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THE TOMATO POMACE AS A POTENTIAL NATURAL ANTIOXIDANT IN THE RAW COOKED MEAT PRODUCT

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ABSTRACT

One of the most significant vegetable crops grown globally is the tomato. Tomato pomace, a waste product that makes up around 4% (w/w) of the total tomato processed into tomato products, is wasted during the industrial processing of tomatoes into juice. Tomato pomace is a rich source of bioactive compounds that could be further used in the meat industry. Since there is a growing interest in replacing synthetic antioxidants with natural ones, tomato pomace has the potential for further use. In this paper, we focused on the possibility of adding tomato pomace to raw cooked meat products. We added 3 and 5 mL.kg^{-1} of extract to these products. The total antioxidant capacity of the extract was 12.07% and the total polyphenols content was at the level of 16.68 mg GAE.g^{-1}. The addition of the extract had no significant effect on the pH of the meat products. The amount of MDA produced in the experimental groups was comparable to the group with the addition of ascorbic acid.

Keywords: tomato, co-product, extract, sausages, oxidation, polyphenols, antioxidant

INTRODUCTION

Meat and meat products are essential to a diet rich in essential nutrients, including high-quality proteins, vitamins (group B), bioactive compounds, carbohydrates, minerals (phosphorus, iron, magnesium, potassium, copper, and zinc), and colorants. Depending on the kind of muscle, they have various ratios of structural (phospholipids) and storage (triacylglycerols) lipids **(Cheng *et al.*, 2020; Amoli *et al.*, 2021).** The limiting factor in the quality and acceptability of meat and meat products is oxidation. Oxidation affects not only sensory attributes such as color, taste, or odor, but also nutrition value and textural properties. Initiators of oxidation reactions are free radicals that react with oxygen and affect lipids, proteins, pigments, and vitamins in meat products **(Ribeiro *et al.*, 2019).**
Lipid oxidation is a highly complex process that involves several interacting mechanisms. Lipid oxidation creates off-flavors and changes in meat products during their cold storage **(Lorenzo *et al.*, 2018).** To prevent or delay lipid oxidation in meat, meat manufacturers have used a variety of synthetic food additives in recent decades, including butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and nitrites. However, to minimize consumer concerns about the toxicity and safety issues associated with synthetic antioxidants, research into new bio-effective antioxidants has recently placed special emphasis on natural antioxidants **(Armenteros *et al.*, 2013).**
Phenolic compounds are a complex group of molecules generated by the metabolism of plants. The most important phenolic compounds are the tocopherols, flavonoids, and phenolic acids. All plant sources generally have these in common **(Kumar *et al.*, 2015).** Plant phenols can be found in every part of plants, including fruits, nuts, seeds, leaves, roots, bark, peels, or husks. The oxidative process in meat and meat products can be controlled technologically by using these plant parts as undiscovered novel sources of natural antioxidants. This will help to avoid the financial and environmental issues associated with all of these co-products **(Nikmaram *et al.*, 2018; Domínguez *et al.*, 2020).** In recent years, a large amount of research has been conducted evaluating these natural ingredients as antioxidant additives in meat products. These studies have led researchers to create innovative food products and lead to extensive evidence of their ability to extend the shelf life of products **(Wagh *et al.*, 2015).**
Globally, a very popular plant antioxidant are tomatoes. Tomatoes are rich in phenols, lycopene, organic acids, vitamins, and other effective components. About 3-7% of raw material is lost during the tomato juice pressing process. A group of co-products from tomatoes, also called pomace, consists of seeds, peels, and small amounts of pulp. The tomato peel has a higher amount of lycopene and β-carotene than the whole tomato. In biological systems, lycopene is the most effective singlet oxygen quencher among carotenoids as it can remove singlet oxygen atoms two and ten times more efficiently than β-carotene and α-tocopherol **(Skwarek & Karwowska, 2023).** Due to the significant amount of polyphenolic compounds and lycopene, tomatoes and tomato by-products are considered as a potential natural antioxidant.
The present study aimed to evaluate the effect of tomato pomace extracts (3 mL.kg^{-1} and 5 mL.kg^{-1}) in raw cooked meat product (frankfurters). Due to their composition and consistency, pork sausages are a suitable product for monitoring changes that occur as a result of lipid oxidation. The experimental sausages were analyzed for their color, pH, and oxidative stability during refrigerated storage for 21 days.

MATERIAL AND METHODS

Extract Preparation

The Botanical Garden of SPU in Nitra provided tomato pomace. Tomato pomace extract was prepared according to **Shirahigue *et al.* (2010).** The extract was prepared from 20g of dried and homogenized material, then combined with 100 mL of 80% ethanol in a shaker. After 24 hours in the dark at room temperature, the liquid part was evaporated to dryness at 65 °C in a vacuum rotary evaporator. Subsequently, the resulting dry residue was dissolved in 50 mL of water. The extract prepared in this way was stored at 4°C.

Determination of Total Antioxidant Capacity (TAC)

The authors **Demianová *et al.* (2021)** suggested using the DPPH radical method to evaluate the antioxidant capacity of tomato pomace extract.

Determination of Total Polyphenol Content (TPC)

The Folin-Ciocalteu assay was used to determine the total polyphenol content according to the methodology reported by **Bobková *et al.* (2021).** The final concentration is expressed in grams of gallic acid equivalents per kilogram of dry matter (g GAE.kg^{-1}).

Preparation of Meat Product

Pork meat (shoulder and flank), black pepper, salt, sweet red pepper, hot red pepper, nutmeg and cutting mixture were used in the sausage product. After adding all the ingredients, the desired amount of extract was added. In the experiment, 4 groups of meat products were prepared. The control group (Con0) was prepared

without the addition of antioxidant, the control group using 0.5 mL.kg^{-1} ascorbic acid (ConC), the experimental group using the extract 3 mL.kg^{-1} (TP3) and the experimental group using the extract 5 mL.kg^{-1} (TP5). Production of meat products and all analysis of meat products and extracts were performed in duplicate. Three measurements were performed in each observed parameter.

Measurement of pH

A benchtop pH meter with an injection probe (Orion Star™ A211 Benchtop pH meter) was used to measure the pH values of meat products. Before measuring the samples, the pH electrode was calibrated using calibration solutions (Hamilton AG Bonaduz, pH 4, 7 and 10) at a temperature of 20 ± 1 °C. pH was measured on the 1st, 7th, 14th and 21st day of storage.

Color Determination

The color was measured with a spectrophotometer (Konica Minolta CM-2600d, Osaka, Japan) set to Specular Component Included (SCI). The D65 light source was used and an 8 mm-diameter port on a 10° observer. The white plate calibration was carried out at 23°C, according to the instructions in the manual. The results of the experiment were shown as values in the CIELab color interface, with L* indicating lightness, a* indicating redness-greenness, and b* indicating yellowness-blueness. The color measurement was done on the 1st, 7th, 14th and 21st days.

Determination of Oxidative Stability

The oxidative stability of sausages was measured using the TBARS methodology published in our previous work by **Jurčaga *et al*. (2022)** using a UV-VIS spectrophotometer. The final results were calculated using a calibration curve and expressed as the amount of malondialdehyde (MDA) (mg) present in 1 kg of sample. Oxidative stability was done on the 1st, 7th, 14th and 21st days.

RESULTS AND DISCUSSION

Determination of Total Antioxidant Capacity (TAC) and Total Polyphenol Content (TPC)

To investigate the properties of the tomato pomace extract, two characteristics were observed. Total antioxidant capacity (TAC) and total polyphenol content (TPC) were measured after extract preparation. The value of the total antioxidant capacity of the tomato pomace extract was 12.07 ± 0.04% of DPPH radical inhibition. Total polyphenol content in extract from tomato pomace was 16.68 ± 0.13 mg GAE.g^{-1}.

Measurement of pH

Table 1 shows the changes in pH values over the storage period in different experimental groups. All groups exhibited minor changes in pH over the storage period. Although there were only minimal changes, but statistically significant differences were observed between groups throughout the storage period ($p<0,05$). The pH of experimental group with 5 mL.kg^{-1} extract from tomato pomace was always the highest over the storage period. On the 21st day, all experimental groups showed lowest values in pH compared with the 14th day. In addition, as storage time increased, the pH value of each test group gradually decreased, which may be caused by the higher antioxidant effect of the extract led to higher oxidation stability of frankfurter samples and reducing the oxidation. **Andrés et al. (2017)** reported different results compared to ours, but even in their case no negative impact on raw lamb patties. **Kim et al. (2010)** reported the pH of fresh sausages reduced significantly with the higher level of tomato powder. **Deda et al. (2007)** and **Candogan (2002)** have also noted a reduction in pH in meat products that contain tomato paste. The low pH value of tomato powder may be the cause of the pH reduction in fresh sausages with increased levels of tomato powder. The growth of lactic bacteria may be the cause of the decrease in pH, but the significant increase after storage is a typical pattern of meat product deterioration during storage because of the growing load of spoilage bacteria **(Jay 1996).**

Table 1 pH values of meat products measured during storage (mean ± S.D.)

	DAY 1	DAY 7	DAY 14	DAY 21
Con0	6.66 ± 0.02^{a}	6.66 ± 0.02^{b}	6.71 ± 0.01^{a}	6.64 ± 0.02^{ab}
ConC	6.60 ± 0.02^{b}	6.62 ± 0.02^{c}	6.66 ± 0.01^{b}	6.57 ± 0.04^{b}
TP3	6.64 ± 0.03^{ab}	6.70 ± 0.01^{a}	6.69 ± 0.03^{a}	6.60 ± 0.05^{ab}
TP5	6.69 ± 0.04^{a}	6.69 ± 0.01^{a}	6.70 ± 0.01^{a}	6.67 ± 0.03^{a}

Legend: Con- negative control group without added antioxidant; Con-C – control group with 0.5 mL.kg^{-1} ascorbic acid; TP-3 – experimental group with 3 mL.kg^{-1} tomato pomace extract; TP-5 - experimental group with 5 mL.kg^{-1} tomato pomace extract. The upper index represents a statistically significant differences between samples in column.

Color Determination

One of the most important aspects of meat and meat products' quality is their color. As can be seen from **Table 2**, the measured values were relatively stable and there was no significant color change in any group during storage. The vacuum packaging, in which the products were stored, also had a positive effect on the preservation of the permanent color, so that the product did not come into contact with oxygen. Statistically significant differences ($p < 0.05$) were found between the samples except on the 7th and 14th days in the parameter redness (a*) and on the 21st day in the parameter yellowness (b*). In his study, **Kim et al. (2010)** also observed color changes in pork sausages with the addition of tomato powder. They observed higher values in the L* parameter than in our case. Similar results to those in our study were observed in a* and b* parameters. **Eyiler and Oztan (2011)** used tomato powder in frankfurters and reported in parameter L* similar results to ours, but in redness (a*) observed significantly higher results compared to our results. **Šojić et al. (2020)** replace sodium nitrite with tomato pomace extract in cooked pork sausages. Cooked pork sausages showed lighter shades in the lightness parameter (L*) compared to our results, which were significantly darker.

Table 2 Results of color determination during the storage period (mean ± S.D.)

	DAY 1			DAY 7		
	L*(D65)	a*(D65)	b*(D65)	L*(D65)	a*(D65)	b*(D65)
Con0	66.73 ± 1.14^{c}	7.66 ± 0.23^{a}	20.30 ± 0.67^{b}	67.69 ± 0.73^{ab}	7.60 ± 0.34^{a}	20.41 ± 0.31^{b}
ConC	68.17 ± 0.46^{ab}	7.69 ± 0.28^{a}	21.81 ± 0.38^{a}	67.47 ± 1.57^{ab}	7.36 ± 0.19^{a}	20.42 ± 0.81^{b}
TP3	68.58 ± 0.23^{a}	7.65 ± 0.10^{a}	21.67 ± 0.06^{a}	66.93 ± 2.70^{b}	7.71 ± 0.31^{a}	21.52 ± 0.39^{a}
TP5	67.50 ± 0.50^{bc}	7.14 ± 0.36^{b}	21.26 ± 0.30^{a}	69.36 ± 0.40^{a}	7.38 ± 0.21^{a}	21.17 ± 0.38^{a}
	DAY 14			**DAY 21**		
	L*(D65)	a*(D65)	b*(D65)	L*(D65)	a*(D65)	b*(D65)
Con0	67.30 ± 0.50^{bc}	7.95 ± 0.43^{a}	20.18 ± 0.23^{b}	68.00 ± 0.25^{ab}	8.25 ± 0.47^{b}	20.48 ± 0.63^{a}
ConC	67.93 ± 0.74^{ab}	7.98 ± 0.20^{a}	20.29 ± 0.65^{b}	67.52 ± 0.60^{b}	9.37 ± 0.48^{a}	20.17 ± 0.55^{a}
TP3	66.51 ± 1.57^{c}	7.68 ± 0.35^{a}	20.54 ± 0.24^{b}	68.46 ± 0.66^{a}	8.32 ± 0.17^{b}	20.49 ± 0.10^{a}
TP5	69.08 ± 0.86^{a}	8.08 ± 0.25^{a}	21.06 ± 0.27^{a}	68.34 ± 0.87^{ab}	8.36 ± 0.11^{b}	20.60 ± 0.37^{a}

Legend: Con- negative control group without added antioxidant; Con-C – control group with 0.5 mL.kg^{-1} ascorbic acid; TP-3 – experimental group with 3 mL.kg^{-1} tomato pomace extract; TP-5 - experimental group with 5 mL.kg^{-1} tomato pomace extract. Upper index represent a statistically significant differences between samples in column.

Determination of Oxidative Stability

Malondialdehyde (MDA) is one of the most important aldehydes formed during the secondary lipid oxidation of polyunsaturated fatty acids. Since it is a major indicator of lipid oxidation and produces a yellowish odor in small amounts, this aldehyde is also particularly important in meat **(Domínguez et al. 2019). Greene and Cumuze (1982)** state that a minimum TBA value of 2 mg malondialdehyde (MDA).kg^{-1} sample is required to produce an off-flavour in meat and meat products. During the 21 days of storage, the samples' MDA.kg^{-1} level did not exceed 1 mg. **Table 3** shows the results found during the storage of pork sausages. Statistically significant differences were found between the experimental groups during the entire storage period. According to assumptions, the control group (Con0) without the addition of antioxidants showed higher MDA values throughout the storage period. After the 1st day of storage, groups TP3 and TP5

showed the lowest values even in comparison with the addition of ascorbic acid (ConC). After 7, 14 and 21 days of storage, the lowest value was measured in the group with the addition of ascorbic acid (ConC), but it was comparable to groups TP3 and TP5. In our previous study, **Mesárošová et al. (2024)** we reached similar results after the addition of sea buckthorn extract in amounts of 3 and 5 mL.kg^{-1}. **Ghafouri-Oskuei et al. (2020)** used the addition of tomato powder as a natural antioxidant to beef sausages and stored the samples for 42 days. They found that the addition of tomato powder in the amount of 3% had no significant effect on the formation of MDA in the steamed meat samples, and the MDA value was the lowest among the other samples. **Devatkal et al. (2010)** also reported that the addition of tangerine and pomegranate peels significantly reduced MDA formation in cooked goat meat patties compared to the control group. The same conclusions were reached by **Kanatt et al. (2010)** who used pomegranate peel and seed extracts in chicken meat products.

Table 3 Results of oxidative stability in sausages (mg MDA.kg^{-1} ± S.D.)

	DAY 1	DAY 7	DAY 14	DAY 21
Con0	0.098 ± 0.012^{a}	0.124 ± 0.025^{a}	0.142 ± 0.009^{a}	0.159 ± 0.03^{a}
ConC	0.081 ± 0.021^{b}	0.099 ± 0.014^{c}	0.115 ± 0.019^{c}	0.135 ± 0.022^{c}
TP3	0.076 ± 0.015^{c}	0.112 ± 0.023^{b}	0.124 ± 0.034^{b}	0.144 ± 0.018^{b}
TP5	0.075 ± 0.018^{c}	0.103 ± 0.020^{c}	0.125 ± 0.027^{b}	0.145 ± 0.015^{b}

Legend: Con- negative control group without added antioxidant; Con-C – control group with 0.5 mL.kg^{-1} ascorbic acid; TP-3 – experimental group with 3 mL.kg^{-1} tomato pomace extract; TP-5 - experimental group with 5 mL.kg^{-1} tomato pomace extract. The upper index represent a statistically significant differences between samples in column.

CONCLUSION

This research deals with the search for new natural additives that could effectively replace synthetic antioxidants. The measured values of the antioxidant capacity and the total content of polyphenols indicate the possible use of tomato pomace as natural antioxidants in raw cooked meat products. The addition of extracts from tomato pomace did not have a significant negative impact on any of the monitored parameters. Regarding color changes in meat products, differences were observed in the redness parameter. These changes could be due to the natural red color of the extracts. Lipid oxidation occurred in all monitored groups. The highest value was measured in the control group without the addition of antioxidants (Con0). In the experimental groups, the measured values were at a similar level. In conclusion, we can state that tomato pomace appears to be a potential natural antioxidant. However, more research is needed to prove it.

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