CI&CEQ
Chemical Industry & Chemical Engineering Quarterly

Available online at
Association of the Chemical Engineers of Serbia AChE
www.ache.org.rs/CICEQ

Chem. Ind. Chem. Eng. Q. 31 (2) 113–121 (2025) CI&CEQ

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THE RELATIONSHIP BETWEEN ERGOSTEROL AND *ALTERNARIA* MYCOTOXINS IN TOMATOES WITH DIFFERENT SURFACE DECAYED PROPORTIONS

Article Highlights

- Ergosterol has the potential to be used as a quality parameter instead of Alternaria mycotoxins
- Correlation between ergosterol and Alternaria of TPU samples with different TSD proportions
- Depending on mold genera, Alternaria and ergosterol can be produced in TPO and TPU samples

Abstract

This study evaluates the relationship between ergosterol (ERG) and Alternaria mycotoxins (AOH, AME, TenA) concentrations in tomato samples with varying decay levels. Using Rio Grande tomatoes, decay levels ranged from 89% to 99%. Samples were categorized based on visible mold, processed into pulp, and evaluated for quality parameters such as soluble solids, pH, acidity, and color. HPLC determined ERG, TenA, AOH, and AME levels, providing data on standard curve linearity, detection limit, recovery, and precision. Correlations between decay proportions and toxin concentrations were analyzed to understand variable relationships and quality implications for the tomato industry. Results indicate significant ($p<0.05$) effects of decay levels on toxin concentrations, emphasizing the importance of these measures for tomato quality assessment. The strong correlations among parameters underscore their relevance for quality control in tomato processing. This study contributes valuable insights for future research in this domain.

Keywords: alternariol; alternariol monomethyl ether; decay; ergosterol; tenuazonic acid; tomatoes.

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SCIENTIFIC PAPER

UDC 577.161.12:632:635.64:543:66

The presence of mold in processed foods is a clear indicator of non-ideal processing conditions and the use of raw materials that do not meet the required quality standards [1]. Fungi are known as organisms that produce many different secondary metabolites, and many of these metabolites are called mycotoxins. Mycotoxins play an important role in the pathogenicity of fungi and pose a serious threat to agricultural products [2]. However, many of these mycotoxins are known to have adverse effects on both animals and humans when consumed. Therefore, it is important to prevent unhealthy processing conditions and the use of low-quality raw materials in the food industry. Compliance with hygienic standards and quality controls during food production and processing can help prevent mycotoxins from entering the food chain

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Paper received: 27 June, 2023
Paper revised: 6 November, 2024
Paper accepted: 15 May, 2024

https://doi.org/10.2298/CICEQ230627019K

[3,4,5].

Alternaria mold species are widespread, in both semi-arid and humid lands. *Alternaria* mold can spread, both to adapt to environmental conditions and to easily infect plant hosts [3,6–8]. Many plants, including cereals, oilseeds, tomatoes, and citrus fruits, are susceptible to severe diseases caused by these fungi [9,10]. Tomatoes are easily infected by *Alternaria* species during and after harvest. As a result of these infections, black rot occurs on the fruits. This infection caused by *Alternaria* mold species causes significant problems in tomato production. Control and management of these pathogens are of great importance for tomato production and tomato products [11,12].

Alternaria mold species are common fungal genera that, under appropriate conditions produce several metabolites, such as mycotoxins. One of the most critical mycotoxins-producing species is *Alternaria alternata*. Researchers have stated that fruits and vegetables with soft peels, such as tomatoes are susceptible to the *A. alternata* invasion [13]. During the ripening phase, water can be found on the surface of the fruit from the dew, or excessive irrigation. Fungus spores sprouting, which can be found on the surface of the fruit, are due to the accumulation of water [14].

Contamination of food with *Alternaria* mycotoxins occurs as a result of *Alternaria* species infecting food crops and agricultural products. *Alternaria* fungi can cause lesions on plant leaves, stems, or fruit. Apart from this, *Alternaria* toxins are formed in humid and hot environments during the storage of agricultural products. Additionally, it can also pass into food when agricultural products are processed. Mycotoxins are released into food during the processing of infected tomatoes, especially in processed foods such as tomatoes or tomato products. It has been reported in studies that *Alternaria* mycotoxins were detected in grains and products produced from grains [15,16], feeds [17], milk and dairy products [18], nuts [19], oilseeds [20], vegetable oils [21] and fermented beverages [22].

To penetrate and grow in tomatoes, *A. alternata* needs a damaged or soft texture. Thus, during harvesting, the fungus can penetrate the tomato peel, caused by physiological disorders (spotty ripening, cracking, sunburn, yellow spot), injuries by insects, puncture injuries, or the calyxes mold growth associated with the scar [23]. For many *Alternaria* spp. that could contaminate tomatoes, the biggest concerns arise from *Alternaria* mycotoxins, which are produced by such species [9]. Several *Alternaria* mycotoxins that are detected in moldy tomatoes include alternariol monomethyl ether (AME), alternariol (AOH), tenuazonic acid (TenA), altertoxin (ATX), and altenuenes (ALT) [9], found even in tomato products with potentially adverse effects on human health [6–8]. The presence of TenA in tomato products may indicate that rotten tomatoes were used in the processing procedure [6]. So, to prevent mycotoxin contamination, damaged or mold-decayed tomatoes should not be used in the processing of tomato products [25].

Even in our daily consumption of fruits and vegetables, these mycotoxins may be considered toxic contaminants, as *Alternaria* mycotoxins can be produced naturally in them in case of infection [3]. Even in Europen Food Safety Authority's (EFSA) opinion [8] stated the need for defined performance criteria and certified reference materials for the analysis of *Alternaria* toxins in various foods and feeds. EFSA has been collecting information on *Alternaria* toxins in food and processed products for a long time. According to EFSA, tomatoes, and tomato products are also exposed to mycotoxins [26]. The co-occurrence of *Alternaria* toxins and metabolites in foods constitutes a problem and remains to be investigated, as well as stated in the International Regulations of Commercial Products [3]. This situation causes a number of difficulties in the trade of products coming from different geographies around the world as a part of international trade. Therefore, further investigation and control of the presence of these mycotoxins in foods is of critical importance both to protect consumer health and to make the food industry safer [27].

Ergosterol (ERG) (3β-hydroxy-5,7,22-ergostatriene) is a substance that forms the fungal cell wall and is widely found in all foods, especially tomatoes [28]. Ergosterol is a critical fungal sterol, the primary sterol in fungal membranes, and has a regulatory role in the selective permeability and location in the membrane. It is considered an essential component of a healthy fungal cell. Studies have shown that there is a positive correlation between mold growth, ERG levels, and subsequent toxin production. This is why the ERG has recently been recognized as an indicator for the determination of fungal growth. The detection of ERG presence is considered a significant quality parameter for the decision on the fungal growth levels in food [29–31]. Ergosterol is a part of mold membranes and is found in high levels in molds. In addition, it is a minor component of various plant and animal sterols. The sterol content in bacteria is insignificant. Because they constitute less than 0.01% of the dry weight and very little of it belongs to ergosterol. Ergosterol can also be found in the structure of yeasts, but molds are considered the primary producers due to their greater biosynthetic capacity compared to yeasts [32].

The presence of ergosterol is associated with the presence of molds in foods, but no specific conditions for ergosterol formation have been identified. However, it may be associated with conditions that cause mold growth. Some mold species, such as *Fusarium, Alternaria*, *Aspergillus, Penicillium*, and *Mucor*, have been reported to produce significant amounts of ergosterol [28]. Moreover, the presence of ergosterol is mainly associated with active biomass and not with total biomass. Marin *et al*. [33] also noticed the high correlation between ergosterol and colony diameter and emphasized the potential for use of both parameters. *A. flavus*, *B. fulva, B. nivea, F. oxsporum, M. plumbeus, P. commune* and *P. roqueforti* with the same colony diameter have also been reported to produce variable levels of ergosterol [34].

For identifying molds, the chemical and biochemical methods are based on the detection and quantification of some specific components, such as ERG, chitin, fungal volatiles, and adenosine triphosphate (ATP). For ERG analysis, the methods are based on direct saponification, hexane extraction, and quantification using TLC (Thin Layer Chromatography), LC (Liquid Chromatography), HPLC (High-Performance Liquid Chromatography), or spectrophotometric methods (UV, infrared) [8,29–31, 35–39]. There exists a relationship between Howard mold count (HMC)-ERG-mycotoxins depending on the decay proportion of figs, apples, nuts, and tomatoes [28], and depending on this relationship, ERG may be used as a microbiological fungal growth indicator. For this reason, various research studies are needed to examine the ERG-mycotoxin relationships in other foodstuffs and, to use ERG as an alternative to mycotoxin analysis as a microbiological quality parameter.

To the best of our knowledge, there is no published research study on the determination of the relationship between ERG and *Alternaria* mycotoxins in pulp and tomato paste obtained from tomatoes with different surface decay rates. The data obtained through this study can be considered an important indicator for the tomato processing industry in terms of product quality.

The objectives of this study are as follows;

1. To determine the contents of ERG and *Alternaria* mycotoxins (AOH, AME, TA) in tomato pulp (TPU) and tomato paste (TPO) samples obtained from tomatoes with different surface rot (25,50,75, and 100%).
2. To reveal the correlation between Ergosterol and *Alternaria* in TPU samples with different TSD ratios.

To investigate the potential of using ergosterol as a quality parameter instead of *Alternaria* mycotoxins.

MATERIAL AND METHODS

Tomato sampling and procedures

For this study, the Rio Grande variety, one of Turkey's most common industrial type tomato varieties, for tomato paste production, is obtained from the Honaz Tomato Paste Factory, located in Honaz district of Denizli province, Turkey. This factory has a daily capacity of 50 tons of tomato processing. The samples were taken from eight different batch productions. With an average value of 4 kg of tomatoes taken for each decay proportion from each production batch. Samples were immediately transported to the university laboratory and processed further into tomato pulp (TPU). Tomatoes were classified in percentage as having a 25, 50, 75, and 100% rotting rate, based on visibly rotten molds on their surface, before processing to TPU. Tomato surface decay (TSD) proportions were determined according to the method of Kadakal *et al*. [40].

The tomatoes were processed with a plant finisher (pilot-type Langsenkamp mfr., model 185S, Indianapolis, IN). Then, the inactivation of the pectolytic enzyme was achieved by heat treatment at 90°C for 3 minutes and then cooled to 25 °C in a cooling water circulating container [40]. After cooling, the samples were passed through a finisher with a series of three sieves, respectively equipped with 1.8, 0.71, and 0.5 mm mesh sizes. Separated pomace and pulp tomatoes samples using a finisher, and were kept at -20 °C until the final determinations.

Determination of some quality parameters: soluble solids, pH, titratable acidity, and color measurement

The soluble solids of TPU samples were determined by refractive index measurements as the mean of two parallels and expressed as Brix degree (°Bx) using a digital refractometer, model RFM 340 (Bellingham & Stanley Co., Atlanta, GA) [40–42].

The pH of TPU samples was measured with a pH meter, model WTW pH 537 (WTW Measurement System Inc., Fort Myers, FL). The titratable acidity (TA) of TPU samples was measured with the titrimetric method and expressed as citric acid g/L. The results are expressed as the mean of two parallel measurements [40,41,43].

The color of the TPU samples is measured as reflectance with a chroma meter, model Konica Minolta CR-300 (Minolta Co., Osaka, Japan). As color values are measured for three color components (Hunter L*, a*, b*). The food industry has widely adopted this

effective system, Hunter L* a* b* color space, for measuring color differences. On the tristimulus coordinate system, the L* value indicates lightness (0 is black and 100 is white), the a* value indicates red (+), or green (-) color, and the b* value indicates yellow (+), or blue (-) color [44]. Results are calculated as the mean value of five parallel measurements.

Determination of ergosterol and *Alternaria* mycotoxins

The HPLC method was used to determine ERG in the samples according to Kadakal *et al.* [10]. ERG an analytical-grade reagent, in crystalline form, was obtained from Sigma (Sigma-Aldrich Chemie GmbH, Deisenhofen-Germany). To determine TenA, AOH, and AME, the HPLC method was used, according to Terminiello *et al.* [45]. Each of the standards for AOH (*Alternaria sp.),* AME (*Alternaria alternata* (*tenuis*), and TenA (*Alternaria alternata*) were obtained from Sigma (St. Louis MO, USA).

The chromatographic separation was performed with an Inertsil 100A ODS-3 reversed-phase column (4.6×150 mm, 5 µm BGB Analytik AG, Boeckten, Switzerland). A photodiode array detector (SPD-M10 Avp, Shimadzu, Kyoto, Japan) set at 282 nm, a Shimadzu LC-10AT-VP HPLC pump, and a column oven (CTO-10AS, Shimadzu) set at 25 °C. The sample (20 µl) was injected into the HPLC system with a syringe (Hamilton Co., Reno, NV). The LabSolutions software (Shimadzu) was used.

A recovery test was performed to determine the extraction efficiency of the method. For this purpose, different concentrations of ERG, TenA, AOH, and AME standards were added to TPU samples of known ERG, TenA, AOH, and AME concentrations. In Table 1, are given data on the linearity of the standard curve, limit of detection, recovery, and precision of the proposed method for the determination of ERG, TenA, and AME.

Table 1. Characteristics of the proposed method: the linearity of the calibration curve, limit of detection, recovery, and precision.

Alternaria Toxins and ERG	Linear range (µg/L)	R	R^2	Detection limit (µg /kg)	Recovery (%)	Precision
					Mean SD[b]	R.S.D. (%)
TenA	5.0-30000	0.9994	99.71	2.2	92.86 ± 0.9	5.7
AOH	1.0-30000	0.9990	99.90	0.8	95.40 ± 1.0	4.1
AME	1.0-30000	0.9976	99.88	1.1	92.60 ± 1.1	2.34
ERG	1-25000	0.9999	99.93	1.0	94.50 ± 1.0	3.68

Mean SDb: Mean ± standard deviation. R.S.D: Relative standard deviation.

Statistical analysis

Statistical analysis of the data was performed using IBM SPSS statistical analysis software for Windows version 23.0 (IBM Corp. 2015). The analysis of variance (ANOVA) revealed a significant effect ($p<0.05$), and the data means are compared with the least significant difference (LSD) test. Furthermore, bivariate correlations revealing a significant effect ($p<0.05$ and $p<0.01$) were examined.

RESULTS AND DISCUSSION

The relationship between ERG and *Alternaria* mycotoxins (TenA, AOH, and AME) concentrations of TPO samples with different surface decay proportions

Table 2 shows ERG (mg/kg) and *Alternaria* mycotoxin (TenA, AOH, and AME) (µg/kg) data for TPO samples, produced with decay proportions of: 25, 50, 75, and 100%. In the moldy tomato samples were detected *Alternaria* mycotoxins, including AOH, AME, and TenA, and these are in accordance with the statements of Hasan [46]. Nizamlıoğlu [26] reported that there is a linear relationship between ergosterol and *Alternaria* toxins depending on the decay rate, and that ergosterol is correlated with the AOH and TenA concentration in tomato paste. ERG and *Alternaria* mycotoxins concentrations in the TPU samples were significantly ($p<0.05$) affected by surface decay proportions (SDP).

Table 2. The relationships of ERG and Alternaria mycotoxins concentrations in TPO samples, with different surface decay proportions.

TSD proportion (%)	ERG (mg/kg)[x]	*Alternaria* Mycotoxins		
		TenA (µg/kg)[x]	AOH (µg/kg)[x]	AME(µg/kg)[x]
0	nd[a*]	nd[a*]	nd[a*]	nd[a*]
25	0.4[b]	340[b]	426[b]	120[b]
50	3.54[c]	2190[c]	2582[c]	1364[c]
75	5.68[d]	2980[cd]	3620[d]	2468[d]
100	8.40[e]	4270[d]	5106[e]	2500[d]

nd: not detected. *Values within the column with different letters are statistically significant ($p<0.05$). [x]Mean values of ten determinations with two replicates.

There is a positive relationship between TSD proportions and ERG concentrations, as revealed by

HPLC analysis in TPO samples. A similar trend is observed even for *Alternaria* mycotoxins concentrations measured. With the raising of TSD proportions, reaching 100%, the ERG concentrations in TPO have been increased too, from an undetectable value to 8.40 mg/kg. Also, the same phenomena are observed for *Alternaria* mycotoxins (TenA, AOH, and AME), where from an undetected level till the TSD proportions reached 100%, such concentrations reached respectively 4270, 5106, and 2500 μg/kg. A limited number of studies have been conducted in the literature on the AME, AOH, and TA contents of tomato paste and tomato pulp. However, Ekinci et al., [29] similarly reported that Aflatoxin, patulin, and ergosterol contents in hazelnuts had a linear correlation with different degradation rates. In a study, high levels of AOH and TA (>50 mg/kg) have been reported in tomatoes showing typical rot due to *Alternaria* decay [47].

The relationship between ERG and *Alternaria* mycotoxins (TenA, AOH, and AME) concentrations in TPU samples, with different surface decay proportions

ERG and *Alternaria* mycotoxins concentrations in the TPU samples were significantly ($p<0.05$) affected by the SDP (Table 3). There is also a positive correlation between the ERG and *Alternaria* mycotoxins concentrations in TPU samples and the TSD proportions.

Table 3. Relationship between ERG and Alternaria mycotoxins (TenA, AOH, and AME) concentrations in TPU samples, with different surface decay proportions.

TSD proportions (%)	ERG (mg/kg)^x	*Alternaria* Mycotoxins		
		TenA (μg/kg)^x	AOH (μg/kg)^x	AME(μg/kg)^x
0	0.12^{a*}	2^{a*}	3^{a*}	0^{a*}
25	3.82^b	1545^b	1780^b	682^b
50	12.23^c	16314^c	18912^c	9672^c
75	19.80^d	18356^d	22768^d	12230^d
100	30.54^e	21890^e	25789^e	14680^e

*Values within a column followed by the different letters are significant ($p<0.05$). ^{x} Values are the mean of ten determinations in two replicates.

The concentration of ERG in TPU, ranged from 0.12 mg/kg to a value of 30.54 mg/kg from sound to 100% TSD, while for the *Alternaria* mycotoxins (TenA, AOH, and AME), have reached 21890, 25789, and 14680 μg/kg concentrations from 2, 3 and 0 μg/kg. Fliszár-Nyúl *et al.* [48] reported that AOH ranged from 6.1 to 25 μg/kg in tomato products. It was similar to the results obtained in TPU samples obtained from tomatoes with a 0% TSD rate. In different studies conducted, the highest AOH and AME were reported in tomato purees, while the highest TenA was detected in tomato products [49]. Ergosterol has been used as a microbiological quality indicator in tomatoes and tomato products in recent years. It is reported that there is a limit value of 15 mg/kg for tomatoes and tomato products [28]. It is observed that TPU samples obtained from tomatoes with 75% and 100% TSD exceed the limit level of 15 mg/kg ergosterol. EFSA reports that the average value for TA is a threshold of toxicological concern of 1500 ng/kg bw/day. AME and AOH in tomatoes have been reported to cause weak acute toxic effects in mice at 400 mg/kg (body weight) [50].

The relationship between some quality parameters of the TPU samples, with different surface decay proportions

The quality parameters (Table 4) observed in TPU samples were pH, °Bx, TA, and Hunter Lab color values, which were prepared from sound at 25, 50, 75, and 100% TSD. As it is presented in Table 4, there is a slight increase ($p<0.05$) in pH and TA values of TPU samples produced using sound, 25, 50, 75, and 100% TSD.

The changes in the ERG and *Alternaria* mycotoxins (TenA, AOH, and AME) concentrations in TPU and TPO samples, depending on different TSD proportions

The changes in the ERG and *Alternaria* mycotoxins (TenA, AOH, and AME) concentrations in TPU and TPO samples, obtained from different TSD proportions, are expressed by trendlines and the coefficient of determination (R^2), which are displayed in Fig. 1 and Fig. 2, respectively.

Table 4. Some quality parameters of the TPU samples, prepared from sound and 25, 50, 75, and 100% TSD.

TSD proportions (%)	pH^x	TA (g/L)^x	ºBx^x	Hunter		
				L^x	a^x	b^x
0	4.20^{a*}	0.368^{a*}	4.88^{a*}	27.42^{a*}	13.56^{a*}	8.22^{a*}
25	4.37^b	0.352^b	5,15^b	27.78^a	13.50^a	8.18^a
50	4.35^b	0.364^a	5.32^c	29.42^b	13.48^a	8.60^b
75	4.35^b	0.375^c	5,16^b	30.26^c	13.60^a	8.90^{cd}
100	4.30^c	0.384^d	4.90^a	31.56^d	13.98^b	9.141^d

* Values within the column with different letters are statistically significant ($p<0.05$). ^{x} Average of ten determinations with two replicates.

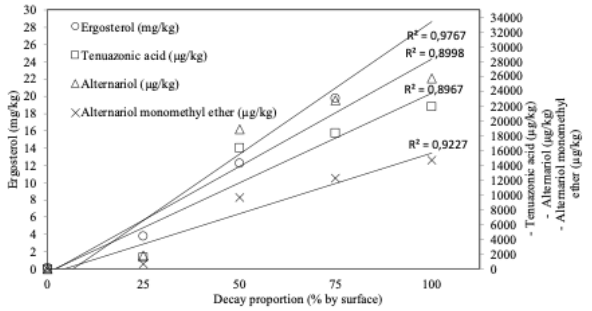


Figure 1. Changes in the concentrations of ERG and Alternaria mycotoxins (TenA, AOH, and AME) of TPU samples with different TSD proportions, expressed by the trendlines and the coefficient of determination (R^2).

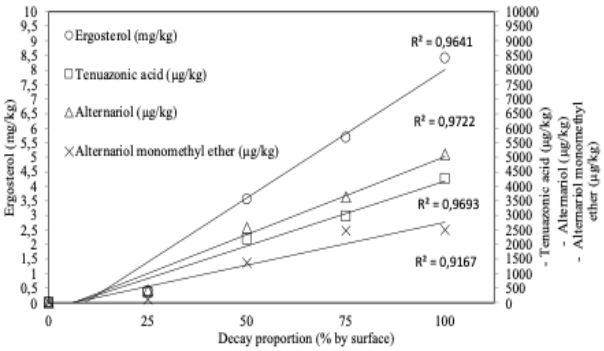


Figure 2. Changes in the concentrations of ERG and Alternaria mycotoxins (TenA, AOH, and AME) in TPO samples, with different TSD proportions, expressed by trendlines and the coefficient of determination (R^2).

It is noted that the amounts of ERG and *Alternaria* mycotoxins (TenA, AOH, and AME) in TPO samples are lower than in TPU samples. The data obtained at different TSD proportions reveal that these substances are transferred more during tomato processing in the TPU samples compared to the TPO samples. Furthermore, this transfer has shown an increasing trend, depending on the proportion of TSD.

The changes in the concentrations of *Alternaria* mycotoxins (TenA, AOH, and AME) depending on ERG concentrations in TPU and TPO samples

The changes in the concentrations of *Alternaria* mycotoxins (TenA, AOH, and AME) depending on ERG concentrations in TPU and TPO samples are displayed in Figures 3 and 4. They are expressed by trendlines and coefficient of determination (R^2) values.

The correlations and significance levels between the TSD proportions, the ERG concentration, the *Alternaria* mycotoxins concentrations, and some quality parameters of TPU and TPO samples

In this study, the correlation method is used to examine the relationship status between variables and to determine how the other variable explains many variations within one variable. As shown in Figures 1–4,

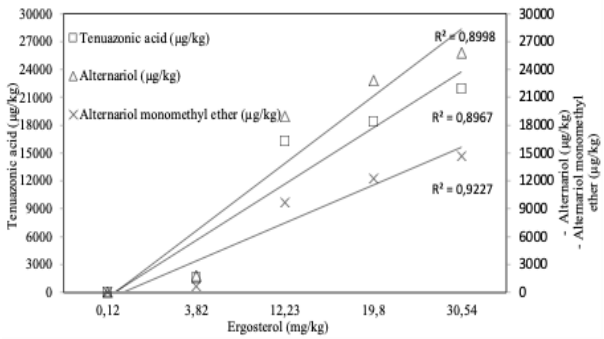


Figure 3. The changes in the concentrations of Alternaria mycotoxins (TenA, AOH, and AME) with different ERG concentrations in TPU samples, expressed by trendlines and the coefficient of determination (R^2).

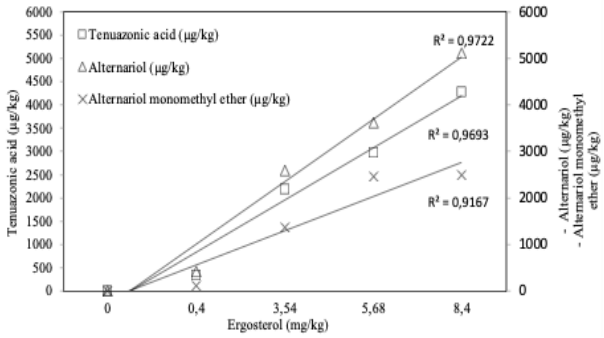


Figure 4. The changes in the concentrations of Alternaria mycotoxins (TenA, AOH, and AME) with different ERG concentrations of TPO samples are given by trend lines, and the coefficient of determination (R^2).

the coefficient of determination value is calculated from the correlation value. Table 5 presents the computed data for correlations between the TSD proportions, the ERG concentration, and the *Alternaria* mycotoxins (TenA, AOH, and AME) concentrations and some quality parameters (such as pH, TA, °Bx, and Hunter L*, a*, b* color values) for TPU and TPO samples and the significance levels. Results show that between all variables a positive relationship exists. The following results emerge according to the coefficient of determination of variables.

The correlation of the TSD proportions between ERG concentration in TPU, and TPO samples has no significant effects on the pH, TA, °Bx, Hunter L*, and a* color values. These findings are consistent with those of Kadakal *et al.* [40] study, except for Hunter b* color values, for which the significances are at the 0.01 level. The variations within TSD proportions in the TPU samples are explained by 93.3% for Hunter b* color values. The variations within ERG concentration in the TPU and TPO samples for Hunter b* color values are explained, respectively, by 96.6% and 99.0%.

The correlations of the TSD proportions are significant at the 0.01 level with ERG concentration, and AME is significant at the 0.05 level with TenA and

AOH concentration in TPU samples. Variations within TSD proportions are explained by 97.6% for the concentration of ERG, and by 89.7% of TenA, 90.1% for AOH, and 92.4% of AME in TPU samples. The relationship between TSD proportions is significant with concentrations of ERG, TenA, and AOH at the 0.01 level, and AME at the 0.05 level in TPO samples. ERG concentration explains 96.4% of the changes in TSD rates. In TPO samples, 97.0% of TenA is accounted for by 97.2% of AOH and 91.6% of AME concentration. Graselli *et al.* [51] stated essential correlations between ERG concentration and TSD.

It is noted that the concentrations of ERG and *Alternaria* mycotoxins in the TPU samples are related at the 0.05 significance level. The concentrations of 87.2% TenA, 87.2% AOH, and 91.0% AME in TPU samples are explained by the changes in ERG concentration in TPU. The concentrations of ERG and *Alternaria* mycotoxins in the TPO are related too. The relationship between the ERG concentration in the TPU samples is significant at the 0.01 level with TenA, and AOH, and at the 0.05 level with the AME concentration in TPO. Variations in ERG concentration of TPU samples are explained by 99.2% of ERG, 98.0% of TenA, 98.2% of AOH, and 89.9% of AME in TPO samples. In the TPO samples, the concentrations of ERG and *Alternaria* mycotoxins are related at the 0.01 significance level. The variations within ERG concentration are explained, respectively, by 99.2% of TenA concentration, 99.4% of AOH concentration, and 92.9% of AME concentration in the TPO samples. Nizamlıoğlu [26], investigated the relationship between ergosterol and three important mycotoxins (alternariol, alternariol monomethyl ether, and tenuazonic acid) in tomato paste and tomato juice. The results revealed that AOH and TA toxins were associated with ergosterol in tomato paste and tomato juice.

Table 5. Correlations and significance levels between the TSD proportions, the concentrations of ERG and Alternaria mycotoxins, and some quality parameters of TPU and TPO samples.

		TPU										TPO			
		pH	TA	°Bx	Hunter L	Hunter a	Hunter b	ERG	TenA	AOH	AME	ERG	TenA	AOH	AME
TSD (%)	R	0.414	0.725	0.042	-0.352	0.726	0.966**	0.988**	0.947*	0.949*	0.961**	0.982**	0.985**	0.986**	0.957*
	p	0.489	0.166	0.946	0.561	0.165	0.007	0.002	0.015	0.014	0.009	0.003	0.002	0.002	0.010
	R^2	0.171	0.526	0.002	0.124	0.527	0.933	0.976	0.897	0.901	0.924	0.964	0.970	0.972	0.916
TPU ERG	R	0.274	0.810	-0.094	-0.430	0.810	0.983**		0.934*	0.934*	0.954*	0.996**	0.990**	0.991**	0.948*
	p	0.655	0.097	0.881	0.470	0.096	0.003		0.020	0.020	0.012	0.000	0.001	0.001	0.014
	R^2	0.075	0.656	0.009	0.185	0.656	0.966		0.872	0.872	0.910	0.992	0.980	0.982	0.899
TPO ERG	R	0.242	0.837	-0.081	-0.503	0.788	0.995**						0.996**	0.997**	0.964**
	p	0.695	0.077	0.897	0.388	0.113	0.000						0.000	0.000	0.008
	R^2	0.059	0.701	0.007	0.253	0.622	0.990						0.992	0.994	0.929

R: correlation; R^2: coefficient of determination; p: significance; °Bx: Brix; TA: Titratable acidity. **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

CONCLUSION

This study examines ERG and Alternaria mycotoxin concentrations in TPO and TPU samples with varying decay proportions and TSD levels. Alternaria mycotoxins (AOH, AME, TenA) were detected in moldy tomato samples, aligning with previous findings. SDP significantly impacted ERG and Alternaria mycotoxin concentrations in TPU samples ($p<0.05$). HPLC analysis revealed a positive correlation between TSD proportions and ERG concentrations in TPO samples, similarly observed for Alternaria mycotoxins. As TSD proportions increased to 100%, ERG and Alternaria mycotoxin concentrations in TPO rose. Notably, concentrations were lower in TPO due to high heat treatment during tomato paste production. Transfer of substances during tomato processing was higher in TPU samples, increasing with TSD proportions. Positive correlations existed among TSD proportions, ERG, and Alternaria mycotoxin concentrations, as well as quality parameters (pH, TA, °Bx, Hunter L*, a*, b* color values) in both sample types. These findings support EFSA's need for defining performance criteria for Alternaria toxin analysis in foods and feeds. Strong correlations suggest these parameters could serve as quality indicators for defect evaluation in the tomato processing industry, warranting further research.

ACKNOWLEDGMENT

The authors would like to acknowledge the Honaz Tomato Paste Factory, for funding this research and providing the samples.

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NAUČNI RAD

ODNOS IZMEĐU ERGOSTEROLA I *Alternaria* MIKOTOKSINA U PARADAJZU SA RAZLIČITIM POVRŠINSKIM PROPORCIJAMA

U ovom radu je istraživan odnos između koncentracija ergosterola (ERG) i mikotoksina alternarije (AOH, AME, TenA) u uzorcima paradajza sa različitim nivoima raspadanja. Koristeći paradajz Rio Grande, nivoi truljenja su se kretali od 89% do 99%. Uzorci su kategorisani na osnovu vidljive buđi, prerađeni u pulpu, pa su procenjeni parametri kvaliteta, kao što su rastvorljive čvrste materije, pH, kiselost i boja. HPLC-om su određeni nivoi ERG, TenA, AOH i AME korišćenjem standardne prave i definisanjem vrednosti granica detekcije, recovery i preciznosti. Analizirane su korelacije između stepena raspadanja i koncentracija toksina, da bi se razumeli promenljivi odnosi i implikacije kvaliteta za industriju paradajza. Rezultati ukazuju na značajne ($p<0,05$) uticaje nivoa raspadanja na koncentraciju toksina, što naglašava njihov značaj ovih za procenu kvaliteta paradajza. Jake korelacije među parametrima naglašavaju njihovu relevantnost za kontrolu kvaliteta u preradi paradajza. Ovaj rad doprinosi dragocenim uvidima za buduća istraživanja u ovoj oblasti.

Ključne reči: alternariol; alternariol monometil etar; raspadanje; ergosterol, tenuazonska kiselina; paradajz.