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CASCARA, THE UNUSUAL ANTIOXIDANT OPTION FOR MEAT INDUSTRY

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ABSTRACT

The modern-day meat industry is facing increased customer demand to abandon synthetic additives and move towards healthier natural options. Multiple fruits, vegetables, and spices were recently evaluated for their potential use in the meat industry. We also must consider the economic side; therefore, food scientists have become interested in polyphenol-rich co-products. Our study was focused on enhancing the antioxidant properties of a popular meat product – pork sausage with cascara extract at 5 mL/kg and powder at 5 g/kg. As cascara polyphenols and antioxidant capacity are highly variable depending on multiple factors, we evaluated total polyphenolic content and total antioxidant capacity at 21.26 ± 0.17 g GAE/kg and 37.65 ± 1.84%, respectively. During our experiment, we observed that cascara powder addition significantly reduced malondialdehyde production (by approx. 30%) compared to negative control. Even though cascara powder caused the difference in the pH values of sausage samples, the sensory panel did not negatively reflect this fact during the sensory evaluation. Based on our results, we believe cascara addition in powdered form presents a natural antioxidant option with high potential to be used in the meat industry.

Keywords: cascara, lipid oxidation, antioxidant, meat product

INTRODUCTION

The coffee cherry comprises of skin, pulp, mucilage, parchment, silverskin, and coffee bean. The skin, known as the pericarp, becomes crimson as it ripens. The yellowish, fibrous, and delicious pulp, known as the outer mesocarp, lies under the skin; underneath is a thin layer of mucilage known as the pectin layer. The parchment or endocarp is the next component. Another layer, silverskin, covers the endosperm, known as coffee bean **(Esquivel & Jiménez, 2012)**. Cascara (coffee husk) is typically used to describe the fruity bittersweet layers with unique flavors covering the coffee bean. Coffee is widely consumed worldwide and ranks among the most traded agricultural products **(Arpi *et al.*, 2021)**. Despite the traditional use of cascara as a beverage prepared with hot water in some coffee processing cultures such as Ethiopia (hashara) or Yemen (qishr) **(Eckhardt *et al.*, 2022)**, we believe cascara presents various other utilization in the food industry. Coffee pulp has been shown to include cellulose (13-27%), fat (2-17%), protein (9-11%), tannin (4.5%), pectin matter (6.5%), reducing sugar (12.4%), non-nitrogen extract (57-63%), and other polyphenolic chemicals **(Pleissner *et al.*, 2016)**. As a result, the coffee pulp may be further processed to provide important bioproducts such as flour, aromatic compounds **(Bonilla-Hermosa *et al.*, 2014),** and cascara tea **(Heeger *et al.*, 2017)**. The cascara has been shown to have high antioxidant activity because of the presence of phenolic compounds, mainly chlorogenic acid **(Oktaviani *et al.*, 2020)**.
Food lipids and proteins are frequently subjected to oxidation, compromising the food's quality and safety. Food ingredients lose shelf life due to oxidation, which also deteriorates their nutritional value and sensory appeal and releases toxins **(Aminzare *et al.*, 2019)**. Double bonds found in polyunsaturated fatty acids in food components act as the actual catalysts for oxidation. Hydroperoxide and free radicals are produced when these double bonds react with ambient oxygen **(De Paula Paseto Fernandes *et al.*, 2018)**. Because they contain acylated sugars, organic acids, and aromatic rings containing hydroxyl groups, phenols have great potential for antioxidant activity. These moieties' ability to suppress the production of free radicals is what gives them their antioxidant capability **(Suleria *et al.*,2020)**. Lipid oxidation, which is frequently assessed using the thiobarbituric acid reactive substances (TBARS) method, is more likely to occur in meat products. Although synthetic antioxidants were first employed to stop lipids from oxidizing, natural sources that may have the same effect on meat have been discovered (**Martillanes *et al.*, 2017)**. Consequently, natural ingredients are now preferred over synthetic ones in the food market. As a result, natural antioxidants devoid of artificial additives that can reduce oxidation processes in high-fat meat and meat products are in great demand in the food market **(Kumar *et al.*, 2015)**. Antioxidants respond to oxidative stress by interacting with both radical and non-radical species to start defense mechanisms that shield intracellular and extracellular components. The most plentiful natural antioxidants come from plants and, in large quantities, can be found in herbs, spices (seeds), and essential oils that are added to meat products for flavoring. Antioxidants and other phytochemicals can be found in several fruits and vegetables **(Tomović *et al.*, 2017)**.
In our study, we tried to utilize a co-product of coffee processing, the cascara, as a natural addition to the pork sausage to reduce lipid oxidation during cold storage. We assume this fortification positively impacts raw cooked meat products' oxidative stability due to cascara's confirmed high polyphenols content. Oxidative stability is major, but only one factor in novelty food product development. Addition of natural antioxidant cannot alter the sensory quality beyond customer acceptance or technological properties of final product. Our study presents a complex look at the current problem faced by the meat industry, and we believe it could be insightful for science and industry alike.

MATERIAL AND METHODS

Plant material and extract preparation

Samples of coffee cascara was purchased at local shop with Panama stated as county of origin, dried for 48 hours at 60 ± 1°C and then grounded by GrindoMix GM 200 (Retsch, Germany). For preparation of cascara extract 20g of dried samples was macerated for 24h in 100 mL of 80% ethanol. The liquid fraction was then evaporated until dry at 65 °C in a vacuum rotary evaporator. The weighed dry residue was redissolved in 50 mL of water.

Sausage preparation

To prepare the meat product, we used the following ingredients: pork meat, water, a salting mixture with 0.3% sodium nitrite concentration, black pepper, sweet and spicy red pepper spice, and nutmeg. For the purpose of the experiment, four sample groups were observed: Ctrl-0 – without any antioxidant addition, Ctrl-C – with

ascorbic acid addition (0.5 g/kg), Cscr-E – cascara extract addition (5 mL/kg), and Cscr-P – cascara powder addition (5 g/kg).

Total antioxidant capacity (TAC) and total polyphenolic content (TPC)

Total antioxidant capacity (TAC) of cascara extract was determined using slightly modified DPPH radical method as suggested by **Demianová *et al.* (2021)** for coffee samples. Total polyphenolic content (TPC) was determined by assay using Folin-Ciocaleu reagent as previously published by **Bobková *et al.* (2020)**.

pH measurement

To measure pH values of the sausage samples pH meter with piercing probe was used (Orion Star™ A211 Benchtop pH meter) calibrated with calibration solutions (pH 4, 7 and 10) at a temperature of 20 °C.

TBARs assay

TBARS assay was used to monitor the lipid oxidation changes in meat products, as in our previous work **Jurčaga *et al.* (2021)**, during storage period of 21 days at 4 ± 1°C. Results of TBARS assay is expressed as mg of malondialdehyde equivalent in kg of meat product.

Color determination

Color measurement was conducted by spectrophotometer (Konica Minolta CM-2600d, Osaka, Japan) with the setting Specular Component Included (SCI). We used the D65 light source and a 10° observer, with a port 8 mm in diameter **(Mesárošová *et al.*, 2024).**

Sensory analysis

Sensory analysis was performed by 7 educated panelists of both genders. Sausage samples were evaluated in five parameters (appearance, color, odor, consistency and taste), on 5-point scale with detailed description for every point (5 – best, 1 – worst).

Statistical analysis

In our study we performed analysis of variance (ANOVA) deploying Duncan's test to determine the statistical differences among samples at significance level $\alpha = 0.05$ using XLSTAT® software (version 2018.5.52280, Addinsoft, New York).

RESULTS AND DISCUSSION

Plant material examination results

Total polyphenol content (TPC) and total antioxidant capacity (TPC) were determined to determine the plant material's quality and antioxidant properties. In purchased cascara samples was, total polyphenolic content determined at 21.26 ± 0.17 g GAE/kg with a total antioxidant capacity of 37.65 ± 1.84%. Multiple authors reported that both TPC and TAC of coffee co-product shows a significant variation depending on multiple factors. **Poláková *et al.*, (2023)** described those differences among coffee co-products (silverskin and cascara) of different botanical varieties *(C. arabica and C. canephora).* Other major factors are extraction agent and time **(Abduh *et al.*, 2023)**, pulp treatment **(Arpi *et al.*, 2021)**, and cherry fermentation **(Kristanti *et al.*, 2022)** were reported before.

pH measurement results

During our experiment, the pH values of the sausage groups were monitored weekly for 21 days, as listed in **Table 1**. We observed a continuous and significant decrease in pH values during the storage period in all groups, regardless of the antioxidant addition or its absence. **Mostafa and Azab (2022)** experimented with chicken nuggets enhanced with ground green coffee. The authors observed a significant *($p \geq 0.05$)* increase in pH values in selected meat products, which conflicts with our findings. This difference could be explained by using vacuum-sealed storage compared to the cold storage used in the mentioned publication. Vacuum package is connected with lactic acid bacteria growth, which decreases the pH values, whereas simple cold storage leads to the inactivation of lactic acid bacteria and degradation of meat proteins and yields essential compounds such as amines and ammonia **(Ouerfelli *et al.*, 2019)**. Within one measuring day, we observed significant differences among groups only on Day 1 and Day 14 of storage. On both days, the lowest pH values were observed in groups with ascorbic acid (Ctrl-C), which is expected. On the other hand, the highest values were observed in the group with cascara powder (Scsr-P), which is surprising due to the acid properties of cascara itself **(Murlida *et al.*, 2021)**. However, it is essential to notice that pH could be affected by various factors, not only the pH of addition. **Araya-Morice *et al.* (2023)** observed limited pH variability in tested fresh pork sausage with coffee husk addition.

Table 1 pH values of sausage sample groups during storage ($\bar{x} \pm S.D.$)

Sample	Day 1	Day 7	Day 14	Day 21
Ctrl-0	6.44 ± 0.01^{bA}	6.35 ± 0.01^{aB}	6.19 ± 0.01^{bC}	6.01 ± 0.00^{aD}
Ctrl-C	6.40 ± 0.02^{cA}	6.29 ± 0.04^{aB}	6.14 ± 0.00^{cC}	5.99 ± 0.01^{aD}
Cscr-E	6.47 ± 0.02^{abA}	6.34 ± 0.02^{aB}	6.13 ± 0.00^{cC}	6.06 ± 0.00^{aD}
Cscr-P	6.49 ± 0.01^{aA}	6.36 ± 0.02^{aB}	6.26 ± 0.06^{aC}	6.08 ± 0.01^{aD}

Note: Ctrl-0 – without any antioxidant addition, Ctrl-C – with ascorbic acid addition (0.5 g/kg), Cscr-E – cascara extract addition (5 mL/kg) and Cscr-P – cascara powder addition (5 g/kg); a,b,c as upper index represents statistically significant differences ($p \leq 0.05$) in a collum; A,B,C,D as upper index represents statistically significant differences ($p \leq 0.05$) in a row.

TBARs assay results

Similarly to the pH measurement, the TBAR assay was conducted on a weekly basis during the whole 21-day storage period. We observed a continuous increment of MDA concentration in all sausage groups during this period, as expected. Differences among groups are significant only at the end of the storage period (21st day). Furthermore, we observed that cascara in powder form (5 kg/kg) was better at delaying lipid oxidation in pork sausages than cascara in the form of extract (5 mL/kg). Similarly to our findings, various studies reported a positive effect of coffee co-product on lipid oxidation in meat product matrices. **Kim *et al.* (2016)** reported retarded lipid oxidation in both raw and cooked chicken meat patties enhanced with coffee residue water and ethanol extract. Positive effect of coffee co-product (silverskin) on chicken meat patties was reported by **Martuscelli *et al.* (2021)**. Studies regarding pork meat products also confirmed improvement of lipid oxidation after coffee husk addition **(Araya-Morice *et al.*, 2023)** and green coffee itself **(Bergamaschi *et al.*, 2023)**.

Table 2 TBARs assay results ($\bar{x} \pm S.D.$)

Sample	Day 1	Day 7	Day 14	Day 21
Ctrl-0	0.081 ± 0.005^{aD}	0.104 ± 0.008^{aC}	0.128 ± 0.002^{aB}	0.165 ± 0.008^{aA}
Ctrl-C	0.086 ± 0.009^{aC}	0.107 ± 0.009^{aB}	0.116 ± 0.005^{aB}	0.130 ± 0.009^{cA}
Cscr-E	0.089 ± 0.007^{aC}	0.104 ± 0.013^{aBC}	0.120 ± 0.006^{aBA}	0.156 ± 0.009^{abA}
Cscr-P	0.086 ± 0.008^{aC}	0.103 ± 0.005^{aBC}	0.115 ± 0.008^{aB}	0.150 ± 0.006^{bA}

Note: Ctrl-0 – without any antioxidant addition, Ctrl-C – with ascorbic acid addition (0.5 g/kg), Cscr-E – cascara extract addition (5 mL/kg) and Cscr-P – cascara powder addition (5 g/kg); a,b,c as upper index represents statistically significant differences ($p \leq 0.05$) in a collum; A,B,C,D as upper index represents statistically significant differences ($p \leq 0.05$) in a row.

Color determination results

The color measurement was carried out on the first and the last day of storage (the 21st day) to observe color differences and changes in meat product samples. During the storage period, we observed significant *($p \leq 0.05$)* darkening of all sausage sample groups, which is observable by a decrease of the lightness (L*) parameter in **Table 3**. Those changes are expected and are connected to the breakdown of myoglobin and other changes in meat products **(Ruedt *et al.*, 2023)**. Regarding changes in redness (a*) and yellowness (b*), we did not observe any significant changes in any observed groups after the 21-day storage period. Among sausage groups, Ctrl-0 group showed the highest values, while groups with cascara extract (Cscr-E) and powder (Cscr-P) proved to be significantly *($p \leq 0.05$)* darker. Similar results were observed with different additions, such as apple peel and silverskin **(Thangavelu *et al.*, 2022)** or kinnow and pomegranate co-product **(Devatkal and Naveena, 2010),** to meat products. The redness parameter (a*) was stable and without significant differences among all groups on the first and the 21st day. The difference among groups in the yellowness (b*) parameter was observed at the end of the storage period (21st day). The highest b* values were observed in the negative control group (Ctrl-0) and group with cascara powder addition (Cscr-P), which is unusual since multiple authors reported increased yellowness in meat products after natural antioxidant addition compared to control samples **(Gök *et al.*, 2011; Alirezalu *et al.*, 2019).**

Table 3 Sausage samples color measurement results ($\bar{x} \pm S.D.$)

Sample	L*(D65)		a*(D65)		b*(D65)	
	Day 1	Day 21	Day 1	Day 21	Day 1	Day 21
Ctrl-0	66.87 ± 0.40^{abA}	65.06 ± 0.35^{aB}	13.35 ± 0.41^{aA}	14.41 ± 0.21^{aA}	18.43 ± 0.51^{aA}	19.25 ± 0.36^{aA}
Ctrl-C	66.66 ± 0.33^{abA}	63.25 ± 0.39^{bB}	13.72 ± 0.86^{aA}	13.23 ± 0.69^{aA}	19.54 ± 1.08^{aA}	18.31 ± 0.39^{bA}
Cscr-E	66.12 ± 0.52^{bA}	61.76 ± 0.58^{cB}	13.64 ± 0.36^{aA}	14.47 ± 0.41^{aA}	17.96 ± 0.45^{aA}	18.83 ± 0.23^{abA}
Cscr-P	67.50 ± 0.21^{aA}	62.37 ± 0.68^{bcB}	14.31 ± 1.03^{aA}	14.48 ± 0.47^{aA}	18.69 ± 0.36^{aA}	19.19 ± 0.13^{aA}

Note: Ctrl-0 – without any antioxidant addition, Ctrl-C – with ascorbic acid addition (0.5 g/kg), Cscr-E – cascara extract addition (5 mL/kg) and Cscr-P – cascara powder addition (5 g/kg); a,b,c as upper index represents statistically significant differences ($p \leq 0.05$) in a collum; A,B,C,D as upper index represents statistically significant differences ($p \leq 0.05$) in a row.

Sensory analysis results

Sensory evaluation of sausage samples was conducted on the first and 21st days of the experiment. On the first day, samples with cascara powder obtained significantly the highest values in overall appearance compared to other groups. No other significant differences among groups were observed at any parameters. Based on our results, the selected cascara addition did not negatively affect the sensory quality of pork sausage. This is a positive evaluation since multiple authors reported deterioration of multiple sensory parameters after natural antioxidant addition. **Özhamamcı (2024)** reported continuous deterioration of various parameters (odor, color, taste, and texture) with increasing addition of silverskin powder into chicken patties. The same pattern of sensory quality deterioration was reported by **Choi et al. (2019)** after enhancing the pork sausage with cacao bean husk.

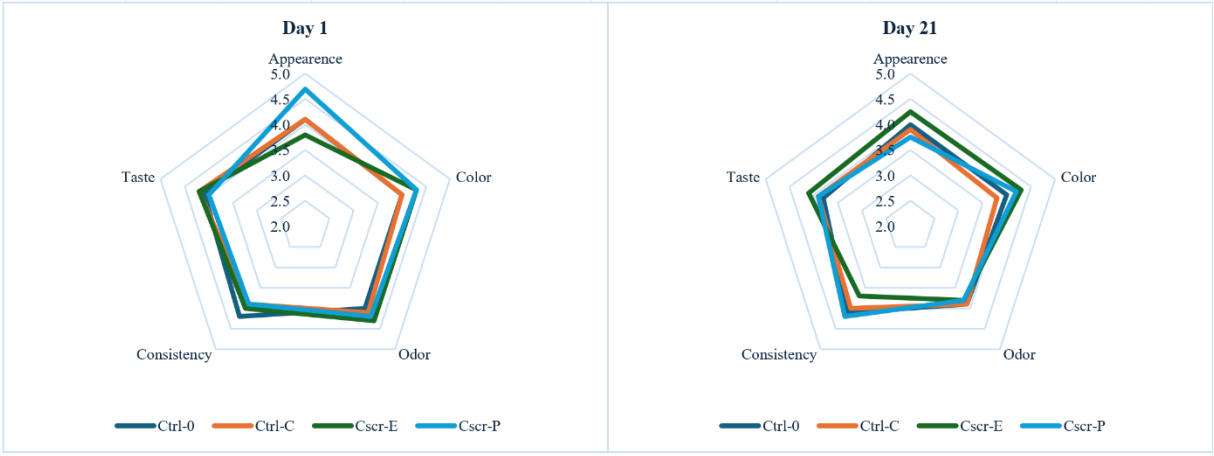

Figure 1 Graphic display of sensory evaluation results on the 1st and 21st day

CONCLUSION

In our study, we enhanced a popular meat product – pork sausage, with a coffee co-product – cascara, in the form of extract and fine-grounded powder. Cascara powder proved to be a more potent natural antioxidant than liquid cascara extract and could significantly lower the MDA creation of sausage samples compared to the negative control. Grounded cascara powder, however, caused increased pH values in raw, cooked meat products at the end of the storage period. It is essential to highlight that the observed difference in pH did not negatively affect the sensory quality of sausages as proved by our sensory evaluation. Based on our results, we consider the powdered cascara as a suitable natural antioxidant for raw meat products. We believe our findings may help focus the efforts of the meat industry and food scientists alike in the right direction regarding the move from synthetic antioxidants towards natural plant-based options.

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REFERENCES

Abduh, M. Y., Nofitasari, D., Rahmawati, A., Eryanti, A. Y., & Rosmiati, M. (2023). Effects of brewing conditions on total phenolic content, antioxidant activity and sensory properties of cascara. *Food Chemistry Advances*, *2*, 100183. https://doi.org/10.1016/j.focha.2023.100183

Alirezalu, K., Hesari, J., Nemati, Z., Munekata, P. E., Barba, F. J., & Lorenzo, J. M. (2019). Combined effect of natural antioxidants and antimicrobial compounds during refrigerated storage of nitrite-free frankfurter-type sausage. *Food Research International*, *120*, 839–850. https://doi.org/10.1016/j.foodres.2018.11.048

Aminzare, M., Hashemi, M., Ansarian, E., Bimkar, M., Azar, H. H., Mehrasbi, M. R., Daneshamooz, S., Raeisi, M., Jannat, B., & Afshari, A. (2019). Using natural antioxidants in meat and meat products as preservatives: a review. *Advances in Animal and Veterinary Sciences*, *7*(5). https://doi.org/10.17582/journal.aavs/2019/7.5.417.426

Araya-Morice, A., Araya-Quesada, Y., Cortés, N., Caamaño, J., & Arroyo, L. (2023). Antioxidant potential of coffee husks in fresh pork sausage. *Journal of Food Science and Technology*, *60*(9), 2423–2432. https://doi.org/10.1007/s13197-023-05764-6

Arpi, N., Muzaifa, M., Sulaiman, M. I., Andini, R., & Kesuma, S. I. (2021). Chemical characteristics of Cascara, coffee cherry tea, made of various coffee pulp treatments. *IOP Conference Series. Earth and Environmental Science*, *709*(1), 012030. https://doi.org/10.1088/1755-1315/709/1/012030

Bergamaschi, M., Simoncini, N., Spezzano, V. M., Ferri, M., & Tassoni, A. (2023). Antioxidant and Sensory Properties of Raw and Cooked Pork Meat Burgers Formulated with Extract from Non-Compliant Green Coffee Beans. *Foods*, *12*(6), 1264. https://doi.org/10.3390/foods12061264

Bobková, A., Hudáček, M., Jakabová, S., Belej, Ľ., Capcarová, M., Čurlej, J., Bobko, M., Árvay, J., Jakab, I., Čapla, J., & Demianová, A. (2020). The effect of roasting on the total polyphenols and antioxidant activity of coffee. *Journal of Environmental Science and Health. Part B. Pesticides, Food Contaminants, and Agricultural Wastes*, *55*(5), 495–500. https://doi.org/10.1080/03601234.2020.1724660

Bonilla-Hermosa, V. A., Duarte, W. F., & Schwan, R. F. (2014). Utilization of coffee by-products obtained from semi-washed process for production of value-added compounds. *Bioresource Technology*, *166*, 142–150. https://doi.org/10.1016/j.biortech.2014.05.031

Choi, J., Kim, N., Choi, H. Y., & Han, Y. S. (2019). Effect of cacao bean husk powder on the quality properties of pork sausages. *Food Science of Animal Resources*, *39*(5), 742–755. https://doi.org/10.5851/kosfa.2019.e62

De Paula Paseto Fernandes, R., Trindade, M. A., & De Melo, M. P. (2018). Natural Antioxidants and Food Applications: Healthy perspectives. In *Elsevier eBooks* (pp. 31–64). https://doi.org/10.1016/b978-0-12-811446-9.00002-2

Demianová, A., Bobková, A., Jurčaga, L., Bobko, M., Belej, Ľ., & Árvay, J. (2021). DETERMINATION OF GEOGRAPHICAL ORIGIN OF GREEN AND ROASTED COFFEE BASED ON SELECTED CHEMICAL PARAMETERS. *Journal of Microbiology, Biotechnology and Food Sciences*, *10*(4), 706–710. https://doi.org/10.15414/jmbfs.2021.10.4.706-710

Devatkal, S. K., & Naveena, B. (2010). Effect of salt, kinnow and pomegranate fruit by-product powders on color and oxidative stability of raw ground goat meat during refrigerated storage. *Meat Science*, *85*(2), 306–311. https://doi.org/10.1016/j.meatsci.2010.01.019

Eckhardt, S., Franke, H., Schwarz, S., & Lachenmeier, D. W. (2022). Risk assessment of coffee cherry (Cascara) fruit products for flour replacement and other alternative food uses. *Molecules/Molecules Online/Molecules Annual*, *27*(23), 8435. https://doi.org/10.3390/molecules27238435

Esquivel, P., & Jiménez, V. M. (2012). Functional properties of coffee and coffee by-products. *Food Research International*, *46*(2), 488–495. https://doi.org/10.1016/j.foodres.2011.05.028

Gök, V., Obuz, E., Şahin, M. E., & Serteser, A. (2011). The effects of some natural antioxidants on the color, chemical and microbiological properties of sucuk (Turkish dry-fermented sausage) during ripening and storage periods. *Journal of Food Processing and Preservation*, *35*(5), 677–690. https://doi.org/10.1111/j.1745-4549.2011.00517.x

Heeger, A., Kosińska-Cagnazzo, A., Cantergiani, E., & Andlauer, W. (2017). Bioactives of coffee cherry pulp and its utilisation for production of Cascara beverage. *Food Chemistry*, *221*, 969–975. https://doi.org/10.1016/j.foodchem.2016.11.067

Jurčaga, L., Bobko, M., Haščík, P., Bobková, A., Demianová, A., Belej, Ľ., & Kročko, M. (2021). Effect of dietary red grape pomace on lipid oxidation in meat of broiler chickens. *Journal of Microbiology, Biotechnology and Food Sciences*, *10*(5), e3769. https://doi.org/10.15414/jmbfs.3769

Kim, J., Ahn, D., Eun, J., & Moon, S. (2016). Antioxidant Effect of Extracts from the Coffee Residue in Raw and Cooked Meat. *Antioxidants*, *5*(3), 21. https://doi.org/10.3390/antiox5030021

Kristanti, D., Setiaboma, W., Ratnawati, L., & Sagita, D. (2022). Robusta coffee cherry fermentation: Physicochemical and sensory evaluation of fermented cascara tea. *Journal of Food Processing and Preservation*, *46*(11). https://doi.org/10.1111/jfpp.17054

Kumar, Y., Yadav, D. N., Ahmad, T., & Narsaiah, K. (2015). Recent trends in the use of natural antioxidants for meat and meat products. *Comprehensive Reviews in Food Science and Food Safety*, *14*(6), 796–812. https://doi.org/10.1111/1541-4337.12156

Martillanes, S., Rocha-Pimienta, J., Cabrera-Bañegil, M., Martín-Vertedor, D., & Delgado-Adámez, J. (2017). Application of phenolic compounds for food preservation: food additive and active packaging. In *InTech eBooks*. https://doi.org/10.5772/66885

Martuscelli, M., Esposito, L., & Mastrocola, D. (2021). The Role of Coffee Silver Skin against Oxidative Phenomena in Newly Formulated Chicken Meat Burgers after Cooking. *Foods*, *10*(8), 1833. https://doi.org/10.3390/foods10081833

Mesárošová, A., Bobko, M., Jurčaga, L., Bobková, A., Poláková, K., Demianová, A., Lidiková, J., Bučko, O., Mendelová, A., & Tóth, T. (2024). Chokeberry (Aronia melanocarpa) as natural antioxidant for the meat industry. Czech Journal of Food Sciences. https://doi.org/10.17221/38/2024-cjfs

Mostafa, H. S., & Azab, E. F. E. (2022). Efficacy of green coffee as an antioxidant in beef meatballs compared with ascorbic acid. *Food Chemistry X*, *14*, 100336. https://doi.org/10.1016/j.fochx.2022.100336

Murlida, E., Noviasari, S., Nilda, C., Rohaya, S., Rahmi, F., & Muzaifa, M. (2021). Chemical characteristics of cascara tea from several varieties of coffee in Aceh Province. *IOP Conference Series Earth and Environmental Science*, *667*(1), 012078. https://doi.org/10.1088/1755-1315/667/1/012078

Oktaviani, L., Astuti, D. I., Rosmiati, M., & Abduh, M. Y. (2020). Fermentation of coffee pulp using indigenous lactic acid bacteria with simultaneous aeration to produce cascara with a high antioxidant activity. *Heliyon*, *6*(7), e04462. https://doi.org/10.1016/j.heliyon.2020.e04462

Ouerfelli, M., Villasante, J., Kaâb, L. B. B., & Almajano, M. (2019). Effect of Neem (Azadirachta indica L.) on Lipid Oxidation in Raw Chilled Beef Patties. *Antioxidants*, *8*(8), 305. https://doi.org/10.3390/antiox8080305

Özhamamcı, İ. (2024). Coffee silverskin as a fat replacer in chicken patty formulation and its effect on physicochemical, textural, and sensory properties. *Applied Sciences*, *14*(15), 6442. https://doi.org/10.3390/app14156442

Pleissner, D., Neu, A., Mehlmann, K., Schneider, R., Puerta-Quintero, G. I., & Venus, J. (2016). Fermentative lactic acid production from coffee pulp hydrolysate using Bacillus coagulans at laboratory and pilot scales. *Bioresource Technology*, *218*, 167–173. https://doi.org/10.1016/j.biortech.2016.06.078

Poláková, K., Bobková, A., Demianová, A., Bobko, M., Lidiková, J., Jurčaga, L., Belej, Ľ., Mesárošová, A., Korčok, M., & Tóth, T. (2023). Quality attributes and sensory acceptance of different botanical coffee Co-Products. *Foods*, *12*(14), 2675. https://doi.org/10.3390/foods12142675

Ruedt, C., Gibis, M., & Weiss, J. (2023). Meat color and iridescence: Origin, analysis, and approaches to modulation. *Comprehensive Reviews in Food Science and Food Safety*, *22*(4), 3366–3394. https://doi.org/10.1111/1541-4337.13191

Suleria, H. a. R., Barrow, C. J., & Dunshea, F. R. (2020). Screening and characterization of phenolic compounds and their antioxidant capacity in different fruit peels. *Foods*, *9*(9), 1206. https://doi.org/10.3390/foods9091206

Thangavelu, K. P., Tiwari, B., Kerry, J. P., & Álvarez, C. (2022). A comparative study on the effect of Ultrasound-Treated Apple Pomace and Coffee Silverskin powders as phosphate replacers in Irish breakfast sausage formulations. *Foods*, *11*(18), 2763. https://doi.org/10.3390/foods11182763

Tomović, V., Jokanović, M., Šojić, B., Škaljac, S., & Ivić, M. (2017). Plants as natural antioxidants for meat products. *IOP Conference Series. Earth and Environmental Science*, *85*, 012030. https://doi.org/10.1088/1755-1315/85/1/012030