط الحيوى ويعتبر ايضا مصدراً كبيراً للمركبات الطبيعية المضادة للأكسدة.

قام بتحكيم البحث

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Table (2): DPPH radical scavenging activity of gamma irradiated and non-irradiated tomato pomace extracted by different solvents compared with BHT.

Gamma irradiation doses (kGy)	Induction periods (min)											
	Solvents											
	Chloroform : ethyl acetate (1:1)				Methanol				Acetone (70%)			
	0	30	60	120	0	30	60	120	0	30	60	120
0	21.78	30.18	32.06	35.53	41.89	53.74	56.07	59.31	35.06	62.35	66.64	69.08
1	22.17	30.94	32.9	36.26	43.46	54.78	57.66	61.12	37.5	63.39	69.81	72.78
3	22.66	33.49	35.42	38.07	44.63	55.53	58.5	62.12	37.99	64.33	70.37	74.05
5	22.07	30.75	32.71	35.99	42.38	54.12	56.45	59.76	35.45	63.1	67.38	69.98
BHT (200ppm)	23.69	47.11	61.13	68.81	23.69	47.11	61.13	68.81	23.69	47.11	61.13	68.81

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