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Antioxidant and Sensorial Properties: Meat Analogues versus Conventional Meat Products

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Abstract: Meat-product alternatives have become more popular among consumers, mainly due to concern for animal welfare and demand for more eco-friendly production. This study focused on the comparison between the antioxidant capacities of selected types of meat products and those of their plant-based alternatives. The analogues of the following products were analyzed: minced meat, burger, steak, Hungarian sausages, Frankfurter sausages and salami. Total polyphenol contents and antioxidant capacities and sensory profiles of the products were determined. The highest polyphenol content (1.85 mg Gallic acid/g) and antioxidant capacity values (DPPH: 41.80% inhibition, CUPRAC: 9.21 Trolox mmol/kg, FRAP: 7.51 mmol/g, ABTS: 7.45% inhibition) were observed in the analogue samples of Hungarian sausages due to the oat flour presence in these products. The results indicated that antioxidant properties of meat analogue products (plant sources) were superior compared to conventional meat products (produced from animal sources). The sensorial attributes indicated no significant ($p > 0.05$) differences in taste (except the Frankfurter sausages). The novelty of the study can be seen in the fact that it confirmed that the sensory properties of meat analogue products can be close to those of traditional meat products.

Keywords: polyphenol; DPPH; FRAP; CUPRAC; ABTS

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1. Introduction

Vegetarian food commodities have begun to occupy a larger shelf space in food markets. The reason for this popularity may relate to the consumers' preferences for healthier food intake, since vegetarian food is, according to certain data, a better option; a vegetarian diet has certain beneficial attributes [1,2] and is considered more environmentally friendly. Meat analogues are foods that are similar to meat in a structural way, but differ in nutritional composition. Different terms are used to express the term "meat analogue"; the following names are often used: imitation meat, meat substitute, faux meat or mock meat [3]. Aesthetic qualities (such as appearance, and in particular, texture and flavour) and/or chemical characteristics of analogue meat approximate those of specific types of meat. It has been observed that meat analogues are healthier and/or less expensive alternatives in comparison with particular conventional meat products [4]. Soy-based meat analogues contain high protein levels, equivalent nutritional values and little or no cholesterol in comparison with conventional meat products [5]. Generally, meat analogues are available in different forms, such as burgers, sausages, nuggets, meatballs, Frankfurters and many others. Such meat analogues are generally made from soy protein or gluten [4].

On the other hand, several studies [6–8] indicate that nutritional ingredients found in meat analogues are not similar to the nutritional profile of conventional meat products. The poorer nutritional profile of plant-based protein products corresponds mainly to the lack of essential amino acids and trace elements. This fact certainly represents the biggest challenge for the development of new meat analogue recipes closely approximating the nutritional profiles of conventional meat products [9]. Therefore, plant-based alternatives are usually enriched or fortified in a certain way (coconut oil, beet juice etc.) to achieve similar nutritional proportions to meat products [10]. A diverse and growing range of additive ingredients, such as enzymes, are now used in meat analogues. As an example, transglutaminase ensures strong protein binding in the texture of plant protein products [11,12].

The intensive processing of proteins and fats through the addition of antioxidants to meat analogue products is necessary for the prevention of fat rancidity and protein oxidation. Antioxidants of plant origin are a group of compounds with various chemical structures. Polyphenols (flavonols and anthocyanins) and essential oils (mainly terpenoids) are most widely used in the meat industry as ingredients in products or as packaging elements [13,14]. Soybeans are the primary ingredient in many meat alternative products, such as veggie burgers and soy meat [15]. Soy products contain very high levels of phenolic compounds with high antioxidant properties. The literature data dealing with the soy nutritional profile and its potential are mostly focused on soy proteins and isoflavones [16]. Isoflavones (a group of phytoestrogens) belong to the group of phenolic compounds with the ability to reduce the risk of hormonal and age-related diseases [17]. Genistein is from the isoflavones group that has been shown to have anti-oxidant and anti-browning actions in vivo and in vitro [18]. Meat analogue products are created in order to mimic the sensorial properties of meat and meat products in [19]. The degree of resemblance between the sensorial properties (for example appearance, colour, aroma, texture and taste) of analogue products and those of meat and meat products plays an important role in consumers' acceptance [20].

The aim of this study was to conduct a comparison between the antioxidant and sensory properties of meat analogue products and those of conventional meat products, and to find which products can be declared advanceable in terms of these important properties, which are responsible for nutritional and shelf-life profiles as well as for consumer acceptance.

2. Materials and Methods

2.1. Samples

Different types of meat products (6 types: each was evaluated at least in triplicate) and their analogue products (6 types: each was evaluated at least in triplicate) were purchased from Czech grocery stores. The group of conventional meat products were: minced meat, burger, steak, Hungarian sausages, Frankfurter sausages and salami. The nutritional values and ingredients (from labelling) of the conventional meat products are shown in the Table 1. The group of meat analogue products represented analogues of minced meat, burger, steak, Hungarian sausages, Frankfurter sausages and salami. The nutritional values and ingredients of the analogue meat products are shown in Table 1. The sources and number of products that were used in the study as samples were as follows (1) Meat analogue products: minced meat analogue (n = 10); burger analogue (n = 10); steak analogue (n = 15); Hungarian sausage analogue (n = 15) (Hungarian klobaňa smoked classic—vegan); Frankfurter sausage analogue (n = 15) (soya frankfurtes classic); salami analogue (n = 10) (soy salami). (2) Conventional meat products: minced meat (n = 10) (ground beef lean); burger (n = 10) (beef burger); steak (n = 15) (pork steak); Hungarian sausages (n = 15) (Hungarian sausages Mives hot); Frankfurter sausage (n = 15) (pork sausages); salami (n = 10) (junior salami).

Table 1. The main composition (in g/100 g) of meat conventional products.

Types	Nutritional Values per 100 g					Ingredients
	Protein	Carbohydrates	Fat	Salt	Fibres	
Minced meat	18.2	0.15 including sugars 0.01	14.2 including saturated fatty acids 7.38	1.55		beef (94.5%), water, salt, stabilizer-sodium acetate
Minced meat (meat analogue product)	17.3	3.6 including sugars 1.0	7.9 including saturated fatty acids 2.9	1.0	5.0	soy protein (22.9%), vegetable oils (rapeseed, coconut), stabilizer (methylcellulose), natural aromas, fermented alcohol vinegar, garlic and onion powder, fruit and vegetable concentrates (beets, carrots, peppers, blackcurrants), malted barley extract, black pepper
Burger	20.0	0 including sugars 0	9.6 including saturated fatty acids 4.0	1.1		beef (99%), salt
Burger (meat analogue product)	17.3	2.8 including sugars 0.5	13.0 including saturated fatty acids 3.6	0.73	6.0	soy protein (19.9%), vegetable oils, rapeseed, coconut, fermented alcohol vinegar, aromas, stabilizer (E461–Methylcellulose), plant concentrates (apple, beet, carrot, hibiscus), malted barley extract
Steak						pork (20%), breadcrumbs, egg, flour, milk, salt, rapeseed oil, butter
Steak (meat analogue products)	16.0	16.0 including sugars 2.4	12.0 including saturated fatty acids 1.3	1.3	5.5	breadcrumbs (16.4%) (wheat flour, water, rapeseed oil, yeast, salt, spice extracts: sweet pepper, turmeric), vegetable oils in various proportions (rapeseed, sunflower), wheat protein (5.8%), soy protein (5.5%), dried egg proteins, mayonnaise (sunflower oil, fermented alcohol vinegar, dried egg yolks, mustard, iodized table salt: table salt, potassium iodate; sugar), corn starch, citrus fibre, fermented alcohol vinegar, dried yeast extract, wheat flour, spice mix (sweet pepper, cumin, chili pepper, oregano), onion powder, tomato concentrate, salt, garlic, garlic powder
Hungarian sausage	22.0	<0.5 including sugars <0.5	42.0 including saturated fatty acids 17.0	3.7		pork, lard, salt, spices, ground hot pepper (1.2%), sweet ground pepper (1.0%), spice extract, color (E160c), sugar, preservative (E250, E202), smoke; stuffed into edible pork intestine.
Hungarian sausage (meat analogue products)	9.6	12.48 including sugars 1.52	7.2 including saturated fatty acids 1.32	2.03		wheat, soy, ground barley, oatmeal, sunflower oil, garlic, ground pepper, salt, spices
Frankfurters sausage	13.2	2.2 including sugars 1.7	23.3 including saturated fatty acids 8.2	2.7		pork (83%), water, salt, glucose, stabilizers (diphosphates, sodium citrates), aromas, spices, spice extracts, antioxidant (sodium erythorbate), preservative (sodium nitrite)
Frankfurters sausage (meat analogue products)	18.0	4.9 including sugars 1.0	10 including saturated fatty acids 0.9	1.9	0.7	soya protein (10.86%), rapeseed oil, wheat protein (7.28%), modified starch (E1422), salt, aromas, thickener- carrageenan (E407), ground red pepper, colorant- iron oxides and hydroxides (E172), smoky aroma
Salami	10.7	5.2 including sugars <0.3	14.7 including saturated fatty acids 6.2	2.4	0.7	pork (28%), water, pork skin, beef (12%), lard, potato starch, salt, pork protein, stabilizers (E250, E450 and E451), modified starch (E1422), thickeners (E407a, E415 and E412), emulsifier (E471), antioxidants (E301 and E330), acidity regulators E500, vegetable fibre, flavour enhancers (E621 and E635), color (E120, E150c, E162), spices, garlic, spice extracts
Salami (meat analogue products)	17.0	5.1 including sugars 1.3	6.9 including saturated fatty acids 0.6	1.9	2.1	soy protein (9%), textured soy protein (7%), rapeseed oil, wheat protein (5%), modified corn starch, salt, thickeners: carrageenan and spices, powdered vinegar, barley sweet extract, color E172

2.2. Total Polyphenolic Content and Antioxidant Activity Assessment

2.2.1. Determination of Total Polyphenol Content

The extraction of the samples was conducted by homogenizing 0. 1 g of the sample in 20 mL of ethanol and water (1:1). The extraction was filtered after 30 min in ultrasound. The filtered extract (1 mL) was mixed with 1:10 Folin–Ciocalteu/water solution (5 mL) and Na_2CO_3 (75 g/L) (4 mal) and incubated in darkness for 30 min. Then the solution was measured on a spectrophotometer at 765 nm. The results were expressed in mg/g of gallic acid equivalent, as gallic acid was used to obtain the calibration curve [21]. The calibration curve of gallic acid ($r^2 > 0.99$) was used for the calculation of the results.

2.2.2. Determination of Antioxidant Capacity

DPPH (2,2-diphenyl-1-picryl-hydrazyl) methods

A homogenized sample (0.1 g) in 20 mL of ethanol and water 1:1 was added and homogenized (20 mL) and was ultrasonically extracted. The extract was filtered (3 mL) in parallel (blank: 3 mL of ethanol) and incubated with an ethanolic solution of 0.1 mM DPPH (1 mL) for 30 min in dark. Then both solutions (filtered extract and blank) were measured on a spectrophotometer at 517 nm; the results (absorbance) were expressed as the percentage of inhibition (discoloration degree) for free radical DPPH with a sample against the blank [22].

DPPH scavenging activity was calculated according to the following formula:

$$\text{DPPH}_{\text{scavenging activity}}\ [\%] = [(\text{Abs}_{\text{ DPPH}} - \text{Abs}_{\text{ sample}})/\text{Abs}_{\text{ DPPH}}] \times 100$$

CUPRAC (Cupric ion reducing antioxidant power)

The CUPRAC method was used to determine the antioxidant activity, and was conducted according to Apak et al., (2004) [23]. The sample was weighed out (0.1 g) into dark glass vials, then 20 mL of ethanol-water mixture (1:1) was added, and the samples were sonicated for 30 min and then filtered. The extract (1 mL) was mixed with the following amounts of chemicals: 1 mL of 0.01 M Copper (II), 1 mL of 0.0075 M Neocuproin, and 1 mL of NH_4Ac buffer pH = 7.0, 0.1 mL. The samples were then incubated in the dark for 1 h, and then the absorbance was measured against a blind sample at 450 nm. Trolox was used to prepare the calibration curve, and the results were expressed as µmol of Trolox per gram of sample.

FRAP (Ferric Reducing Antioxidant Power) method

The extraction of the samples was conducted by homogenizing 0. 1 g of the sample in 20 mL of ethanol and water (1:1). The extraction was filtered after 30 min in an ultrasound bath. The filtered extract (180 µL), with the addition of distilled water (300 µL) as well as 3.6 mL of working solution (acetate buffer + TPTZ + $FeCl_3 \times 6H_2O$ in a ratio of 10:1:1), was incubated in the dark for 8 min. The measurement of the absorbance was performed using spectrophotometer (CE7210, UK) at 593 nm. The results were expressed as the amount of Trolox (µmol) in 1 g of sample, because Torlox was used as standard [24]. The calibration curve of Trolox was carried out with a high Trolox regression ($r^2 > 0.99$).

ABTS (2,20-Azino-Bis(3-Ethylbenzothiazoline-6-Sulfonic Acid))

For the ABTS reaction, 0.1 g of the sample was weighed into dark vials, to which 20 mL of ethanol and water (1:1) was added and homogenized. The sample was extracted in an ultrasound water bath for 30 min and then filtrated. Then 10 mL of 0.007 M ABTS solution was mixed with 10 mL of 0.00245 M potassium persulphate solution, and the mixture was left to react (12–16 h before the measurement). This solution was diluted till its final absorbance was 0.7 at 735 nm. Then 1980 µL of ABTS reaction mixture was mixed with 20 µL of the prepared extract and left to react in the dark for 5 min. Then the absorbance was measured at 735 nm [25].

The results were calculated according to the following formula:

$$ABTS\ [\%] = [(Abs_{ABTS} - Abs_{\ sample})/Abs_{ABTS}] \times 100$$

2.2.3. Polyphenolic Profile

The HPLC 1260 Infinity (Agilent Technologies, Santa Clara, CA, USA) was used for the polyphenolic profile determination. The method by Gómez-Estaca et al. [26] was used, with some modifications. Thus, 1% phosphoric acid (A) and acetonitrile (B) were used as a mobile phase, as follows: 80% A and 20% B for 20 min, 70% A and 30% B for 20 to 25 min, 60% A and 40% B for 25 to 40 min. The separation was performed on Zorbax SB-C18 4.6 × 250 mm (Agilent Technologies, Santa Clara, CA, USA). The flow rate was 1 mL/min, the injection volume was 10 µL and the DAD setting was 324.5 nm. Each sample was analyzed in triplicate.

2.3. Sensory Analysis

The applied conditions for the sensory analysis consisted of the following: a total of 10 panellists participated in the session (9 female and 1 male panellists aged 19–70 years old, possessing the necessary knowledge and education concerning sensory analysis). The panellists were trained before the evaluation process. The procedure for the selection of the panellists was based on their previous education, expertise with the sensory analysis and willingness to cooperate in this study (to simulate a regular consumer frame of mind). However, they were not acquainted with any details prior to the analysis. All the samples were administered anonymously, marked with random three-digit numbers and served on sensor-neutral dishes. The samples were heated, if necessary (in accordance with the product labelling). The panel conducted the hedonic sensory analysis in a panel room established according to ISO 8589, and each panellist undertook the sensory analysis in a single tasting booth. The panellists evaluated samples using a non-structured 100-mm hedonic scale with well-defined anchor points, from 0 (not perceivable) on the one side to 100 (perceivable at the level of saturation) on the other side, for the quantitative descriptive sensory analysis and hedonic sensory testing. Samples of minced meat, burger, steak, Frankfurter sausage, and their analogues were evaluated separately before and after the heat treatment. The samples of salami, Hungarian sausages, and their analogues were evaluated at room temperature only. It was necessary to wash the mouth using water prior to starting of the evaluation and then to use a piece of bright pastry to ensure the mouth was clean after the previous bite. Every single sample was evaluated on a separate protocol. The panellist received samples and found perceivable product attributes through the identification of several descriptors (texture, product similarity, overall appearance, overall impression, interest in the product, preferences, cut appearance, aroma, animal character, taste and meat taste).

2.4. Statistical Analysis

Statistical analysis of data was performed using Microsoft Office Excel 2016 (Redmond, WA, USA). Student's *t*-test was used for determination of differences between samples. The 0.05 level of significance was used.

3. Results and Discussion

3.1. Total Polyphenolic Content and Antioxidant Activity Assessment

The results of the polyphenol and antioxidant capacity analysis are shown in Table 2. Polyphenol content in all types of meat analogue products were significantly ($p < 0.05$) higher than in conventional meat products. Generally, most antioxidant capacity values of the meat analogue products were significantly ($p < 0.05$) higher than those of the conventional meat products. The reason for the obtained results was the ingredients used in the preparation. The soybeans used in the production of meat alternative products are a good source of phenolic compounds with high antioxidant properties [17]. However, soy protein contains lower quantities of many amino acids (especially methionine and lysine) in comparison with animal products [27,28]. Soy protein isolates are a better option for addition to meat analogues, since unprocessed or minimally processed soy protein has the ability to darken meat analogue products and to elicit a bitter flavour [29]. The inclusion of cereal ingredients in meat analogues leads to lower protein content and higher carbohydrate content; furthermore, the digestibility of cereal proteins is lower [30].

Table 2. Total polyphenol content and antioxidant capacity (DPPH, CUPRAC, FRAP, ABTS).

Sample Types	Polyphenols mg Gallic acid/g	DPPH (%)	CUPRAC Trolox mmol/kg	FRAP mmol/g	ABTS (%)
minced meat analogue	1.24 ± 0.01 [a]	10.40 ± 0.34 [a]	8.17 ± 0.39 [a]	7.42 ± 0.38 [a]	6.28 ± 0.16 [a]
minced meat	0.69 ± 0.01 [b]	7.50 ± 0.66 [b]	1.71 ± 0.27 [b]	3.79 ± 0.06 [b]	2.10 ± 0.21 [b]
burger analogue	0.83 ± 0.01 [a]	15.07 ± 1.81 [a]	7.07 ± 0.17 [a]	4.21 ± 0.1[5]	6.53 ± 0.26
burger	0.46 ± 0.01 [b]	3.74 ± 3.28 [b]	1.44 ± 0.08 [b]	0.00 ± 0.00	6.39 ± 0.28
steak analogue	1.33 ± 0.04 [a]	0.00 ± 0.00	7.37 ± 0.88 [a]	5.59 ± 0.05 [a]	6.61 ± 0.52 [a]
steak	0.87 ± 0.03 [b]	0.88 ± 0.52	5.11 ± 0.21 [b]	4.30 ± 0.14 [b]	4.93 ± 0.38 [b]
Hungarian sausage analogue	1.85 ± 0.05 [a]	41.80 ± 0.45 [a]	9.21 ± 0.23 [a]	7.51 ± 0.40 [a]	7.45 ± 0.43 [a]
Hungarian sausage	1.27 ± 0.11 [b]	36.40 ± 4.19 [b]	6.05 ± 0.46 [b]	4.82 ± 0.18 [b]	3.59 ± 0.12 [b]
Frankfurter sausage analogue	1.48 ± 0.02 [a]	21.17 ± 1.85 [a]	6.11 ± 0.36 [a]	5.37 ± 0.22 [a]	5.30 ± 0.21 [a]
Frankfurter sausage	0.81 ± 0.10 [b]	17.20 ± 3.61 [b]	2.62 ± 0.11 [b]	3.62 ± 0.08 [b]	4.96 ± 0.11 [b]
salami analogue	1.15 ± 0.06 [a]	29.71 ± 1.96 [a]	5.65 ± 0.32 [a]	6.03 ± 0.03 [a]	5.61 ± 0.31 [a]
salami	0.58 ± 0.06 [b]	1.09 ± 1.94 [b]	2.30 ± 0.12 [b]	3.46 ± 0.04 [b]	4.16 ± 0.25 [b]

Values with different letters [a, b] between each product and it alternative are significantly different ($p < 0.05$).

Plant-origin antioxidant compounds are a chemically heterogeneous group. Polyphenols (flavonols and anthocyanins) and essential oils (particularly terpenoids) are most often used as product ingredients in the meat industry [13,14]. There is a tendency to incorporate phenolic compounds in food formulation due to their antioxidant properties and their beneficial effects against age-related diseases [31]. Polyphenols with strong antioxidant power found in soybeans include the following compounds: isoflavones, lignans, phenolic acids, anthocyanins, tannins and stilbenes. The external layers of soybeans contain these components with a wide variability, depending on their cultivars and processing [32]. Soy is the main source of saponins, representing anti-nutritional properties. The antioxidant capacity of saponins is far greater than that of superoxide dismutase. Isoflavones and saponins are not found in the aglycone form naturally, but can be obtained after the processing of soy foods [33]. The polyphenols and antioxidant capacity (values of DPPH, CUPRAC, FRAP and ABTS) of the Hungarian sausage analogue were the highest in comparison with other meat analogues and conventional meat products. This can be attributed to the content of oat. Oat is an abundant source of compounds with antioxidant properties, such as avenanthramides, phenolic compounds, phytic acid and vitamin E (tocols), as flavonoids and sterols. The concentrations of these antioxidant compounds are often in the outer layers of the kernel. The stability of processed oat products is dependent on the function of antioxidants in maintaining the stability of the oil in the product: oxidative–hydrolytic changes result in rancidity [34]. According to Dimberg et al. [35] the antioxidant activity of avenanthramides is 10–30 times greater than other phenolic antioxidant compounds such as vanillin and caffeic acid, explaining the reason for the higher antioxidant activity in the Hungarian sausage analogue than in the other meat analogue products in our study.

The methods used for measuring antioxidant activity have different mechanisms of reaction. The FRAP method is performed in a low pH value (pH = 3.6) and indicates new formed ferrous ions; the ABTS method is based on oxidation of ABTS to form radical cation $ABTS^{\bullet +}$ [36]; and the CUPRAC method measures antioxidant activity in physiological pH (pH = 7) [37].

Previous studies have indicated that meat analogues can provide nutrients and can simulate "real" meat products' nutrient specifications, but meat analogue products also provide many different ingredients that can also lead to higher antioxidant activity due to the presence of bioactive compounds. It should be emphasized that meat analogue products are defined as ultra-processed food [29].

The differences between the meat products and meat analogue products included in the experiment, were clearly shown in the polyphenolic profiles analysis (Figures 1–6); all the vegetarian products showed a higher presence of polyphenolic compounds, with the chromatograms representing the meat analogue products showing more chromatographic peaks (Figures 1–6).

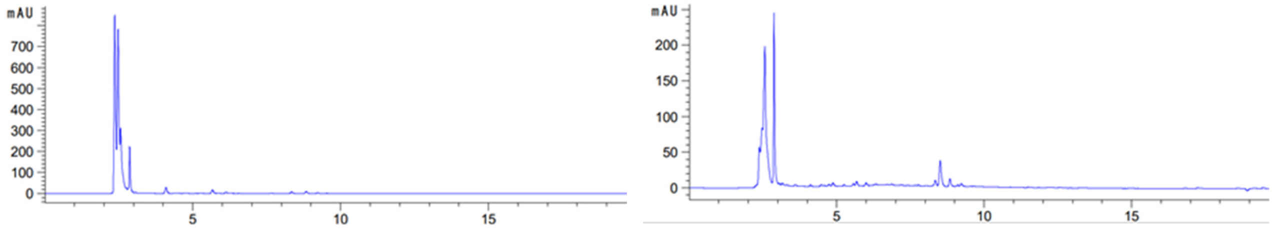

Figure 1. Polyphenolic profiles of minced meat product (**left**) and minced vegetarian product (meat analogue products) (**right**).

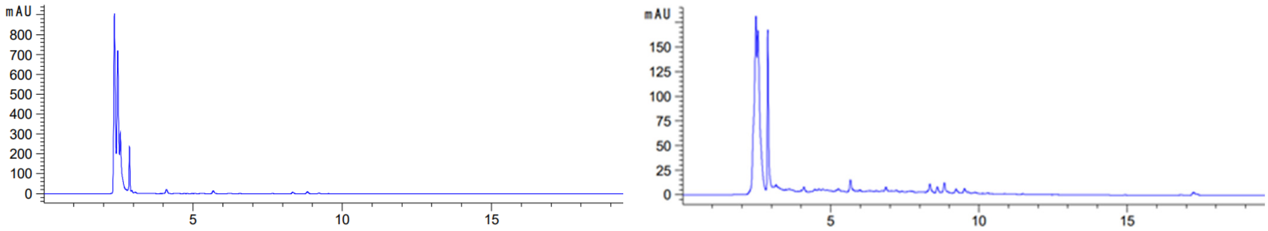

Figure 2. Polyphenolic profiles of burger meat product (**left**) and burger vegetarian product (**right**).

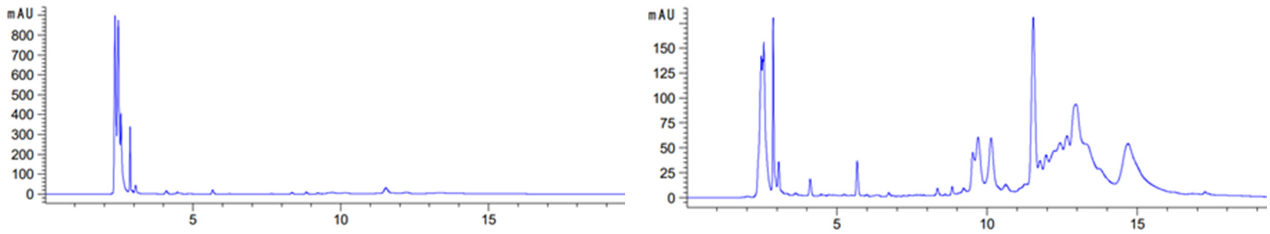

Figure 3. Polyphenolic profiles of steak meat product (**left**) and steak vegetarian product (**right**).

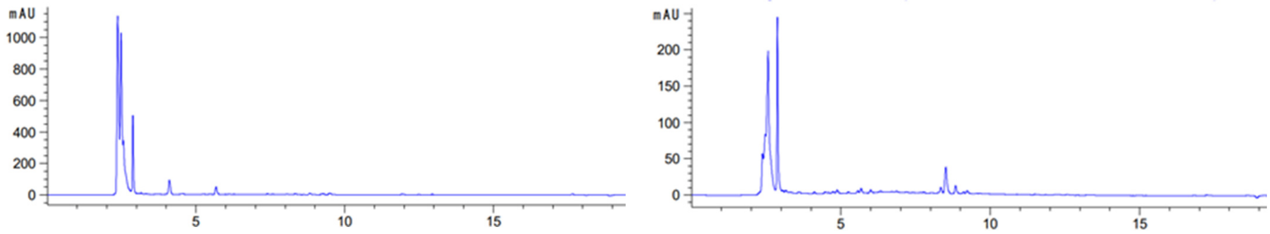

Figure 4. Polyphenolic profiles of Hungarian sausage meat product (**left**) and Hungarian sausage vegetarian product (**right**).

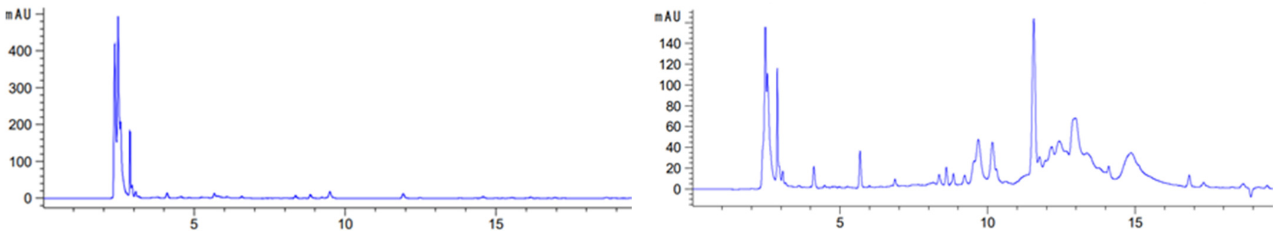

Figure 5. Polyphenolic profiles of Frankfurter sausage meat product (**left**) and Frankfurter sausage vegetarian product (**right**).

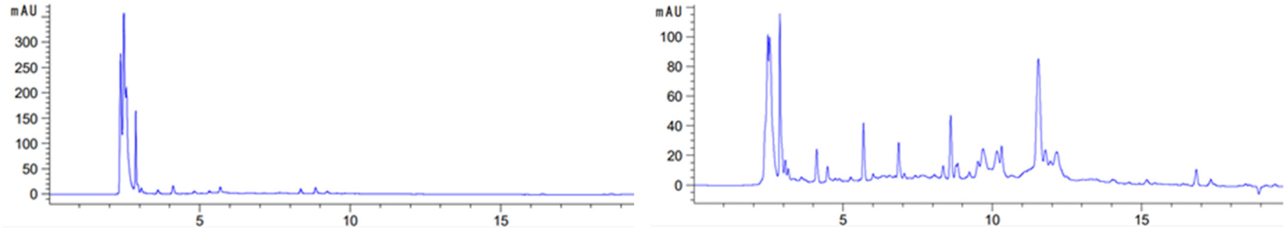

Figure 6. Sm salami meat (**left**); Sv salami vegetarian (**right**).

Polyphenolic profiles determined by high pressure liquid chromatography technique are given in Figures 1–6.

Vegetable oils are used in analogue meat as a replacement for animal fat. Proteins and fats of meat analogues undergo intensive processing; therefore, antioxidants are added in order to prevent fat rancidity and protein oxidation [38,39]. Several spices and aromatic plants are used in the production of meat and meat analogues to improve their antioxidant activity (as well as flavour and antimicrobial) properties. The most common such spices and aromatic plants are oregano, parsley, rosemary, dill, basil, marjoram, sage, coriander, thyme, tarragon, bay, and mint [40].

3.2. Sensory Analysis

Results of the sensory analysis are shown in Tables 3 and 4. There was no significant difference between the meat products and their analogue products ($p > 0.05$). This result includes the mutual visual inseparability of the meats and their analogue products. For all meat products and their analogues, there were no significant differences in the texture ($p > 0.05$), except for the Hungarian sausage and its analogue ($p < 0.05$). Generally, meat analogues should resemble meat products in their textural properties in order to be accepted by consumers [41]. Meat analogues are designed to match the organoleptic properties (such as the color, texture, flavour, and sensation in the mouth) of real meat as far as possible in order to constitute desirable and acceptable products for consumers [42].

Table 3. Sensorial attributes of minced meat, burger, steak and their analogue products.

Parameters	Minced Meat	Minced Meat Analogue	Burger	Burger Analogue	Steak	Steak Analogue
Texture	77.5 ± 34.3	76.6 ± 34.2	94 ± 8	75.5 ± 35.5	77.4 ± 19.6	87.4 ± 24
Product similarity	21.6 ± 22	21.1 ± 20.3	27.4 ± 23.7	27.9 ± 24.4	90.9 ± 14.5	85.7 ± 24
Overall appearance	41.8 ± 32.9^{a}	73.3 ± 28.5^{b}	78.2 ± 26.4	76.7 ± 24	85.1 ± 16.2	72.8 ± 26
Overall impression	45.4 ± 23.8	62.5 ± 28	67.2 ± 27.3	61 ± 25.5	79.4 ± 19.5	67.9 ± 33.2
Interest in the product	44.5 ± 32	51.2 ± 23.6	53.2 ± 31.8	47.6 ± 34.4	23.3 ± 24.7	23.2 ± 23.7
Preferences (%)	40	60	90	10	50	50
Cut appearance	-	-	75.2 ± 26.3	62.6 ± 33	82.4 ± 17.6	81 ± 19.7
Aroma	$64.1 \pm 27.8^{*}$	$62 \pm 34.4^{*}$	$75.9 \pm 18.6^{*}$	$53.7 \pm 37.1^{*}$	$94.4 \pm 14.4^{a*}$	$68.5 \pm 29.6^{b*}$
Animal character	$75.2 \pm 33^{a*}$	$25 \pm 34.2^{b*}$	$82.7 \pm 28^{a*}$	$38.5 \pm 37.3^{b*}$	$99.2 \pm 2.2^{a*}$	$23.4 \pm 35.2^{b*}$
Taste	$65 \pm 31.2^{*}$	$53.4 \pm 36.9^{*}$	$70.8 \pm 24.2^{*}$	$50.8 \pm 31.5^{*}$	$95.4 \pm 12.2^{*}$	$74 \pm 34.6^{*}$
Meat taste	$70.6 \pm 28.4^{*}$	$43.1 \pm 36.7^{*}$	$80.6 \pm 18.8^{a*}$	$47.3 \pm 35.6^{b*}$	$94.4 \pm 11.2^{a*}$	$29.2 \pm 34.1^{b*}$

Values with different letters $^{a,\,b}$ between each product and it alternative are significantly different ($p < 0.05$), values with symbol * are belong the parameters that evaluated after heat treatment).

Table 4. Sensorial attributes of Hungarian sausage, Frankfurters sausage, salami and their analogues products.

Parameters	Hungarian Sausage	Hungarian Sausage Analogue	Frankfurter Sausage	Frankfurter Sausage Analogue	Salami	Salami Analogue
Texture	96 ± 5.7 [a]	58.6 ± 31.9 [b]	86 ± 19.3	67.6 ± 30.2	79.4 ± 26.9	72.1 ± 31.4
Product similarity	15 ± 18.6	13.4 ± 18	30.4 ± 25.3	31.6 ± 27.7	36.8 ± 19	36.7 ± 16.6
Overall appearance	95.3 ± 9.3	79.5 ± 26.3	96.7 ± 6.4	85.8 ± 19.2	63.5 ± 16.8 [a]	39 ± 23.5 [b]
Overall impression	92 ± 10.3 [a]	55.3 ± 23.9 [b]	74.7 ± 22.6	56.2 ± 23.7	74.3 ± 17.9 [a]	52 ± 20.5 [b]
Interest in the product	83.7 ± 21.2 [a]	23.6 ± 22.3 [b]	64 ± 21	49.6 ± 22.2	54.6 ± 29.5 [a]	20.9 ± 21.8 [b]
Preferences (%)	100	0	75	25	100	0
Cut appearance	93.3 ± 10.9 [a]	52.7 ± 37.6 [b]	84.4 ± 19.3	86.3 ± 20.3	86.5 ± 16.3 [a]	40.5 ± 23 [b]
Aroma	89.2 ± 19.7 [a]	48.2 ± 31.5 [b]	89.4 ± 23.3 [a*]	39.1 ± 31.8 [b*]	90.4 ± 15.2 [a]	52.5 ± 35.1 [b]
Animal character	97.2 ± 5.4 [a]	13.4 ± 31.6 [b]	93.2 ± 17.2 [a*]	7.2 ± 10.2 [b*]	91 ± 13 [a]	12.2 ± 21.5 [b]
Taste	94.1 ± 15.2 [a]	43 ± 29.4 [b]	89 ± 18.4 [a*]	25.5 ± 28.6 [b*]	78.1 ± 21.3 [a]	39.8 ± 29.1 [b]
Meat taste	91.3 ± 13.3 [a]	16.1 ± 20 [b]	79.6 ± 18 [a*]	14.9 ± 18.4 [b*]	69.8 ± 15.2 [a]	26.7 ± 24.3 [b]

Values with different letters [a, b] between each product and it alternative are significantly different ($p < 0.05$), values with symbol * are belong the parameters that evaluated after heat treatment).

According to the conducted sensory analysis, meat products were preferred more than their analogues in almost all cases in the study. The only exceptions were the steak and steak analogue, where both products got the same evaluation (50% and 50%) and minced meat with its analogue, where panellists preferred the analogue (40% and 60%, respectively). This choice was made without the specification regarding which product was a meat product. However, it is already known that many consumers who know this information prefer meat products rather than their analogues. Their decisions are sometimes based on their awareness about the environment and animal well-being [43]. The aroma parameter differed ($p < 0.05$) between all selected types of meat products and their alternatives. It should be emphasized that the simulation of a meat aroma is very complicated [44]. Some plant-based burgers contain plant-based heme to simulate a meaty flavour and appearance [43]. The aroma is often given by spices used in the product recipe. The applied spices affect the final product aroma [45]. Panellists did not recognize differences ($p > 0.05$) in the taste parameter of meat products and their analogues for minced meat, burger and steak. On the other hand, they noted the difference ($p < 0.05$) in the taste parameter for Hungarian sausages, Frankfurter sausages, salami and their analogues. For the descriptor of animal character, describing the sense that the product tastes like a meat product, differences ($p < 0.05$) were observed for all products and their analogues. This could be related to the fact that soy proteins are the main protein source in meat analogues [46].

Based on the main EU market for new protein products, female (in our research, panellists were mainly females) consumers were selected from Denmark, Finland, Germany, Iceland, and Romania. The selected meat analogue was presented to them as a soy, potato starch and gluten free product. The main plant protein in the product was the rapeseed protein. All the female assessors believed that the use of plant proteins to substitute meat was useful and morally acceptable. Based on this, the authors confirmed positive female consumer attitudes to plant-based proteins. They confirmed that consumer attitudes toward meat analogues depends on the plant protein source [47]. On the other hand, attitude also depends on the consumer's lifestyle. For example, vegetarians and flexitarians tend to favour the idea of plant-based dishes rather than omnivores [48].

Godschalk-Broers et al., (2022) [49] investigated several types of chicken pieces and burgers and their analogues in their study. Of all the products, the meat products were preferred to the meat analogues by the panellists. Conversely, Ettinger et al., (2022) [50] found plant-based meat analogues to be significantly different ($p < 0.05$) than the real meat products in the following terms: flavour, texture, and overall liking.

4. Conclusions

The producers of meat analogue products try to develop these products to have high similarity levels with conventional meat products, since they present them as alternatives to conventional meat products. Such mimicry is focused not only on their physical and sensory properties, but also on their nutritional and chemical properties. This study attempted to explain for the consumer the differences in antioxidant capacity levels between selected types of conventional meat products and their alternative products (meat analogues), available in retail markets. The results of the study indicated that total polyphenol content and antioxidant properties of the meat analogue products were higher in comparison with the conventional meat products, leading to the conclusion that antioxidant properties of products from plant sources were superior to products from animal sources.

Certainly, the nutritional profiles of food commodities are important for consumers, but they should be supported by acceptable sensory properties. A food commodity without acceptable sensory properties would not be purchased by consumers in high quantities. The analyzed samples did not present obvious differences from a sensory point of view.

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