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The effect of *Solanum lycopresicum* L. extract on quality and flavor stability of ready to eat meat products*

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Synthetic antioxidants such as butylated hydroxyl toluene (BHT) added to meat products have been actually restricted because of their toxic activity. This fact encourages the application of natural antioxidants as a protection from lipid oxidation process. Hence, the effect of addition of *Solanum lycopresicum* L. extract to pork and beef meatballs during frozen storage (-18°C/90 days) was investigated on physicochemical parameters, antioxidant activity and flavour. In the study, three kinds of meatballs were analysed: control (C) without antioxidant; with added BHT (0.01%) and with *Solanum lycopresicum* L. extract (1%, ET). Addition of 1% of *Solanum lycopresicum* L. extract to beef and pork meatballs ET resulted in a significant (P<0.05) decrease in lipid oxidation and increased redness stability. In conclusion, the addition of Solanum lycopresicum L. extract (1%) as a natural plant antioxidant to steamed beef and pork meatballs during frozen storage can result in reduced lipid oxidation level, stabilized red colour and intensity of meaty flavour

KEYWORDS: antioxidants / flavor / frozen storage / meatballs / *Solanum lycopresicum* L. / steam treatment

Ready-to-eat (RTE) products as a functional food are in a line with actual trends [Akcan *et al*. 2017]. Grinding of meat to prepare meatballs causes that the muscle surface is more prone to oxygen activity, resulting in significant lipid oxidation. The

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oxidation of lipids is a complex chain reaction involving unsaturated fatty acids and oxygen [Horbańczuk *et al*. 1998, Haraf 2014]. Hydroperoxides are the first products of this reaction which contribute to cell cytotoxicity [Domínguez *et al*. 2019, Sayed Mostafa and Fawzy El Azab 2022]. Freezing is one of the most important strategies for preserving meat quality during long-time storage [Culleré *et al*. 2013, Beltrán and Bellés 2018], however, processes such as lipid oxidation may occur. Synthetic and natural antioxidants are added to meat products to prevent lipid oxidation and off-flavours. Using antioxidant is important due to the economic losses in the meat industry caused by product rejection by the consumers [Falowo *et al.* 2014].

Butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) or tert-butylhydroquinone (TBHQ) are examples of synthetic antioxidants. Moreover, to maintain the acceptable colour of meat products, some additives such as nitrite or colourants could also be added [Dominguez *et al*. 2020]. Components obtained from natural sources with an antioxidative potential in the food industry are considered as natural antioxidants [Jóźwik *et al.* 2010, Kumar *et al.* 2015, Tewari *et al*. 2017ab, Poltorak *et al*. 2018, Mozos *et al*. 2018, 2021, Wang *et al*. 2018, 2020, Yeung *et al.* 2018, 2019, 2020abc, 2021abc, Abbas *et al*. 2020, Pieczynska *et al*. 2020, Li *et al.* 2021, Chopra *et al.* 2021, Horbańczuk *et al*. 2021, Jakubowska and Karamucki 2021, Stelmasiak *et al*. 2021], what is in line with the strategies aimed to produce "clean label".

The tomato (*Solanum lycopersicum* L.) fruit is a good source of compounds with antioxidant and colourant properties such as carotenes (lycopene, β-carotene, phytoene, phytofluene and lutein), phenolic compounds (phenolic acids and flavonoids), vitamins (ascorbic acid and vitamin A) and glycoalkaloids [Calvo *et al.* 2008, Viuda-Martos *et al*. 2014, Andres *et al*. 2017, Pinela *et al*. 2019]. Carotenoids as natural pigments present in plants and fruits are promising additives, which characterize an antioxidant activity and intensive colour. Hance, they can be applied as potential antioxidants and colorants in the meat industry [Lourenço *et al*. 2019]. Their consumption protects against many civilization diseases such as cardiovascular, cancer, atherosclerosis or diabetes [Sharoni *et al*. 2012], however natural antioxidants are generally more expensive and less efficient [Zwolan *et al*. 2020].

RTE products such as meatballs are widely consumed but due to changes during storage time, there is a need to analyse the effect of the addition of natural antioxidants on the final product. Therefore, the aim of the study was to evaluate the effectiveness of extract from *Solanum lycopresicum* L. on flavour stability and the qualitative characteristics of steamed meatballs during long-term freezing storage.

Material and methods

Experimental design

Meat (beef and pork) and pork jowl were purchased from the local producer. Meat and jowl were minced and then randomly divided into three groups. Tomato

extract was obtained from a local producer. Three groups were formulated. Negative control (C) was prepared with beef (44.2%), pork (27.2%), pork jowl (21%), water (6%), salt (1.2%) and black pepper (0.4%). Positive control (BHT) was formulated exactly as control group with an addition of 0.01% BHT. To the third - experimental group (ET) 1% of tomato extract (*Solanum lycopersicum* L.) was added. Then, the meatballs (20±2 g) were prepared. The steam heat treatment was applied to meatballs preparation (internal end point was 75°C). Subsequently, samples were placed in polythene bags under vacuum conditions and then frozen (-18±1°C). The analyses were conducted at day 0, 14, 28, 42 and 90 of frozen storage.

pH measurement

The pH measurement of raw meatballs was carried out using a potentiometric method. Hand-held pH-meter (Model 205, Testo AG, Lenzkirch, Germany) was used for analysis. The pH-meter was calibrated with two buffers (pH = 4.01, pH = 7.00). Each sample was analyzed in nine repetitions.

Water-holding capacity mesurement

Water-holding capacity (WHC) of raw meatballs was analyzed according to Grau and Hamm method (1953) with a slight modification [Szpicer *et al*. 2018]. 300 mg of sample was moved into a Whatman filter (no. 1) between two plates. Subsequently, sample was left under 2 kg weight for 5 minutes. Afterwards, liquid (Al) and meat (Am) areas were calculated by the Image-Pro Plus (v.7.0) software. Then, WHC was computed using following equation (1).

$$WHC\ (\%) = (Am/Al) \times 100 \quad (1)$$

Each sample was analyzed in nine repetitions.

Chemical composition analysis

Near-infrared spectrometer NIRFlex N-500 (Büchi Labortechnik AG, Flawil, Switzerland) was applied to measure chemical composition (moisture, protein, fat) of samples. The chemical components were measured in raw meatballs. After homogenization the layer of 0.5 cm of meat was placed on a Petri dish. Each sample was analyzed in nine repetitions.

Color measurement of meatballs

CIE L*a*b* analysis was conducted on the outside surface and on the cross-section of meatballs. The analysis was performed using a Minolta chromameter (CR-400, Konica Minolta Inc., Tokyo, Japan). Calibration was made using a white standard calibration plate (L* = 98.45, a* = -0.10, b* = -0.13). The analysis of color parameters was conducted by the measurement of 10 different places of the sample.

DPPH radical-scavenging activity

The antioxidant activity of each treatment group was carried out. Therefore, the ability of radical scavenging, using the free radical DPPH (1, 1-diphenyl-2-

picrylhydrazyl) as a reagent [Mariem *et al*. 2014] was measured. 2.5 g for each treatment group of meatballs was homogenized (120 s at 9500 rpm) in 7.5 ml of ethanol. Extraction processes were carried out at room temperature using rotator with shaking (MyLab SLRM-3, NanoEnTek Inc., Korea) and after that samples were centrifuged for 15 min at 18.000 rpm. Subsequently, the 0.5 ml of supernatant was added with 3.5 ml 0.1 mM DPPH in ethanol and mixed for 30 s. Then, samples were stored in the room temperature for 30 min in darkness conditions. The absorbance at 517 nm (Tecan Spark TM 10M, Männerdorf, Switzerland) against to ethanol was measured. For control sample, ~~all reagents were~~ added except sample solution which was replaced by 96% ethanol. The DPPH was calculated according to equation (2):

$$\text{DPPH activity \%} = \frac{A_{control} - A_{sample}}{A_{control}} \times 10 \quad (2)$$

Total phenolic content

Total phenolic content (TPC) of meatballs was calculated according to method of Singleton and Rossi (1965) with a slightly modification. A 2.5 g of sample from each treatment was homogenised in 7.5 ml of ethanol. Then, 0.5 ml of Folin's reagent and 6.0 ml of distilled water were added to 0.1 ml of ethanolic extract. Subsequently, 1.5 mL of sodium carbonate with the concentration of 200 mg/ml was added to the reactive mixtures. The mixture was filled with water to 10 ml. Afterwards, the solution was incubated for 30 min in the water bath (40°C). The absorbance was measured using spectrophotometer at wavelength of 765 nm (SparkTM 10M-Tecan Group, Männedorf, Switzerland). The content of phenolic compounds was expressed as a gallic acid equivalent based on calibration curve (the concentrations of gallic acid: 0 mg/ml, 0.1 mg/ml, 0.2 mg/ml, 0.3 mg/ml, 0.4 mg/ml and 0.5 mg/ml and the linear equation was: $y = 1.3071x + 0.016$). Obtained results were presented in mg gallic acid equivalent (GAE) per 100 g of the sample.

The analysis of lipid oxidation by TBARS

The secondary lipid oxidation of meatballs has been analyzed according to the method of presented by Brodowska *et al*. [2016]. The obtained results have been presented as mg MDA (malandialdehyde)·kg-1of meat. Measurements were performed in nine repetitions.

Volatile compound profile

Volatile compounds profile was measured using the Heracles II an electronic nose (AlphaM.O.S., Toulouse, France). The method was previously reported by Wojtasik-Kalinowska *et al*. [2021, 2016] and Górska-Horczyczak *et al*. [2017]. The application of the electronic nose is based on ultrafast gas chromatography with headspace method. The equipment consisted of a detector system with two metal columns of different polarities (nonpolar MXT-5 and slightly polar MXT1701, diameter=180µm,

length=10 m) and two FIDs. The Kovats' indexes were determined based on alkane standards (n-butane to n-hexadecane) (Restek). AroChemBase (Alpha MOS Co., Toulouse, France) was used for volatile compound identification. The base contained 44 000 compounds and included a base of sensory descriptors for each compound. 2 g of sample was placed in 20 mL headspace vials and capped with a teflon-faced silicon cap. Subsequently, the vials with the analysed samples were incubated at 55°C for 900 s. Agitation speed was 8.33 Hz. Hydrogen as a carrier gas was circulated at a constant flow rate (1 mL min–1). The injector temperature was 200°C, injected volume was 2500 μL and injection speed was 125 mL s–1. The analytes were collected in a trap at 15°C and then divided and transferred into two columns. A carrier gas was applied at a constant pressure (80 kPa). The split flow rate was10 mL min–1at the column heads. The temperature program in the oven was set as: 60°C for 2s, 3°Cs–1ramp to 270°C and held for 20 s, and FID1/FID2 at 280°C. The analysis of volatile compound profiles was performed on six samples from each analysed group.

Statistical analysis

The results were statistically analyzed using a one-way (raw meatballs) and two-way (steamed meatballs) ANOVA using Statistica 13.1 (StatSoft Inc., Tulsa, USA) program. The differences between the groups were tested the Tukey's multiple-range test at level of significance of $P<0.05$..

Results and discussion

Characteristic of raw samples of meatballs

The physicochemical characteristic of raw meatballs was presented in Table 1. Before steaming process, the a* parameter in ET group was statistically significantly higher compared to both control groups (C and BHT). Addition of tomato extract increased the intensity of the red colour of meatballs as it was in the study of Modzelewska-Kapitula (2012) where with the increase of tomato extract addition, a* parameters of batters before heat treatment increased.

In both groups with BHT and tomato extract addition the analysis has shown a significant increase of WHC at the beginning of the experiment ($P<0.05$). It was reported that the addition of plants to meat products enhanced the WHC of the product [Hajrawati *et al*. 2021]. Researchers [Serdarolu et al. 2018] studied that the beef patties with dried pumpkin pulp and seed by 5% pumpkin mix incorporated caused the WHC increase.

The pH values analysed in raw samples ranged from 5.74 to 5.78. There were no statistically significant differences in pH values between controls and experimental group. On D0 the TBARS value in ET group was statistically significantly lower compared to C group.

The NIR method was used to describe the meatballs composition before and after steaming process. In the control group of raw meatballs (C) fat content [%] was

Table 1. The effect of *Solanum lycopersicum* L. extract and synthetic antioxidant (BHT) on physicochemical parameters of raw and steamed meatballs during frozen storage (means and their standard errors)

Item	Day	Group					
		C		BHT		ET	
		mean	SE	mean	SE	mean	SE
		raw meatballs					
L*		44.33	1.02	44.68	1.17	41.76	1.33
a*		16.27^{a}	1.52	18.28^{a}	0.50	18.88^{b}	0.34
b*		9.67	0.35	9.97	0.35	10.11	0.34
WHC		59.20^{a}	2.06	70.24^{b}	1.05	67.02^{b}	0.93
pH		5.78	0.03	5.76	0.02	5.74	0.01
Moisture (%)		63.11^{a}	0.15	63.63^{ab}	0.23	64.11^{b}	0.16
Fat (%)		17.54^{c}	0.12	15.14^{a}	0.13	15.80^{b}	0.10
Protein (%)		16.57^{a}	0.07	19.07^{b}	0.28	17.04^{a}	0.07
TBARS		0.68^{c}	0.01	0.54^{a}	0.01	0.63^{b}	0.02
		steamed meatballs					
Moisture (%)	D0	61.10^{bD}	0.03	61.31^{bAB}	0.12	59.28^{aC}	0.04
	D14	60.60^{bC}	0.08	61.49^{cB}	0.06	59.92^{aD}	0.06
	D28	61.35^{bD}	0.10	61.28^{bAB}	0.04	60.04^{aD}	0.03
	D42	60.02^{bB}	0.05	61.51^{cB}	0.05	57.82^{aA}	0.05
	D90	58.73^{aA}	0.08	61.10^{bA}	0.02	58.79^{aB}	0.05
Fat (%)	D0	15.71^{aA}	0.13	15.95^{abA}	0.16	16.31^{bA}	0.12
	D14	18.41^{bD}	0.06	16.07^{aA}	0.06	16.26^{aA}	0.07
	D28	16.65^{bB}	0.10	16.12^{aAC}	0.02	17.44^{cB}	0.08
	D42	17.27^{bC}	0.04	16.63^{aD}	0.03	20.57^{cD}	0.09
	D90	19.68^{bE}	0.04	17.31^{aE}	0.10	18.22^{cC}	0.06
Protein (%)	D0	20.64^{aD}	0.10	20.75^{aC}	0.07	21.92^{bD}	0.18
	D14	19.17^{aA}	0.03	19.58^{bA}	0.09	21.23^{cC}	0.03
	D28	20.14^{aBC}	0.04	20.17^{aB}	0.03	20.79^{bB}	0.04
	D42	19.34^{aA}	0.02	20.10^{bB}	0.04	20.46^{cCD}	0.05
	D90	20.05^{aB}	0.04	20.01^{aB}	0.05	20.60^{bB}	0.09

C – control group; BHT – positive control group with 0.02% addition of BHT; 1% T – experimental group with 1% of *Solanum lycopersicum* L.
[ab]In a row means with different small letters show a significant effect of treatment group (P≤0.05).
[ab]In a column means with different capital letters show a significant effect of day (P≤0.05).

characterised by the statistically significant highest value (17.55±0.12), compared to the others groups with BHT addition 15.14±0.13 (BHT) and 15.80±0.10 (ET) group.

No statistically significant differences were observed in the moisture of all samples and in protein content between C and ET samples. In the case of steamed meatballs, the lowest values of moisture were observed in E2 group in all analysed groups. In all analysed days (except D14) the lowest values of fat content were observed in the case of E2 group. Statistically the highest values of protein content were observed also in the case of E2 group, where the values decreased within the storage time.

Color of meatballs

Colour is one of the most important factors influencing consumer acceptance and purchasing decisions of meat products [Guyon *et al*. 2016]. Both outside and inside

Table 2. Test probabilities for physicochemical characteristics of stored meatballs, depending on group and storage period – two-factor analysis of variance including interactions

Item	Variable		Interaction
	group	day	group x day
L* Outisde surface	**[1]	***	***
a* Outisde surface	***	NS	***
b* Outisde surface	***	NS	***
L* Inside surface	NS	***	***
a* Inside surface	NS	***	***
b* Inside surface	NS	***	***
Moisture (%)	***	***	***
Fat (%)	***	***	***
Protein (%)	***	***	***
DPPH (%)	NS	***	***
Polyphenols (mgGAE/100 g f.w.)	***	***	***
TBARS (mg/kg)	***	***	***

*P<0.05; **P < 0.01; ***P<0.001; NS – not significant.

surface was analysed. As it was demonstrated in Table 2 L* parameter (outside surface) was affected by both treatments' groups (P<0.01) and day of storage (P<0.001). L*, a* and b* in the case of inside surface were not affected by treatment group. Parameters a* and b* on outside surface were not affected by day of storage.

Analysing the outside surface of the meatballs (Tab. 3) no differences of L* parameter between groups in all analysed days except D90 where the highest lightness was observed for C and BHT groups were found. Addition of tomato extract caused darker colour of meatballs. No effect of time of frozen storage was observed in the case of a* parameter.

On all analysed days there were statistically significant differences in a* (redness) between C, BHT and TE groups. The outside surface was redder (higher a* value) in samples with the addition of tomato extract (TE group). The heat treatment process caused that meatballs were characterized by an attractive red and brown colour what is well acceptable. Heat treatments over 40°C and steam can have a significant effect on the colour of the final meat product [Bak *et al*. 2019, Tănase (Butnariu) *et al*. 2020].

Inside colour parameters (L* and a*) of meatballs presented significant differences among days of storage. It has also been observed in the case of inside colour of meatballs but additionally b* parameter has been significantly different among the days of storage. The treatment group had also a significant influence on both outside and inside colour parameters, however an exception has been observed in L* parameter of inside colour.

Total antioxidant activity (% DPPH)

Antioxidant activity of extract addition obtained from Solanum lycopresicum L. and synthetic antioxidant (BHT) on meatballs was assessed (Tab. 4).

On D0 there was noted the highest DPPH value in the case of group with an addition of extract obtained from Solanum lycopresicum L. and BHT. During the

Table 3. The means of color components measured on outside and inside surface of steamed meatballs with an addition of *Solanum lycopersicum* L. extract and synthetic antioxidant (BHT) during the frozen storage (means and their standard errors)

Item	Day	Outisde surface						Inside surface					
		group											
		C		BTH		ET		C		BHT		ET	
		mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
L*	D0	49.67^{AB}	1.05	51.61	0.73	51.13^{B}	0.50	56.19^{AB}	0.36	55.59	0.86	54.89	0.67
	D14	50.41^{AB}	0.55	50.82	0.70	48.11^{AB}	0.80	57.81^{bAB}	0.99	56.80^{ab}	0.73	53.96^{a}	0.28
	D28	48.91^{A}	0.78	51.29	1.06	49.46^{AB}	0.62	59.97^{bB}	0.76	54.91^{a}	0.24	55.51^{a}	0.44
	D42	53.03^{B}	0.58	52.14	0.46	51.54^{B}	0.99	54.10^{aA}	0.50	58.57^{b}	1.07	53.70^{a}	1.32
	D90	50.80^{bAB}	0.62	50.84^{b}	0.62	47.20^{aA}	0.52	56.66^{AB}	1.07	55.53	0.84	54.86	0.92
a*	D0	6.47^{a}	0.32	5.96^{a}	0.29	6.61^{b}	0.12	11.72^{a}	0.24	11.13^{a}	0.50	13.64^{b}	0.75
	D14	6.04^{a}	0.11	5.48^{a}	0.24	7.09^{b}	0.31	11.46	0.62	12.17	0.30	12.60	0.21
	D28	5.95^{a}	0.25	5.32^{a}	0.14	6.87^{b}	0.25	10.35^{a}	0.34	12.65^{b}	0.39	12.86^{b}	0.24
	D42	6.25^{a}	0.16	5.68^{a}	0.11	7.24^{b}	0.21	12.36^{ab}	0.34	10.47^{a}	0.28	13.93^{b}	0.63
	D90	6.09^{a}	0.25	6.02^{a}	0.26	7.16^{b}	0.17	11.77	0.81	11.21	0.34	12.31	0.21
b*	D0	10.84^{a}	0.19	10.94^{a}	0.30	13.05^{bA}	022	10.24^{aB}	0.20	9.78^{a}	0.27	14.73^{b}	0.62
	D14	10.33^{a}	0.17	10.96^{a}	0.27	14.38^{bAB}	0.27	8.64^{aA}	0.22	9.76^{a}	0.23	14.50^{b}	0.52
	D28	10.62^{a}	0.34	10.90^{a}	0.30	14.68^{bB}	0.33	9.25^{aAB}	0.20	8.95^{a}	0.16	14.58^{b}	0.31
	D42	9.99^{a}	0.21	10.16^{a}	0.51	13.30^{bAB}	0.21	9.00^{aAB}	0.09	8.61^{a}	0.19	13.92^{b}	0.45
	D90	10.69^{a}	0.27	10.99^{a}	0.22	13.87^{bAB}	0.30	8.54^{aA}	0.31	8.91^{a}	0.26	13.63^{b}	0.26

C – control group; BHT – positive control group with 0.02% addition of BHT; ET – experimental group with 1% of *Solanum lycopersicum* L.
Means with a different capital letters show a significant effect of treatment group with a column ($P \leq 0.05$).
Means with a different small letters show a significant effect of treatment group with a row ($P \leq 0.05$).

storage this value decreased, however in ET group on D90 it was statistically higher $P<0.05$ (20.18±0.12) compared to C group (9.98±0.49).

Decrease in the antioxidant capacity of meatballs with an addition of natural extracts during the frozen storage was also observed by Akcan *et al*. [2017]. It has been reported that lycopene from tomatoes characterized antioxidant activity in vitro [Djuric and Powell 2001] and in vivo researches [Giovannucci 1999]. The mechanism of antioxidant activity for this group of compounds seems to be related to the carotenoids scavenges peroxyl radicals by forming adducts between carotenoid

Table 4. The means of DPPH, polyphenols and TBARS content of steamed meatballs with an addition of *Solanum lycopersicum* L. extract and synthetic antioxidant (BHT) during the frozen storage (means and their standard errors)

Item	Day	C		BTH		ET	
		mean	SE	mean	SE	mean	SE
DPPH (%)	D0	18.16^{aC}	0.29	48.15^{bD}	0.00	47.96^{bE}	0.48
	D14	14.67^{aB}	0.67	47.18^{bD}	0.02	45.15^{bD}	0.76
	D28	11.12^{aA}	0.40	43.82^{cC}	0.46	39.18^{bC}	0.87
	D42	10.64^{aA}	0.47	40.12^{cB}	0.40	35.72^{bB}	0.40
	D90	9.98^{aA}	0.49	37.18^{cA}	0.49	20.18^{bA}	0.12
Polyphenole (mg GAE/100 g f.w.)	D0	70.12^{aD}	0.48	179.12^{bE}	0.02	263.18^{cE}	0.03
	D14	68.75^{aD}	0.40	172.21^{bD}	0.41	241.21^{cD}	0.02
	D28	60.64^{aC}	0.02	158.64^{bC}	0.02	201.34^{cC}	0.01
	D42	40.17^{aB}	0.47	148.57^{bB}	0.40	187.58^{cB}	0.47
	D90	32.15^{aA}	0.03	136.12^{bA}	0.03	142.17^{cA}	0.60
TBARS (mg/kg)	D0	0.82^{A}	0.02	0.70^{A}	0.02	0.79^{A}	0.02
	D14	0.97^{cB}	0.03	0.80^{aA}	0.02	0.89^{abA}	0.02
	D28	1.48^{bC}	0.02	1.04^{aB}	0.03	1.39^{bB}	0.02
	D42	1.74^{cD}	0.03	1.16^{aBC}	0.03	1.58^{bC}	0.02
	D90	1.88^{bD}	0.03	1.27^{aC}	0.02	1.86^{bE2}	0.03

C – control group; BHT – positive control group with 0.02% addition of BHT; ET – experimental group with 1% of *Solanum lycopersicum* L.
Means with different small letters show a significant effect of treatment group in a row ($P \leq 0.05$).
Means with different capital letters show a significant effect of day in a column ($P \leq 0.05$).

and the peroxyl radical, yielding a resonance-stabilized carotenoid radical [Burton and Ingold 1984].

The content of total phenolic compounds

In spices and herbs the antioxidant activity of phenolic compounds results from redox features and also from chemical properties, which can be active as reducing agents, Fe2+ chelators, free radical scavengers or quenchers of formation of singleton oxygen [Pizzale *et al*. 2001, Das *et al*. 2016]. The content of the total phenolic in analysed meatballs was shown in Table 4.

On D0 the antioxidant activity in the control group was 70.12±0.48%. After 90 days of frozen storage this value decreased by 54.15%. In group where Solanum lycopresicum L. extract was added this value decreased by 46.00%, however on the last day of frozen storage was still on the quite high level (142.17±0.60% with the initial value at the level 263.18±0.03). As it was reported by Akcan et al. (2017) a total phenolic compound content was higher in meatballs treated with natural antioxidant extracts than in the control group suggesting that these natural compounds contributed to the oxidative stability of frozen meatballs.

The TBARS analysis

In Table 4 the results of addition of Solanum lycopresicum L. extract on oxidation of lipids in meatballs during period of 90 days of frozen storage has been presented.

The TBARS values of all samples increased during the frozen storage. The tomato extract slowed down oxidation of lipids during the frozen storage. When TBARS value is on the level of 3 mg MDA·kg-1 in meat it is regarded as well preserved. The group with an addition of 0.01 % of BHT was the most effective against TBARS formation during 90 days of frozen storage of meatballs.

However, on D42 the TBARS value on ET group (1.58±0.02mg MDA·kg-1) was statistically significant lower compare to C group (1.74±0.03). It can be concluded that Solanum lycopresicum L. extract on D42 was an effective antioxidant against lipid oxidation.

Analysis of volatile compounds of meatballs depending on experimental groups during the frozen storage

Table 5 shows characteristic volatile compounds in all analysed groups. Based on the chromatographic diagrams (on D0), 12 compounds in C group, 12 in BHT group, 24 in ET group were detected. After 90 days of frozen storage 14 characteristic compounds were identified in the case of C, 12 in the case of BHT

Table 5. The effect of *Solanum lycopersicum* L. extract and synthetic antioxidant (BHT) on volatile compounds in meatballs

Compound	DB 5*	DB 1701**	Sensory descriptor	D0			D90		
				C	BHT	ET	C	BHT	ET
Methanol	425	502	alcoholic	+	+	+	+	+	+
Propanal	504	579	acetaldehyde	+	+	+	+	+	+
Dimethyl sulfide	508	572	cabbage			+			+
Methyl acetate	527	603	blackcurrant	+	+	+	+	+	+
2-methylpropanal	515	626	aldehydic			+			+
1-propanol	543	666	alcoholic		+	+		+	+
Butane-2,3-dione	589	690	butter	+	+	+	+	+	+
Butanal	578	668	chocolate	+	+		+	+	
Thiophene	672	734	aromatic				+		+
Propanoic acid	739	889	acidic		+	+			+
Pyrrole	757	915	sweet			+			+
Octane	800	800	fruity			+			+
1-Hexanol	870	880	floral			+			+
2-methylpentanal	760	843	etheral	+		+	+		+
(E)-2-pentan-1-ol	769	888	grassy				+	+	+
3-heptanone	888	968	fatty	+	+	+	+	+	+
2-Butylfuran	893	927	fruity			+			+
1R-(+)-alpha-pinene	935	945	aromatic	+	+	+	+	+	+
1S-(a)-pinene	943	956	herbaceous	+	+	+	+	+	+
Beta-Pinene	979	994	dry	+	+	+	+	+	+
2,5-dimethyl-3-furanthiol	968	1022	meaty			+			+
Myrcen	966	1024	balsamic	+		+	+		+
Benzeneacetaldehyde	1045	1188	floral	+	+	+	+	+	+
2-phenylethanol	1116	1282	flower			+			+
p-methylacetophenone	1182	1321	almond			+			+
Dodecane	1200	1300	alkane			+			+
(R)-linden ether	1252	1330	floral			+			+

*MXT-5 – non polar column; **MXT-1701 – slighty polar column.
C – control group; BHT – positive control group with 0.02% addition of BHT; ET – experimental group with 1% of *Solanum lycopersicum* L.

group, and 26 compounds in the case of ET group. Compounds found in all groups were methanol, propanal, methyl acetate, butane-2,3-dione, 3-heptanone, 1R-(+)-alpha-pinene, 1S-(a)-pinene, benzeneacetaldehyde. 6 characteristic compounds were found only in ET group: dimetyhyl sulfide, 2-methylpropanal, 2-phenylethanol, p-methylacetophenone, dodecane and (R)-linden ether. Hence it may be concluded that identified compounds are characteristic for Solanum lycopresicum L. extract addition. Characteristic for tomato extract is 2-phenylethanol, alcohol formed from the reduction of 2-phenylacetaldehyde [Distefano *et al*. 2022].

2-Phenylethanol is an important phenolic volatile, conferring flower notes to tomato fruits [Wang *et al*. 2016]. In the case of 0.01% BHT addition the lowest amount of volatile compounds was noticed after ninety days of frozen storage compared to other treatment groups. It can be concluded that BHT addition to meatballs caused decrease of a characteristic intensive meat flavour [Wojtasik-Kalinowska *et al*. 2021]. In these group the lowest amount of volatile compounds was noticed on day 90 compared to other research trials. The most intensive flavour both on D0 and D90 of frozen storage was noted in ET group. Therefore, the addition of Solanum lycopresicum L. extract enhances the intensity and stability of the flavour of frozen meatballs.

Conclusions

The addition of plant origin antioxidants may have a preservative effect in beef-pork meatballs during the frozen storage. There has been observed a beneficial effect on lipid oxidation inhibition in steamed meatballs by reducing TBARS value compared to the control during frozen storage at -18°C for 42 days. Therefore, Solanum lycopresicum L. extract is the promising natural compounds towards replacing the use of commercial antioxidants for extending the shelf-life of ready to eat pork and beef meatballs during frozen storage and reduced characteristic intensive flavor as compared to meatballs with addition of the synthetic antioxidants. However, the effect of Solanum lycopresicum L. extract on the specific changes of beef and pork meatballs flavor needs more analyses.

Conflict of interest

The authors declare no conflict of interest.

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