Short Communication

Danuta Górecka, Agata Wawrzyniak, Anna Jędrusek-Golińska, Krzysztof Dziedzic*, Jadwiga Hamułka, Przemysław Łukasz Kowalczewski, Jarosław Walkowiak

Lycopene in tomatoes and tomato products

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Abstract: This article focused on the content of lycopene in fresh and dried tomatoes and tomato pomace, as well as in tomato paste at different harvest times (harvest 1 – August and harvest 2 – September). The lycopene content of tomatoes and tomato products was evaluated by using high-performance liquid chromatography (HPLC). The results showed that the highest content of lycopene was estimated in the tomato paste independent of the time of harvest (211.73 mg/100 g dm in August and 184.29 mg/100 g dm in September) and the lowest content in fresh pomace (20.45 and 16.11 mg/100 g dm in August and September, respectively). Good sources of lycopene are tomato by-products, in particularly dried tomato pomace (25.11 mg/100 g dm – harvest 1 and 19.30 mg/100 g dm – harvest 2). This study showed that tomato waste can be considered as a promising source of lycopene for the production of functional foods.

Keywords: lycopene, fresh and dried tomato, tomato products, by-products, technological process

1 Introduction

Lycopene is a major dietary carotenoid protecting cells against oxidative damage to lipids, proteins, and DNA [1,2]. It is present almost exclusively in tomato and tomato-based products. More than 80% of dietary lycopene is derived from processed tomato products such as ketchup, tomato juice, spaghetti sauce, and pizza sauce [3–5]. Other dietary sources of lycopene include watermelons, jackfruits, bananas, grapes, and papayas [6].

During the processing of tomatoes, the main residue generated is the tomato pomace [7]. The by-products of tomatoes, especially tomato pomace, are an important source of functional food ingredients such as dietary fiber, β-carotene, lycopene, phenolic acids (ellagic and chlorogenic acids), and flavonoids (rutin and myricetin) [8–12]. They are known as potential factors in decreasing the serum level of oxidative stress biomarkers. For example, Abete et al. [13] showed that daily consumption of 160 g of a high-lycopene tomato sauce caused a decrease in oxidized-LDL cholesterol level supporting the role of lycopene, in combination with other bioactive compounds, in the prevention of oxidative stress-related diseases. Li et al. [14] showed that drinking tomato juice (280 mL per day) for 2 months decreased markers of lipid oxidation, without affecting the antioxidant capacity status and increased the anti-inflammatory adiponectin level in healthy adults. Lycopene's singlet-oxygen-quenching ability is twice as high as β-carotene and ten times higher than α-tocopherol [15]. The consumption of tomato products with lycopene reduced the risk of cardiovascular diseases in men and women [16], breast cancer in postmenopausal women [17], and ovarian cancer in premenopausal and postmenopausal women [18]. Several epidemiological studies have associated the increased consumption of tomato-based products and lycopene with the decreased prostate cancer risk [6,19]. Giovannucci [20] found that the consumption of tomatoes and tomato products was inversely related to the risk of cancers, most prominently, cancers of the prostate, lung, and stomach.

Technological processing of tomatoes, such as cooking and baking, do not affect the limitation of lycopene content in products to a greater extent, and lycopene losses are usually insignificant. Lycopene in its natural state occurs in the form of *trans* and is poorly absorbed in the human body. During heat processing of tomatoes and tomato products, and in the presence of fat, lycopene is released from the tissue of the product, which induces isomerization of

*** Corresponding author: Krzysztof Dziedzic,** Institute of Food Technology of Plant Origin, Poznań University of Life Sciences, Poznań, Poland; Department of Pediatric Gastroenterology and Metabolic Diseases, Poznan University of Medical Sciences, Poznań, Poland, e-mail: krzysztof.dziedzic@up.poznan.pl
Danuta Górecka, Anna Jędrusek-Golińska: Department of Gastronomy Science and Functional Foods, Poznań University of Life Sciences, Poznań, Poland
Agata Wawrzyniak, Jadwiga Hamułka: Department of Human Nutrition, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences, Warsaw, Poland
Przemysław Łukasz Kowalczewski: Institute of Food Technology of Plant Origin, Poznań University of Life Sciences, Poznań, Poland
Jarosław Walkowiak: Department of Pediatric Gastroenterology and Metabolic Diseases, Poznan University of Medical Sciences, Poznań, Poland

lycopene from the all-*trans* to *cis* configuration, increasing its bioavailability [21–25].

The consumption of thermally processed tomato juice together with some fat increased the bioavailability of lycopene compared to the use of lycopene from nonprocessed juice [26]. A higher content of lycopene from tomato paste was also found in chylomicrons than from fresh tomatoes, which proves that the technological processes carried out increase the digestibility and bioavailability of tomato pasta. This is probably due to transformation of the all-*trans* isomer into the *cis*-isomer, thereby increasing the solubility in bile acids [21,22,26,27].

Technological processes such as grinding, marinating, fermentation, freezing, and gentle heating also improve the release and absorption of carotenoids [26,28]. The authors explain that this process occurs by releasing carotenoids as a result of the breakdown of plant tissues and the transition of these compounds to the lipid carrier. It is believed that since carotenoids in plant tissues occur in the form of complexes with proteins, mild thermal processes allow them to break down these connections and destroy cellulose structures in plant cells, thus contributing to an increase in the absorption of these compounds [24,26].

Lycopene is used in the production of meat products such as sausages, hamburgers, mortadella, and patties [29,30].

Therefore, this study aims to evaluate the content of lycopene in fresh and dried tomatoes and tomato pomace, as well as in tomato paste depending on the harvesting period.

2 Materials and methods

2.1 Plant material and reagents

In this study, we used fresh and dried tomatoes, tomato paste, and fresh and dried tomato pomace. Fresh tomatoes, tomato paste, and fresh pomace were obtained from a Polish Food Industry Company "HJH Polska Sp. z o.o." (Grandimat variety, from harvests in August 2015 – harvest 1, and September 2015 – harvest 2). All tomatoes were harvested ripe and ready for consumption. The production of tomato pasta (final product) proceeded with the following stages: washing, sorting, crushing and removing seeds, heating (65–75°C), wiping (tomato pomace), preserving, compaction, and pasteurization (80–85°C, 560–745 hPa). All products coming from the tomato processing industries were frozen at −70°C. After thawing, the samples were tested, except for dried tomato and dried tomato pomace, which were dried using a freeze dryer under the following process parameters: process temperature, −20°C; condenser temperature, −80°C, not longer than 48 h, and then kept at room temperature in the dark. Before the analysis, the sample was ground in a Foss Tecator mill (Hillerod, Sweden).

All solvents (e.g., acetonitrile purity: 99.9%; hexane purity: 98.5%; dichloromethane purity: 99.9%; methanol purity: 99.5%) and lycopene standard L9879 were purchased from Sigma Aldrich (St. Louis, MO, USA).

2.2 Determination of lycopene

Lycopene was extracted and quantified using the previously described method with some modifications [31]. To obtain representative samples for analysis, before weighing, each product was mixed thoroughly and homogenized (homogenizer IKAWERTKE T25 BASIC, 13,500 oscillations/min, Staufen, Germany). Frozen tomatoes were homogenized entirely with tomato peel. Following this, the products weighed 0.2–2.0 g (depending on the product), and 20 mL of methanol and 0.2 mL 2% alcoholic solution of hydrochinon were added. The prepared samples were homogenized again to obtain a uniform consistency. The extraction of lycopene from the samples was performed using petroleum ether. Depending on the color intensity of the samples, 20 mL of ether was added four to five times. The ether extracts were poured and filtered through filter paper into a laboratory cylinder. The collected ether extracts were thoroughly mixed and later evaporated in a nitrogen atmosphere on a heated water bath (Memmert WB22, Schwabach, Germany). The evaporated residue was dissolved in 2.0 mL hexane. The analysis was conducted using an HPLC UV-vis detector (Gilson Company, Middleton, WI, USA). Hexane solution of lycopene filtered through a 0.45 μm microfilter (Sigma Aldrich, Germany) were injected onto the chromatographic column C18 RP (Vydac 201 TP54, Vydac, Hesperia, CA, USA; 250 × 4.6 mm, 5 μm) with a precolumn (10 × 4.6 mm, 5 μm) from the same producer. The mobile phase applied was acetonitrile/hexane/dichloromethane/methanol (50/20/20/10; v/v), with 0.1% BHT as an antioxidant, at a flow rate of 1.0 mL/min with a wavelength of 470 nm. The obtained results were compared to the standard curve performed with the use of lycopene standard and expressed per 100 g of weight. The data were reported as the mean of three measurements. The recovery rate for the tested method was 95%.

Table 1: Lycopene content in tomatoes and its products

Tomato products	Dry matter 1 (%)	Dry matter 2 (%)	Harvest date 1 (mg/100 g of product)	Harvest date 2	Harvest date 1 (mg/100 g dm)	Harvest date 2
Fresh tomato	5.59^{e1}	5.48^{e1}	3.35^{e1}	2.54^{e2}	59.97^{c1}	46.45^{c2}
Dried tomato	84.52^{b1}	83.18^{b1}	118.10^{a1}	70.10^{a2}	139.79^{b1}	84.33^{b2}
Tomato paste	28.95^{d1}	29.05^{d1}	61.21^{b1}	53.52^{b2}	211.73^{a1}	184.29^{a2}
Fresh pomace	65.69^{c1}	65.03^{c1}	13.43^{d1}	10.47^{d2}	20.45^{e1}	16.11^{e2}
Dried pomace	90.23^{a1}	89.99^{a1}	22.65^{c1}	17.37^{c2}	25.11^{d1}	19.30^{d2}

$^{a-e}$Different letters in columns indicates significant differences ($p \leq 0.05$); $^{1-2}$different numerical values in lines means significant differences ($p \leq 0.05$); harvested day 1: 26.08.2015, harvested date 2: 16.09.2015, dm – dry matter.

2.3 Statistical analysis

The experiments were executed in three independent trials. Statistica software, version 10 (StatSoft Inc., Tulsa, OK, USA) was used to carry out the statistical analysis. A one-way ANOVA analysis and the Tukey test were conducted.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and discussion

The content of lycopene in tomatoes and their products depends on the type of the product and the date of harvest. Dried tomatoes harvested in August (118.10 mg/100 g product) had the highest lycopene content (Table 1). The content of lycopene was about 68% higher than tomatoes harvested in September. The lowest lycopene content was found in fresh tomatoes, regardless of the date of harvest (3.35 mg/100 g of product harvested in August and 2.54 mg/100 g of product harvested in September). Fresh tomatoes harvested in August contained 31% more lycopene than those harvested in September. The paste prepared from tomatoes harvested in August contained 48% less lycopene compared to dried tomatoes and as much as 1,827% more than fresh tomatoes. A similar trend was found in tomatoes harvested in September.

Based on the results calculated on the dry matter, tomato paste had the highest lycopene content (184.29 and 211.73 mg/100 g dm for harvest 2 and 1, respectively; (Table 1). The lowest lycopene content was found in fresh pomace (20.45 mg/100 g dm, harvested in August and 16.11 mg/100 g dm, harvested in September). Despite this, they are still a good source of lycopene. The paste prepared from tomatoes harvested in September contained 12.9% less lycopene compared to the tomato paste from tomatoes harvested in August.

According to the study by Wawrzyniak et al. [32], the lycopene content of tomato paste was the function of many factors, such as the degree of processing, ripeness, as well as the variety and the period of tomato harvest. Liu et al. [33] observed that between days 4 and 21, the lycopene content of the sun light-treated tomatoes increased about 2.4-fold; furthermore, after incubation in UV-C and red light, the lycopene content increased by sixfold and ninefold over the same period, respectively. The higher lycopene content in tomato products harvested in August is due to a longer day and better insolation compared to that in September. Studies carried out in Great Britain revealed that the lycopene content of tomatoes with an intensive red color was 50 mg/kg, and the yellow variety of tomatoes was characterized by a 10-fold lower content of lycopene, that is, 5 mg/kg [34]. In the present study, the lycopene content of fresh tomatoes is 53.21 mg/100 g dm or 2.94 mg/100 g of the product (Table 1). These data are in agreement with the results of studies performed by other scientists [32,35,36], who found that the lycopene content of fresh tomatoes ranged from 0.88 to 7.74 mg/100 g of product. Alda et al. [37] showed that the content of lycopene of fresh tomatoes was approximately 12 mg/100 g. Studies conducted in Hungary demonstrated that the average lycopene content of tomatoes accounted for 0.85 mg/100 g of product in winter, 1.10 mg in spring, and 13.6 mg/100 g of product in summer [35]. Nour et al. [12] found that the content of lycopene in dried tomato waste was 51 mg/100 g. Apart from fresh tomatoes, the main sources of lycopene in the Polish diet are tomato products. Since fresh tomatoes are a good raw material for the food industry, they can be consumed in different forms throughout the year. Among the foods available on the Polish market, the highest concentration of lycopene was found in tomato pastes, the mean content being 38.88 mg/100 g of product [32]. The amount of lycopene in 30% tomato pastes ranged from 53.52 to 58.30 mg/100 g of product.

4 Conclusions

The lycopene content in the analyzed samples depended on the type of the tomato product and the harvesting period. Products obtained from tomato harvested in August were characterized by a higher content of lycopene compared to that harvested in September. Since a good source of lycopene is tomato pomace, it is a promising raw material for the production of functional foods.

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