

A Promising Food Waste for Food Fortification: Characterization of Dried Tomato Pomace and Its Cold Pressed Oil

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Abstract

In this study, some physicochemical properties of tomato pomace (skins and seeds), which are waste of tomato plants and contain many active food components, were determined. For this purpose, tomato pomace was supplied by a plant in Manisa, Turkey. Firstly, tomato pomaces were dried at 30°C for 12h and then, ground into powder. Physicochemical properties of tomato pomace powder were investigated to determine its suitability as a fortification agent. Ash, protein, fat, carbohydrate, dietary fibre contents of dried tomato pomace were 3.55 g/100g, 32.69 g/100g, 15.43 g/100g, 43.31g/100g, and 29.42 g/100g, respectively. Additionally, tomato pomace contained substantial amounts of polyphenolics, flavonoids, and carotenoids. The high CIE a^* and b^* values indicated the presence of various pigments. Cold-pressed oil of dried tomato pomace was mainly composed of linoleic acid, followed by oleic, and palmitic acids. It is concluded that tomato pomace and oil obtained from dried pomace are promising and valuable ingredients for food fortification due to their unique nutritional properties.

Keywords

Carotenoid, DPPH-scavenging, Flavonoid, Phenolic, Oil, Tomato pomace

Abbreviations

A_w : Water activity; DPPH: 2,2-diphenyl-1-picrylhydrazyl; d.w.: Dry weight basis; FFA: Free fatty acid; GAE: Gallic acid equivalent; p -AV: Para-anisidine value; QE: Quercetin equivalent; TE: Trolox equivalent; TFC: Total flavonoid content; TPC: Total phenolic content; TCC: Total carotenoid content

Introduction

Tomato (*Lycopersicon esculentum*) is a fruit that can be consumed both freshly and in processed form [1]. While most of the tomatoes produced in the world are used in tomato paste production, it is also used in different processed products such as ketchup, sauce and soup [2, 3]. According to statistical data, each year about 145 million tons of tomatoes are produced in the world and 11 million tons of tomatoes in Turkey [4, 5] Tomato is the most consumed vegetable in Mediterranean countries [6]. Organoleptic quality of tomatoes is associated with nutrients they include [7]. Tomatoes contain high levels of phenolic compounds, carotenoids, flavonoids, vitamins C and E [3]. The highest percentage of these carotenoids; lycopene, α -carotene, β -carotene, lutein, zeaxanthin, and β -cryptoxanthin [8]. Many studies conducted so far have shown

that most fruits and vegetables, including tomatoes, are involved in the prevention of cancer and cardiovascular disease through regular consumption [3]. Lycopene, especially found in tomato, is a compound that provides protection against prostate cancer [9]. These health-promoting effects are caused by antioxidant compounds, especially flavonoids [10].

When processing the tomato peel and seeds into tomato paste, 1/3 of its weight is discarded [3]. However, the nutritional content of tomato peels and seeds is very high. For example, tomato peels contain 2.5 times more lycopene than pulp and seed [11, 12]. In addition, tomato peels are rich in flavones [13]. Tomato skins and seeds are rich in essential amino acids, especially the seeds contain high amounts of lysine [11, 14, 15]. Studies have shown that tomato waste contains a high amount of mineral substances such as iron, manganese, zinc, and copper [11]. Seeds constitute 50–55% of tomato wastes [16]. The fat fraction of tomato seeds also contains high percentage of protein, carotenoids, polyphenols, phytosterols, minerals, and fibres [17, 18]. It is rich in bioactive components including rutin, naringenin, naringenin chalcone, and chlorogenic acid [19]. In addition, high proportions of linoleic (C18:2) and oleic acids (C18:1) are found in tomato seed oil. It also contains 7–24% palmitic acid (C16:0) which is a common saturated fatty acid [20].

One of the biggest problems of the food industry is valorisation of wastes [1, 6]. Most carotenoids found in tomatoes are lost with waste during processing [21]. Tomato wastes (skins and seeds), which are commonly used in animal nutrition [9, 22] are very rich in bioactive components [17]. Therefore, it is used as a carotenoid source for eggs by incorporating into animal feed [9]. Many studies have been carried out for valorisation of tomato wastes. Another way of evaluation of tomato waste is the extraction of residual oil [15]. The usability of tomato peels in meat and meat products is being investigated [12, 23–25]. Due to the high carotene and dietary fibre content, tomato wastes are also used in extruded foods to increase nutrients [26]. In the present study, we aimed to obtain tomato pomace powder without deteriorated by heat and then, to determine basic chemical properties of conventionally dried tomato pomace and its cold pressed oil to evaluate their suitability for food fortification.

Material and Methods

Preparation of dried tomato pomace

Two lots of tomato processing waste (a mixture of skins and seeds, 99% seed and 1% skin) were collected from a plant in Manisa, Turkey in September 2019. These wastes were kept in plastic bags at -18°C until drying process. Then, they were dried using a rotating tray dryer (EKSIS TK-10, EKSIS Industrial Drying Systems, Isparta, Turkey) at 30°C to prevent undesirable alterations in physicochemical and functional properties of tomato wastes. After a 12h-drying process, dried materials were ground into powder with a knife mill (Grindomix GM-200, Retsch GmbH, Germany), while a batch of dried sample was separated for pressing of oil and this batch was not ground into powder. Both dried and non-

ground pomace and powder were stored in freezer bags at 4°C until further analyses.

Physicochemical characterization of dried tomato pomace

Moisture (Method 934.01), ash (Method 942.05), protein (Method 2001.11), solvent-extracted crude fat (920.39), and total dietary fibre (Method 991.43) contents of the dried tomato pomace samples were determined using official methods of AOAC [27]. The proximate carbohydrate content was calculated by subtracting moisture, ash, crude fat, and protein contents from a total of 100. Eq.1 was used to predict energy value of tomato wastes:

$$\text{Energy value (kcal/100g)} = (4 \times \% \text{ protein}) + (4 \times \% \text{ carbohydrate}) + (9 \times \% \text{ crude fat}) \text{ -----(1)}$$

Dried tomato pomace samples were extracted with methanol/water (v/v; 1:1). These methanolic extracts were used for determination of total phenolic content (TPC), total flavonoid content (TFC), and total antioxidant activity. TPC of the samples were estimated using Folin-Ciocalteu assay suggested by Alvares-Parrilla et al. [28] with slight modifications. Briefly, 0.5 mL of methanolic extract was taken into 10 mL-volumetric flask and mixed with 0.5 mL of Folin-Ciocalteu solution (10%, v/v). After 2 min, 0.2 mL of Na_2CO_3 solution (7.5%, w/v) was added to the mixture and diluted to 10 mL with distilled water. The 10 mL-volumetric flasks were kept under dark conditions for 2 h. Then, absorbance was read at 760 nm using a spectrophotometer (Shimadzu UVmini-1240, Kyoto, Japan). TPC was expressed as mg gallic acid equivalent (GAE) per 100 g using a calibration curve ($R^2 = 0.919$)

TFC of the pomace samples were determined according to the method described by Olumese and Oboh [29] with some modifications. 1 mL of methanolic extract was taken into a 10 mL-volumetric flask and mixed with 0.5 mL of methanol, 50 μL of AlCl_3 solution (10%, w/v), and 50 μL of 1 M potassium acetate solution, respectively. Then, the mixture was diluted to 10 mL with distilled water. The volumetric flasks were kept in the dark for 30 min. Finally, the absorbance was read at 415 nm against blank. TFC of pomaces were expressed as quercetin equivalent (QE) per 100 g using a calibration curve ($R^2 = 0.9947$).

Total carotenoids contents (TCC) were spectrophotometrically estimated according to the method suggested by Guizhen et al. [30]. Total antioxidant activity of the pomace samples was evaluated by DPPH-scavenging assay [31, 32]. The results were expressed as Trolox equivalent (TE) antioxidant capacity (mM TE/100g) using a Trolox calibration curve ($R^2 = 0.9849$).

Water activity (a_w) determination was carried out using a digital a_w -meter (Rotronic Hygropalm, Bassersdorf, Swiss). Colour measurements were performed with a bench-top colorimeter (Konica Minolta CR-5, Tokyo, Japan). The average values of three consecutive readings for L^* (lightness), a^* ($-a$ = greenness, $+a$ = redness), and b^* ($-b$ = blueness, $+b$ = yellowness) were reported.

Cold pressing of dried tomato pomace

Cold pressed oil was obtained by pressing the pomace

at room temperature with a laboratory scale cold-pressing machine (Toper Machine TBP 100, Izmir, Turkey) (20–30 liter capacity, 3 hp, 0.5 kW heating power, exit die 10 mm). The inner temperature of the cold-pressing machine was 40 ± 5 °C. The machine operates at 380 V and 50 Hz. After pressing, the oils were immediately centrifuged at 4000 rpm for 30 min at 20 °C. Following centrifugation, the supernatants were immediately transferred to amber coloured glass bottles under nitrogen and stored at 4 °C.

Physicochemical Characterization of Cold-Pressed Oil

Colour values of the oils (R: redness, Y: yellowness, B: blueness; CIE L^* , a^* , b^*) were measured by a Lovibond Tintometer using a 1-inch cell. The refractive index of oil samples was measured by a digital Abbe refractometer at 20 °C. The free fatty acid (FFA) value (Method Ca 5a-40), conjugated diene (Method Ti 1a-64), and *p*-anisidine values (Method Cd 18-90) were determined according to official methods of [33] while peroxide value [34] and iodine number [35] were determined according to national official methods. TOTOX value was calculated using Eq.2:

$$\text{TOTOX} = (2 \times \text{Peroxide value}) + p\text{-anisidine value} \quad (2)$$

Total carotenoid contents were determined as described by Franke et al., [36]. Total chlorophyll contents were estimated using method suggested by Pokorný et al. [37].

Identification of fatty acid composition by GC

Fatty acid methyl esters (Method Ce 2-66) were prepared according to official method of AOCS [33]. Chromatographic analyse was carried out on Agilent 6890 series GC (Agilent Technologies, Palo Alto, CA) equipped with SP-2380 fused silica capillary column (60 m × 0.25 mm i.d., 0.20 µm film thickness; Supelco, Bellefonte, PA) and a flame ionization detector. The injection volume was 1 µL and the split ratio was 1:20. The oven temperature was 190°C during analysis. The temperatures of the injector and detector were 250°C and 260°C, respectively. Nitrogen was used as carrier gas at a flow rate of 1 mL min⁻¹. The peaks were identified by comparing their retention times with those of 37-component F.A.M.E. Mix standard (C4:0-C24:1). Fatty acids were quantified using relative peak area and expressed as percentages (%).

Statistical analyses

The tomato wastes were obtained and dried as two separate series. All chemical analyses were performed in duplicate, while colour measurement was performed in triplicate. The results were presented as mean values ± standard deviation.

Result and Discussion

Properties of dried tomato pomace

The physicochemical characteristics of dried tomato pomace were given in table 1. Moisture content was found to be 5.03 g/100g. Our finding agreed with the results of Nour et al. [17], who found the moisture content of dried tomato waste as 5.35%. On the other hand, Del Valle et al. [6] reported very

high moisture contents (64.31–92.55%) for non-dried tomato pomaces collected from different production stages in a plant. Similarly, Bhat and Ahsan [38] stated that moisture content of fresh tomato pomace was 87.63%, while those of 4.77% in cabinet-dried and 7.37% in freeze-dried tomato pomace. Due to great amount of moisture found in non-dried tomato wastes, they are very susceptible to microbial spoilage and undesirable fermentation. Moreover, they cannot be stored for a long time. Therefore, drying is a reliable pre-treatment for food wastes containing high levels of moisture to extend their stability. Differently from studies using whole tomato pomace (mixture of seed and peel), some researchers separated seeds and/or peels from pomace and evaluated the quality attributes of these parts individually. In one of these studies, Persia et al. [39] reported that moisture contents of tomato seeds collected from air-dried tomato ranged between 7.40–9.60%.

Dried tomato pomace contained 3.55 g/100g ash on dry weight basis (Table 1). This is in line with the results of Işık and Topkaya [4]. On the contrary, Nour et al. [17] and Bhat and Ahsan [38] reported higher ash contents in dried tomato pomaces (4.21% and 7.62–7.82%, respectively). The differences may be mainly attributed to different tomato varieties, and ecological and/or environmental conditions as well as different seed/peel ratio of the pomaces. Knoblich et al. [9] evaluated the characteristics of tomato peel and seed by-products separately and found markedly higher ash content (25.64 g/100g d.w.) in tomato peel by-products than that of tomato seed by-product (5.18 g/100 g d.w.). Hence, the ash content of tomato pomace may be affected by amounts of tomato seeds and peels in the pomace. The dominant minerals found in tomato wastes were reported as iron, sodium, potassium, zinc, manganese, and copper [9]. Recently, Işık and Topkaya [4] detected presence of phosphorus, magnesium, and calcium in tomato seed. Ash content of tomato pomace is comparable to that of carrot pomace (3.20%) and lower than red carrot pomace (5.89%) and beetroot waste powder (5.60%) [40–42].

Table 1: Physicochemical properties of dried tomato pomace.

Parameter	Experimental value
Moisture content, g/100g	5.03 ± 0.13
Ash content, g/100g (d.w.)	3.55 ± 0.07
Protein content, g/100g (d.w.)	32.69 ± 0.58
Crude fat content, g/100g (d.w.)	15.43 ± 0.25
Total carbohydrate, g/100g (d.w.)	43.31 ± 1.03
Dietary fibre, g/100g (d.w.)	29.42 ± 4.38
Energy value, kcal/100g	442.87 ± 0.49
Total phenolics, mg GAE/100g	109.57 ± 2.44
Total flavonoids, mg QE/100g	68.82 ± 5.09
Total carotenoids, mg/100g	2.72 ± 0.47
DPPH-scavenging activity, mM TE/100g	2.20 ± 0.23
a_w	0.356 ± 0.04
L^*	60.10 ± 0.33
a^*	8.27 ± 0.15
b^*	24.67 ± 0.74

In general, food wastes containing high levels of seeds have relatively high protein contents. Therefore, oilseed cakes obtained through oil processing are commonly utilized as animal feed to enhance their diets in terms of protein. As can be seen in [table 1](#), dried tomato pomace was characterized by its high protein content (32.69 g/100g, d.w.) in the present study. The protein content of tomato pomace consisting of 22.20% seed and 77.80% pulp and skin was reported to be 17.62 g/100g [17]. However, we used tomato pomace which was composed of almost completely tomato seeds (99%). Likewise, Shao et al. [43] concluded that protein, ash and fat contents of tomato pomace increased as the seed ratio increased in pomace. Carlson et al. [14] determined very high levels of crude protein in tomato seeds (37.50% d.w.). Similarly, Sogi et al. [16] reported that defatted tomato seeds, which were separated from tomato pomace, contained 33.07% (d.w.) crude protein. This remarkable difference may be explained by different seed contents of pomaces. As a result of its great amount of protein, tomato pomace may be efficiently utilized as fortification agent in foods to increase their protein contents. Mainly glutamic acid, aspartic acid, arginine, glycine, alanine, tyrosine, and essential amino acids such as leucine, lysine, isoleucine constitute the protein fraction of tomato pomaces [9, 17].

Recent years, researchers have been focused on characterization of tomato seed oil. For edible purposes, tomato seed oil can be extracted through mechanical pressing or solvent extraction systems from tomato pomaces that are rich in seeds. As can be understood from [table 1](#), dried tomato pomace mainly composed of tomato seed was rich in crude fat content (15.43 g/100g, d.w.). Our finding was lower than crude fat content of dried tomato pomace (21.90%) reported by Nour et al. [17]. Similarly, Knoblich et al. [9] declared higher crude fat contents for by-products of tomato peel (25.64 g/100g) and tomato seed (51.80 g/100g). On the other hand, Carlson et al. [14], Yilmaz et al. [44] and Işık and Topkaya [4] reported higher crude fat contents (24.55% d.w., 17.83%, and 21.58% d.w., respectively) in tomato seeds than the finding of our study. However, in summary, tomato pomace can be considered as a rich source of edible oil.

The approximate carbohydrate content of dried tomato pomace was estimated to be 43.31 g/100g d.w. Lenucci et al. [45] identified glucose, fructose, galacturonic acid, cellobiose, mannose, galactose and lower amounts of isoprimeverose, xylobiose, arabinose, rhamnose, xylose, and glucuronic acid in carbohydrate fraction of tomato pomace. Additionally, Knoblich et al. [9]; Del Valle et al. [6]; Işık and Topkaya [4] and Nour et al. [17] agreed that tomato by-products are rich in soluble and insoluble dietary fibres. In our study, dried tomato pomace contained 29.42% total dietary fibre in dry weight basis ([Table 1](#)). Our result is comparatively lower than the findings of Majzoobi et al. [46] (76.27% in d.w.), Alvarado et al. [47] (49.53%), Nour et al. [17] (52.44%) and Concha-Meyer et al. [48] (47.80%), while similar to that of fresh (non-dried) tomato pomace (23.36% in d.w.) reported by Sandei et al. [49]. In general, fibre content of tomato peels is higher than tomato seeds. Tsatsaronis and Boskou [22] reported that tomato seeds contained 19.10 g/100 g crude fibre, while skins

had 55.90 g/100g crude fibre. Similarly, Karthika Devi et al. [26] found more crude fibre content in tomato peels (29.35%) than that of tomato seed (13.37%). Recently, Bhat and Ahsan [38] showed that the type of drying method has little influence on fibre content of tomato pomace. They determined 37.77% total fibre in cabinet-dried (at 60 °C for 8-9 h) tomato pomace and 36.69% in freeze-dried (for 12-13 h) tomato pomace. Thanks to its high dietary fibre content, few studies have been carried out for incorporation of tomato pomace into ketchup, tomato paste, beef frankfurter and meat-free sausages, chicken sausages, bread, spaghetti, muffin, crackers, and corn-based extruded snack up to now [4, 48, 50-57].

The energy value of tomato pomace depends on the composition of pomace. In our study, dried tomato pomace had energy value of 442.87 kcal/100g, which was higher than the energy value (239.90 kcal/100g) calculated by Concha-Meyer et al. [48]. This difference may be attributed to higher fat (15.43%) and protein (32.69%) contents of dried tomato pomace that we used in this study.

Antioxidant activity of any material is caused by natural bioactive constituents. Phenolic compounds are the dominant group of these biologically active constituents. In the present research, dried tomato pomace was characterized by its very high TPC (109.57 mg GAE/100g). Our result is in accordance with the result of Nour et al. [17] who reported that TPC of dried tomato waste was 122.95 mg GAE/100g. A very recent study showed that freeze-dried tomato pomace yielded higher phenolic content (85.30 mg GAE/100g) than cabinet-dried tomato pomace (65.30 mg GAE/100g) [38]. Compared to other agri-food by-products, it can be concluded that dried tomato pomace had lower TPC than those of white and red grape pomaces (1371 and 2399 mg GAE/100g, respectively), white and red grape seeds (6090 and 6495 mg GAE/100g, respectively), white and red grape peels (239 and 1502 mg GAE/100g, respectively), olive tree leaves (2058 mg GAE/100g), apple peels (647 mg GAE/100g), onion peels (422 mg GAE/100g), carobs (1224 mg GAE/100g), potato peels (177 mg GAE/100g), apple pomace (870 mg GAE/100g d.w.), broccoli stems (494 mg GAE/100g d.w.), cauliflower cut-offs (402 mg GAE/100g d.w.), and white cabbage cut-offs (341 mg GAE/100g d.w.) [58, 59]. Caffeic acid, protocatechuic acid, salicylic acid, ferulic acid, vanillic acid, chlorogenic acid, ellagic acid, catechin, coumarin, cinnamic, catechol, and caffeine were identified in dried tomato pomace [60]. Addition to these, *p*-coumaric acid, rosmarinic acid, rutin, naringenin derivatives, syringic acid, and myricetin were detected in tomato pomaces [17, 61]. The contents of phenolic found in hydrophilic fractions of tomato skin, pulp, and seeds were reported to be higher than their lipophilic counterparts and skin had the highest TPC (34.70 mg/100g), followed by seeds (35.50 mg GAE/100g), and pulp (15 mg GAE/100g) [3]. Flavonoids are the most abundant phenolic class of tomato by-products. As seen in [table 1](#), TFC of dried tomato pomace was 68.82 mg QE/100g. This is slightly higher than the results determined in dried tomato waste (41.53 mg QE/100g) by Nour et al. [16] in dried tomato pomaces (22–41.54 mg QE/100g) by Farcas et al. [62]. The presence

of various flavonoid compounds including kaempferol-3-O-glucoside, procyanidin B2, quercetin, phloretin, coumaric acid, kaempferol, luteolin-7-O-glucoside, phloridzin, ferulic acid, quercitrin, gallic acid, rutin, epicatechin was recently confirmed by Palomo et al. [63] and Concha-Meyer et al. [48] in tomato pomace extract and dried tomato pomace powder.

Another biologically active component of tomato pomace is carotenoids. Total carotenoid content of dried tomato pomace was found to be 2.72 mg/100g (Table 1). Our result is in comparable with the finding of Luengo et al. [64] who reported that total carotenoid contents of dried tomato pomaces (non-sonicated control groups) were in the range of 3.54–5.54 mg/100g (d.w.). The reason of this slight difference may be different extraction rates of carotenoids by various solvent mixtures, application of different total carotenoid determination methods, expression of results in terms of different standard compounds, and chemical compositions of tomato pomaces influenced by seed/peel ratio and their chemical properties. Main carotenoid compounds of tomato pomace are lycopene, β -carotene, lutein, *cis*- β -carotene, zeaxanthin along with minor amounts of α -carotene (found only in seed) [9].

All bioactive components mentioned above contribute to total antioxidant capacity of dried tomato pomace. As given in table 1, DPPH-scavenging activity of dried tomato pomace was 2.20 mM TE/100g. This value is higher than those previously reported by Savatović et al. [65] (0.79–1.61 mM TE/100g d.w.), Nour et al. [66] (0.25 mM TE/100g) and Nour et al. [17] (0.68 mM TE/100g) for dried tomato waste.

An essential indicator of shelf-life stability of any food product, water activity, was found to be 0.356 in dried tomato pomace. Our finding was lower than that of dried tomato pomace powder (0.48) with higher moisture content (5.59%) reported by Concha-Meyer et al. [48]. The CIE L^* , a^* , and b^* values were 60.10, 8.27, and 24.67, respectively. Our results were partially agreed with the results of Concha-Meyer et al. [48] who reported 61.22 for L^* , 12.75 for a^* , and 26.26 for b^* values in dried tomato pomace powder. On the other side, Işık and Topkaya [4] declared 49.86 for Hunter L, 3.38 for Hunter a, and 9.95 for Hunter b values in dried tomato seeds separated from tomato pomace. The differences between results of the present study and results reported by Işık and Topkaya [4] may be attributed to different colour measurement scales (CIE L^* a^* b^* , and Hunter L a b scales). It can be concluded that the high a^* (redness) and b^* (yellowness) values of tomato pomaces may be the result of lycopene, β -carotene, lutein, *cis*- β -carotene, and zeaxanthin as previously identified by Knoblich et al. [9]. As the amount of tomato skin increases in pomace, it is expected that the redness value increases due to its higher lycopene content than that of tomato seed [3].

Physicochemical properties of cold-pressed tomato pomace oil

Physical and chemical characteristics of cold-pressed tomato pomace oil was summarized in table 2. The refractive index of the oil is closely in agreement with those of cold-pressed tomato seed oil $n_{20}^D = 1.47$ and expeller-pressed tomato

seed oils $n_{20}^D = 1.4707-1.4722$ obtained through cold and hot break treatments [44, 67]. The turbidity value of the oil is higher than findings of Yilmaz et al. [44]. The $+a$ and $+b$ values of the cold-pressed oil indicate the presence of carotenoid compounds. The oil obtained in this study had brighter with more intense red and yellow colour than the oil used by Giuffrè and Capocasale [68]. On the other side, Yilmaz et al. [44] reported higher L^* (36.69) and lower a^* (-0.14-1.57) and b^* values (38.08-38.40) for cold-pressed tomato seed oils. Contrast to common vegetable oils, cold-pressed tomato pomace oil was characterized by its extraordinary Lovibond B value (2.90). High B value may be the result of green-coloured pigments, namely chlorophylls. The FFA value of the oil (0.46 oleic acid %) did not exceed the maximum limit of 4% (oleic acid) set by regulations [69]. Our finding partially agrees with the results of Giuffrè et al. [67] (0.24–1.26%). The iodine number of cold-pressed tomato pomace oil was 109.02 g/100g. Botineştean et al. [70], Yilmaz et al. [44] and Giuffrè et al. [71] reported higher iodine numbers for tomato seed oils (125.83 g/100g, 127.08–129.26 g/100g, and 108.60–118.50 g/100g, respectively) which can be related to higher unsaturation degree of oils.

Table 2: Physicochemical characteristics of cold-pressed oil of dried tomato pomace.

Parameter	Experimental value
Refractive index,	1.4735 ± 0.01
Turbidity, NTU	22.50 ± 0.80
CIE Colour	
L^*	30.72 ± 0.39
a^*	16.60 ± 0.05
b^*	52.56 ± 0.72
Lovibond Colour	
R	9.05 ± 0.15
Y	72.90 ± 0.01
B	2.90 ± 0.01
Free fatty acids, oleic acid%	0.46 ± 0.01
Iodine number, g/100g	109.02 ± 4.43
Peroxide value, meq O ₂ /kg	2.47 ± 0.91
K ₂₃₂ , %	0.13 ± 0.01
p-anisidine value	7.82 ± 1.50
TOTOX value	11.88 ± 0.10
Total carotenoids, mg/100g	6.74 ± 0.04
Total chlorophylls, mg pheophytin a/kg	5.11 ± 0.07

Oxidative stability indices of cold-pressed oil was investigated in our study. The peroxide value (2.47 meq O₂/kg) was lower than the allowed limit of 15 meq O₂/kg defined in the regulation [69]. This value partially agrees with the findings of Giuffrè et al. [67] who reported a wide range of peroxide values (0.97 meq O₂/kg–6.14 meq O₂/kg) for tomato seed oils obtained through hot and cold break processes. Compared to our finding, Shao et al. [72] reported lower peroxide value (0.63 meq O₂/kg) in hexane-extracted tomato

seed oil, while Yilmaz et al. [44] declared higher peroxide values (3.93–4.52 meq O₂/kg) for cold-pressed tomato seed oils. Similar to peroxide value, the conjugated diene test is also used to determine the level of primary oxidation products [73]. Due to the instability of hydro peroxides, measurement of conjugated diene formation is accepted as a more reliable method to detect early stages of oxidation than peroxide value [74]. The conjugated diene value (K₂₃₂) of cold-pressed tomato pomace oil was found to be 0.13% which was lower than the K₂₃₂ values reported by Giuffrè and Capocasale [68] in tomato seed oils (1.47–1.73%). *p*-AV measures the level of secondary oxidation products, mainly aldehydes, which lead to rancid odour and flavour development in fats and oils [75]. The *p*-AV of the oil was comparable with *p*-AV of expeller pressed tomato seed oils (0.40–10.53) obtained through hot and cold break processes [67]. Total oxidation level of any oil is determined by TOTOX values. In our study, TOTOX value of the oil was 11.88. As a result of different treatments, Giuffrè et al. [67] reported TOTOX values for tomato seed oils ranging from 3.85 to 24.68.

Carotenoids are heat, light and acid-sensitive due to presence of conjugated double bonds in their structure [76]. Accordingly, chlorophylls which are responsible for green colour of seed oils promotes photo-oxidation of oil [77]. However, thanks to their high antioxidant activity, chlorophylls and carotenoids contribute to oxidative stability of oils together with tocopherols [73]. Cold-pressed oil of dried tomato pomace had higher carotenoid content (6.74 mg/100g) than cold-pressed oils of virgin rapeseed oils (0.9–3.03 mg/100g) and orange seed oils (0.55–0.76 mg/100g) previously reported by different researchers [78, 79]. β -carotene, *cis*-1-lycopene, *cis*-2-lycopene, all-*trans*-lycopene, and *cis*-3-lycopene are the identified carotenoid compounds of tomato seed oil [80]. The chlorophyll content (5.11 mg pheophytin a/kg) of the oil produced in our study is comparable of that of cold pressed corn oil (4.90 mg/kg), while higher than chlorophyll contents of cold-pressed flaxseed oil (3.40 mg/kg), peanut oil (1.50 mg/kg), and sunflower oil (2.30 mg/kg) [81].

Fatty acid composition of cold pressed tomato pomace oil

The seed fraction of tomato pomace is rich in oil content. Therefore, studies have been focused on characterization of tomato seed oils until today. Fatty acid composition of the oil is summarized in table 3. The cold-pressed oil included polyunsaturated fatty acids (53.10%), followed by monounsaturated (28.84%) and saturated fatty acids (18.06%). It is composed of linoleic acid (50.77%), oleic acid (28.02%), palmitic acid (12.17%), stearic acid (5.26%), linolenic acid (2.32%) and traces of heneicosanoic acid, palmitoleic acid, nervonic acid, margaric, and lauric acids. Tomato pomace oil is characterized by its very high linoleic acid level, which is an essential fatty acid for human. Our results are in accordance with the results of Nour et al. [17] who reported that tomato pomace oil includes linoleic acid (51.91 g/100g), oleic acid (18.50 g/100g), palmitic acid (16.32 g/100g), stearic acid (5.43 g/100g), and α -linolenic acid (3.35 g/100g). Similar results were also declared by Cantarelli et al. [82]. Oil obtained from tomato pomace may be attractive due to its extraordinary fatty

acid profile, particularly in terms of essential fatty acids such as linoleic and α -linolenic acids. However, its high linolenic acid content, a polyunsaturated fatty acid, is a limiting factor for oxidative stability of the oil.

Table 3: Fatty acid composition of cold-pressed oil of dried tomato pomace.

Fatty acid	Experimental value (%)
Lauric acid (C12:0)	0.11 ± 0.01
Palmitic acid (C16:0)	12.17 ± 0.01
Palmitoleic acid (C16:1)	0.26 ± 0.01
Margaric acid (C17:0)	0.11 ± 0.01
Stearic acid (C18:0)	5.26 ± 0.01
Oleic acid (C18:1)	28.02 ± 0.04
Linoleic acid (C18:2)	50.77 ± 0.03
Linolenic acid (C18:3)	2.32 ± 0.01
Heneicosanoic acid (C21:0)	0.40 ± 0.01
Nervonic acid (C24:1)	0.17 ± 0.01
Σ SFA*	18.06 ± 0.01
Σ MUFA*	28.84 ± 0.03
Σ PUFA*	53.10 ± 0.03

*MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, SFA: Saturated fatty acids

Conclusion

In summary, dried tomato pomace mainly consisting of tomato seeds was characterized by its high protein, ash, and fat contents. Additionally, it is a rich source of bioactive compounds such as carotenoids, and phenolic, particularly flavonoids. Excellent antioxidant capacity of tomato pomace may be the result of these biologically active constituents. Hot air drying at low temperatures is a suitable technique to protect the pomace against undesirable changes in quality characteristics which may be triggered by high temperatures. Now, tomato pomace is commonly used as animal feed throughout world. Several studies reveal its suitability for lactic acid fermentation, extraction of bioactive compounds, extraction of pectin, protein gel production, and high-value added food production that were mentioned above [83–86]. Our further studies will focus on utilization of dried tomato pomace in different food products. More studies should be carried out to determine in vitro and in vivo bioavailability and bio accessibility of bioactive compounds of tomato pomaces.

Conflict of Interest Statement

The authors declare no conflict of interest.

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