processes

MDPI

Article

Tomato Pomace Powder as a Functional Ingredient in Minced Meat Products—Influence on Technological and Sensory Properties of Traditional Serbian Minced Meat Product Ćevapi

Slaviša Stajić [1,*], Patrycja Skwarek [2], Sanja Đurđević [1], Małgorzata Karwowska [2,*], Boris Pisinov [3], Igor Tomasevic [1,4] and Vladimir Kurćubić [5]

1 Department of Animal Source Food Technology, Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11080 Belgrade, Serbia; sanja.djurdjevic@agrif.bg.ac.rs (S.Đ.); tbigor@agrif.bg.ac.rs (I.T.)
2 Department of Animal Food Technology, Sub-Department of Meat Technology and Food Quality, University of Life Sciences in Lublin, Skromna 8, 20-704 Lublin, Poland; patrycja.skwarek@up.lublin.pl
3 Department of Phytopharmacy and Environmental Protection, Institute for Plant Protection and Enviroment, 11000 Belgrade, Serbia; boriss752002@yahoo.com
4 DIL German Institute of Food Technology, Prof.-von-Klitzing-Str. 7, D-49610 Quakenbrück, Germany
5 Department of Food Technology, Faculty of Agronomy, University of Kragujevac, Cara Dušana 34, 32000 Čačak, Serbia; vkurcubic@kg.ac.rs
* Correspondence: stajic@agrif.bg.ac.rs (S.S.); malgorzata.karwowska@up.lublin.pl (M.K.)

Abstract: The aim of this research is to evaluate the impact of tomato pomace (TP) on the technological and sensory properties of ćevapi. Four treatments were prepared as follows: control (CON) and samples with the addition of TP in amounts of TP5 (0.5%—5 g/kg), TP10 (1%—10 g/kg), and TP20 (2%—20 g/kg). Technological properties (pH values, water activity (aw) cooking loss, length reduction), instrumental colour and texture, and sensory properties were examined. The addition of TP powder did not result in significant differences in pH and aw values between CON and modified treatments (in both raw and grilled). The addition of TP in the amounts higher than 10 g/kg significantly reduced cooking loss, while length reduction was observed when 20 g/kg was added. Also, significantly higher values of yellowness were observed in both the raw and grilled ćevapi, when 10 g/kg and more of TP was added. Significantly higher hardness and chewiness were observed in all experimental treatments. However, differences in instrumental colour and texture were not negatively perceived by the assessors, and there were no significant differences in any observed sensory properties between the CON and experimental treatments. Moreover, all the experimental treatments received a relatively high mark of around seven and higher on a nine-point hedonic scale. Further research could focus on the examination of salt/meat reduction as well as oxidative stability during freeze storage.

Keywords: minced meat product; ćevapi; tomato pomace; instrumental colour; instrumental texture; sensory quality

check for updates

Citation: Stajić, S.; Skwarek, P.; Đurđević, S.; Karwowska, M.; Pisinov, B.; Tomasevic, I.; Kurćubić, V. Tomato Pomace Powder as a Functional Ingredient in Minced Meat Products—Influence on Technological and Sensory Properties of Traditional Serbian Minced Meat Product Ćevapi. *Processes* **2024**, *12*, 1330. https://doi.org/10.3390/pr12071330

Academic Editor: Elzbieta Klewicka

Received: 28 May 2024
Revised: 14 June 2024
Accepted: 21 June 2024
Published: 27 June 2024

1. Introduction

The collection, treatment, and disposal of waste is a major problem faced by the food industry. For this reason, there is an increasing number of proposals for the recovery of food waste around the world, with the growing demand for its transformation into useful by-products that are conducive to environmental sustainability [1]. In this context, a new type of food is being developed, called upcycled foods, that contain unmarketable ingredients including the by-products and scraps from food preparation [2,3]. Tomato processing by-products are particularly rich in bioactive ingredients and are usually called tomato pomace (TP), which consists mainly of skins and seeds with a small amount of pulp [4]. The chemical composition of the skins and seeds is clearly different. The peel is rich in dietary fibre, lycopene, and phenols, while the seeds are mainly composed of oil and protein. Tomato skins also have a low sodium-to-potassium ratio (Na/K), which makes this product a potential factor in the treatment of cardiovascular diseases [5]. The fat content in tomato seeds can be up to 24% [6], and fat is characterized by a high proportion of unsaturated fatty acids (about 80%) [7]. The protein content in tomato seeds could be up to 40%, while amino acid composition shows that tomato seed protein represents an important source of the essential amino acids, lysine, valine, leucine, and threonine [6]. The research performed by Bianchi et al. [8] also confirmed that peels and seeds are the richest in the bioactive compounds (lycopene and phenols) that are beneficial for human health, which show antioxidant activity and prevent oxidative stress. Among the nutritionally valuable components of tomato, lycopene is also worth mentioning, as it is the strongest antioxidant among carotenoids, and it also reduces the risk of cardiovascular diseases, cancer, and diabetes. Depending on the variety and harvest time, the content of lycopene in fresh tomato pomace ranges from 16.11 to 25.45 mg/100 g [9].

Freeze-dried tomato pomace as a by-product of tomato processing can be used as an additive to animal feed, but also as human food, and thus it is an innovative addition to minced meat products [10]. Due to its high content of different bioactive compounds, TP has been used in different forms (e.g., freeze-dried, extract) in nitrite-reduced dry-fermented sausages [11] and emulsion-type sausages [12]. Moreover, due to its high content of dietary fibres, TP can be potentially used in meat products where fibres are used as phosphate or/and salt replacements [13,14], since dietary fibres exhibit a water-binding capacity, oil-binding capacity, and gel-forming ability [15].

Minced meat products (burgers, patties, fresh sausages) are prepared without nitrites and usually without phosphates (not allowed by some national regulations). Salt is mainly responsible for the extraction and activation of myofibrillar proteins, and the improvement in the water-holding capacity (WHC), thereby defining the flavour and shelf-life [16]. These meat products are intended for heat treatment (e.g., grill, barbecue) before consumption, therefore it is highly important to maintain their shape during heat treatment as well as to ensure the formation of their characteristic texture, colour, and aroma.

Grilled minced meats are one of the most popular types of food all over the world and a hallmark of the fast-food industry. This category of products includes the Serbian traditional minced meat product, ćevapi (pronounced [tɕeʋǎ:pi]), which is prepared with various meats and shaped into cylindrical shapes usually around 2 cm in diameter and 6–8 cm in length. It is often served with a special type of bread (somun), chopped fresh onions, and various (types of) salads. It is a meat product highly appreciated by consumers due to its sensory and nutritional values.

Due to the popularity of these products, attention to their nutritional value seems fully justified. One of the ways to improve the nutritional value of meat products is to enrich them with bioactive compounds [17], which are present in significant amounts in the by-products of fruit and vegetable processing [18]. In this context, the use of tomato pomace in local meat products from Serbia seems to be an innovative and interesting solution.

As far as the authors are aware, the scholarly literature data about TP use in minced meat products are very difficult to find. Because of the presence of different bioactive ingredients in TP (dietary fibres, lycopene, etc.) and because of the popularity of ćevapi in Serbia and the Balkans region as well, the aim of this research is to evaluate the impact of TP on the technological and sensory properties of traditional Serbian minced meat product, ćevapi.

2. Materials and Methods

2.1. Tomato Pomace Preparation and Analysis

The tomato pomace powder was prepared in the same manner as described by Skwarek and Karwowska [11]. The procedures and methods for determination of the DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging activity, ABTS*+ (2-Azino-bis-3-ethylbenzothiazoline-6-sulfonic acid) radical scavenging activity, and the amount of total phenolic compounds (TPC) were the same as described by Skwarek and Karwowska [11]. The contents of the following compounds of tomato pomace were determined: moisture by AOAC 934.06:1996 [19], protein by ISO 1871:2009 (multiplying factor: 5.84) [20], total fat by NMKL Method No. 160:1998 [21], ash by NMKL Method No. 173:2005 [22], total dietary fibre content by AOAC 985.29:1986 [23], and the content of available carbohydrates by Gafta Method 10.1:2018 [24]. The content of total carbohydrates was calculated by difference, subtracting the sum of the constituent's contents from the total solids by AOAC 986.25:1988 [25].

2.2. Ćevapi Preparation and Analysis

Four treatments of ćevapi were prepared in the same manner. The control treatment (CON) was prepared from beef (34%), pork (34%), backfat (18%), water (11.5%), salt (1.5%), sodium bicarbonate (0.5%), and dextrose (0.5%). Experimental treatments were prepared as CON with the addition of different amounts of TP powder, including TP5 (0.5%—5 g/kg), TP10 (1%—10 g/kg), and TP20 (2%—20 g/kg). In order to obtain the tomato pomace powder, dried TP was ground in a coffee grinder Bosch KM-13 (Robert Bosch GmbH, Munich, Germany).

The beef, pork (shoulder muscles), and backfat were bought at a local store, trimmed of the visible fat and connective tissue, and cut into small pieces (beef: moisture 73.97 ± 0.48%, fat 4.84 ± 0.62%, protein 20.06 ± 0.88%; pork: moisture 74.87 ± 0.47%, fat 5.59 ± 0.45%, protein 18.35 ± 0.45%. Then, the meat and backfat were weighed, mixed by hand with other ingredients (including TP for modified treatments) and ground in batches (separately) through an 8 mm plate (82H, Laska, Traun, Austria), then covered with foil and kept refrigerated for 24 h. After that, all the treatments were ground once again (separately) through a 4.5 mm plate and formed into cylindrical shapes about 6–8 cm in length and 2 cm in diameter. The average weight of raw ćevapi was 27.7 ± 1.9 g (n = 48). After shaping, the ćevapi were grilled on an electric grill IEG-820 (Guangzhou Ideal Catering Equipment Co., Ltd., Guangzhou, China) at 250 °C until an internal temperature of 75 °C was reached. Then, they were cooled at room temperature, covered with foil, and kept refrigerated for 24 h before analysis. Batches of all the treatments weighed approximately 1 kg, and the experiment was conducted in two replications on different days.

2.3. Determination of Technological Properties

Twelve ćevapi were used for pH measurements, before and after grilling (and cooling to room temperature), with pH meter Testo 206 pH2 (Testo, Lenzkirich, Germany) equipped with a penetration probe, and calibrated before then measurements with standard buffer solutions at pH4 and pH7.

Water activity (a_w) was determined on the raw ćevapi samples (n = 6) using an aw meter LabSwift-aw (Novasina, Lachen, Switzerland).

Cooking loss (CL) was determined by measuring 10 individual ćevapi before grilling and after grilling (and cooling to room temperature), and it represented the mass difference (in %) between these measurements.

Length reduction (dL) was calculated as a difference in length (%) of 10 ćevapi, measured by a digital nonius (with a 0.01 mm precision ratio), before grilling and after grilling (and cooling to room temperature).

2.4. Instrumental Colour and Texture Analysis

Instrumental colour measurements were carried out before and after grilling (and cooling to room temperature). The colour was measured using the computer vision system (CVS), with the equipment and under conditions as described by Tomasevic et al. [26]. RAW photographs were taken from each individual raw (n = 12) and grilled (n = 12) ćevapi sample. Three readings (5 × 5 pixels measuring area) were taken from each product's RAW photograph, from the meat parts (without fat parts), using a Photoshop Average Colour Sampler Tool. The average values of these measurements were calculated and used as one iteration for statistical analysis. C* (chroma) and h (hue angle) were calculated using the standard Equations (1) and (2) as follows:

$$C^* = [(a^*)2 + (b^*)2]^{1/2} \quad (1)$$

$$h = \arctan b^*/a^* \quad (2)$$

Total colour difference (ΔE*) represents the quantification of the overall difference between two colours, e.g., modified treatments vs. CON. ΔE* will be calculated using the standard equation Equation (3) as follows:

$$\Delta E^* = \sqrt{\left(L^*_{TP} - L^*_{CON}\right)^2 + \left(a^*_{TP} - a^*_{CON}\right)^2 + \left(b^*_{TP} - b^*_{CON}\right)^2} \quad (3)$$

TP—ćevapi with tomato pomace; CON—control.

To perform texture profile analysis, we used the universal texture analyser (TA.XT Plus; Stable Micro System, Ltd., Godalming, UK). Five grilled ćevapi from each treatment were held for equilibration to room temperature. From the centre of each individual ćevapi, we took two samples (dimensions: 10 mm in height and 12 mm in radius) and compressed them twice to half their original height. This was achieved using a compression aluminium plate of 25 mm (P/25) and a 50 kg load cell. The pretest speed was 60 mm/min, test speed was 60 mm/min, and post-test speed was 300 mm/min. We evaluated the hardness, adhesiveness, springiness, cohesiveness, and chewiness using the available computer software (Exponent software (version 6.2), Stable Micro Systems, Godalming, UK).

2.5. Sensory Analysis

Quantitative Descriptive Analysis (QDA) was performed using "The Smart Sensory Solutions Software" software (Sassari, Italy), version 2024. A total of 20 untrained assessors (aged 21–60, 35% male, 65% female) participated in the sensory analysis and were selected on the grounds of regular (at least twice per month) consumption of ćevapi (and similar meat products). The assessors were students (aged 21–30—70%) and staff members (aged 31–60—30%) from the Faculty of Aquiculture, University of Belgrade. Prior to the sensory evaluations, the samples (about 3 cm in length) were coded with a randomly selected three-digit number, heated in a microwave (for 20 s at 650 W, about 50 °C in the centre), and served in broad daylight, randomly. The assessors evaluated the appearance, surface colour, hardness, juiciness, odour, taste, saltiness, and overall acceptability using a nine-point hedonic scale (1—extremely unacceptable, 5—neither like nor dislike, 9—extremely acceptable). The assessors used water (at room temperature) to cleanse their palate between samples. The sensory evaluations were performed in two time-separated assessments (replicates). Instructions for evaluation were briefly presented before each assessment.

2.6. Statistical Analysis

Statistical data processing and analysis were performed using the IBM SPSS (Statistical Package of Social Science) software version 17. A one-way analysis of variance (ANOVA) and Tukey's post hoc test were used in the work to examine the difference between groups. A level of 0.05 was used for the threshold value of significance. Results are presented as mean ± standard deviation (SD).

3. Results and Discussion

3.1. Tomato Pomace Powder Analysis

As mentioned in the Introduction section, tomato pomace is a by-product obtained during tomato processing that contains different bioactive components such as dietary fibre, lycopene, phenols, oil, and proteins. The results of the chemical composition and antioxidative properties of tomato pomace used in this research are presented in Table 1. The chemical composition of TP differs depending on the applied technological production process of the tomato paste [7]. Fibre is the major component of tomato pomace [6,27] and, according to Lu et al. [6], it can be contained in a 39–68% range (on a dry weight basis). Protein and fat originate from tomato seeds and their content can be 15.1–24.7% and 2.0–16.2%, respectively [6]. The contents of protein, fat, and sugars in TP used in this research are lower than the stated literature data. However, Del Valle et al. [27] reported that the protein content can be lower than 15% and fat content lower than 1%, depending on the step of tomato processing in which the TP was obtained. The ash content was higher than the literature data (2.9–5.3%, Lu et al. [6]). The antioxidant activity of TP was higher in case of the ABTS radical compared to DPPH.

Table 1. Chemical composition and antioxidative properties of tomato pomace (TP) (mean ± standard deviation).

Properties	Freeze-Dried TP
DPPH [mg Trolox eqv./g]	0.033 ± 0.000
ABTS [mg Trolox eqv./g]	0.062 ± 0.001
TPC [mg gallic acid eqv./g]	4.08 ± 0.167
Moisture [g/100 g]	7.52 ± 0.12
Protein [g/100 g]	8.86 ± 0.76
Total fat [g/100 g]	0.91 ± 0.14
Ash [g/100 g]	6.77 ± 0.12
Available carbohydrates [g/100 g]	13.39 ± 0.03
Total carbohydrates [g/100 g]	75.95 ± 0.58
Total dietary fibre [g/100 g]	62.71 ± 0.65

3.2. Technological Properties

The pH values of the raw and grilled ćevapi had the same pattern (Table 2). No significant differences were found between CON and the modified treatments. However, significantly higher values were observed in the treatment with the lowest TP amount (TP5) compared to the one with the highest TP amount (TP20). These pH values are somewhat higher compared to the literature data for burgers and patties (usually in a 5.5–6 range). However, this was not unexpected considering the similar meat products in Serbia, where it is common to use sodium bicarbonate (use of phosphates is not allowed by national regulations) and then leave the salted and ground meat to rest for 24 h to 48 h, as this increases pH value and contributes to the extraction and activation of myofibrillar proteins and WHC. Djekic et al. [28] reported pH values of close to 7 for the ćevapi made of game meat and with the use of sodium bicarbonate prior to resting, while Kurćubić et al. [29] reported pH values of around 6.5 for the pork and beef pljeskavica (burger-type product) without sodium bicarbonate but with resting.

Table 2. Technological properties of ćevapi.

	CON	TP5	TP10	TP20
pH (raw)	7.36 ± 0.20 ^{ab}	7.49 ± 0.21 ^{b}	7.36 ± 0.24 ^{ab}	7.17 ± 0.13 ^{a}
pH (grilled)	7.43 ± 0.23 ^{ab}	7.47 ± 0.17 ^{b}	7.33 ± 0.12 ^{ab}	7.27 ± 0.18 ^{a}
CL (%)	16.70 ± 1.49 ^{c}	17.21 ± 2.80 ^{c}	13.86 ± 1.53 ^{b}	11.63 ± 0.86 ^{a}
dL (%)	23.69 ± 3.88 ^{ab}	24.51 ± 3.05 ^{b}	20.96 ± 3.50 ^{ab}	20.29 ± 2.94 ^{a}
aw	0.96 ± 0.00 ^{a}	0.96 ± 0.00 ^{a}	0.96 ± 0.00 ^{a}	0.96 ± 0.01 ^{a}

$^{a–c}$ Values (mean ± SD) in the same row with different superscripts are significantly different ($p < 0.05$). CON—control treatment; TP5—treatment with 5 g/kg of TP; TP10—treatment with 10 g/kg of TP; TP20—treatment with 20 g/kg of TP; CL—cooking loss; dL—length reduction after grilling.

Cooking loss (CL) and length reduction (dL) can be useful as an indication of deformation of minced meat products during grilling [30] and therefore provide the first information about product appearance. Adding 10 g/kg of TP and more appears to progressively and significantly ($p < 0.05$) reduce CL (Table 2). A similar effect was observed regarding dL (Table 2), except without any significant differences between CON and the TP treatments. The obtained data indicate that the addition of more than 10 g/kg of TP increases the processing yield and can reduce product shrinkage during grilling. This could result in juicier products and products with more pleasant appearance. Moreover, this confirms the water-binding ability of TP fibres [15] and opens up the possibility of reducing the salt content in these products. Also, it opens up the use of TP as a meat replacer in a certain amount, which is indicated in some research studies on the use of other sources of fibres [31,32].

Piñero et al. [33] also reported an improvement in the cooking yield and moisture retention of low-fat patties with added oat fibre, a source of β-glucan. Also, Angiolillo et al. [34] found that introducing oat fibre in beef burgers with inulin/fructo-oligosaccharides reduces diameter reduction and cooking loss (and by extension, deformation during grilling), as well as improves cooking yield. Moreover, López-Vargas et al. [35] reported a significant and progressive increase in the yield, moisture, and fat retention, and a significant and progressive decrease in diameter reduction with the addition of 2.5% and 5% of passion fruit albedo-fibre powder. The authors attributed this to the high water-holding and swelling capacity of the used dietary fibre source, which can contain a high amount of total dietary fibre (71.79 g/100 g).

The addition of TP in the amounts of 5–20 g/kg did not alter the aw value (Table 2). López-Vargas et al. [35] reported no significant changes in the aw value of raw burgers with the addition of passion fruit albedo-fibre powder in the amount of 25 g/kg (2.5%), while a significantly higher aw value was obtained when 5% was added.

3.3. Instrumental Colour Analysis

Based on the results shown in Table 3, it can be concluded that as for raw ćevapi, there is no significant difference ($p > 0.05$) regarding the L* and a* values, whereas there is a significant difference in the values of b*, C, and h values. The post hoc test determined that a significant difference in the b* values existed between the control group and TP5 ($p < 0.001$), TP10 ($p < 0.001$), and TP20 ($p < 0.001$), where the control treatment has significantly lower b* values compared to other treatments, which also means that the yellowness of the sample increased progressively and significantly ($p < 0.05$) with the content of TP in the ćevapi formulation. Calvo et al. [36] reported similar results in an experiment with dry fermented sausages enriched with lycopene from tomato peels, where the results showed that the biggest difference between the control and the samples enriched with different concentrations of tomato pomace was precisely in the b* value, as these values were twice as high as in the controls. The consequence of the increase in yellowness can be the oxidation of lycopene, the main pigment in tomatoes, whereby the colour changes from red to orange, which can be seen from the results for h values. The control group has significantly lower h values compared to the other groups whose range of values moves towards orange colour, which is in accordance with the statements of Calvo et al. [36]. The other study examined the impact of the addition of tomato pomace on the colour of beef patties, and the results showed that the control patties were lighter, less red, and less yellow than those with tomato pomace. The yellowness and redness values increased with concentration, similar to previous studies [37]. These claims are consistent with the results for the grilled product obtained in this experiment. Regarding the grilled product, there is a significant difference between CON and TP10 and TP20 in terms of a* and b* values, with the CON being less yellow and less red. A significant difference in the C values existed between CON and TP20, for the raw sample and control group, and TP10 ($p < 0.001$) and TP20 ($p < 0.001$), for grilled ones, where the CON had significantly lower C values compared to the TP20.

Table 3. Differences in the values of instrumental colour parameters.

Raw	CON	TP5	TP10	TP20
L*	56.38 ± 3.46 [a]	57.00 ± 3.82 [a]	59.19 ± 2.37 [a]	56.94 ± 3.90 [a]
a*	41.72 ± 1.70 [ab]	42.36 ± 2.28 [b]	41.08 ± 1.74 [ab]	40.16 ± 2.11 [a]
b*	14.30 ± 1.04 [a]	17.69 ± 1.54 [b]	20.41 ± 1.72 [c]	25.74 ± 2.36 [d]
C	44.12 ± 1.89 [a]	45.92 ± 2.59 [ab]	46.27 ± 1.97 [ab]	47.77 ± 2.45 [b]
h	18.85 ± 0.87 [a]	22.64 ± 1.14 [b]	26.16 ± 1.66 [c]	32.57 ± 2.45 [d]
ΔE	/	4.98 ± 1.82	7.46 ± 1.63	12.05 ± 1.83
Grilled				
L*	52.27 ± 5.66 [a]	50.08 ± 4.04 [a]	49.94 ± 3.29 [a]	50.24 ± 3.90 [a]
a*	16.91 ± 0.94 [a]	17.61 ± 2.45 [a]	19.63 ± 1.69 [b]	20.55 ± 1.54 [b]
b*	25.50 ± 1.91 [a]	27.27 ± 2.40 [ab]	29.55 ± 3.07 [b]	32.88 ± 3.90 [c]
C	30.66 ± 1.44 [a]	32.59 ± 2.59 [a]	35.58 ± 2.57 [b]	38.87 ± 3.55 [c]
h	56.30 ± 2.81 [a]	57.31 ± 3.89 [a]	56.20 ± 3.81 [a]	57.78 ± 3.37 [a]
ΔE	/	6.53 ± 3.58	9.01 ± 3.93	9.68 ± 4.07

[a–d] Values (mean ± SD) in the same row with different superscripts are significantly different ($p < 0.05$); CON—control treatment; TP5—treatment with 5 g/kg of TP; TP10—treatment with 10 g/kg of TP; TP20—treatment with 20 g/kg of TP.

The ΔE* values could be an additional colour parameter that can provide a more complete insight into the colour difference between the two products, which in this research are control and experimental. The results presented in Table 1 indicate that the ΔE* values of raw ćevapi were within the 5–12 range, while in the grilled product, this range was somewhat narrow at 6.5–10. This indicates that the colour difference between CON and the TP treatments will probably be noticeable according to Ramírez-Navas and Rodríguez De Stouvenel [38], with all values being higher than 2.7. In the study of characteristics of the ćevapi made of game meat, Djekic et al. [28] pointed out that there was a perceptible difference when ΔE* values were within the 2–10 range. The ΔE* values progressively increased with the content of TP in ćevapi formulation, where TP5 had the lowest ΔE* values, and TP20 the highest, which was also confirmed by the examination carried out by Skwarek and Karwowska [11].

3.4. Instrumental Texture Analysis

Significantly higher values of hardness and chewiness were observed in the TP treatments compared to CON (Table 4). However, there was no progressive increase in both properties with the higher content of TP, i.e., no significant differences within the modified treatments. López-Vargas et al. [35] also reported significantly higher hardness and chewiness in burgers with 2.5% and 5% of passion fruit albedo-fibre powder. Moreover, they reported a progressive increase in the values of those texture parameters in burgers with higher amounts of fibre source. Polizer-Rocha et al. [31] also reported higher values in hardness and chewiness of beef burgers with 1% of pea fibre (50% of fibre and 35% of starch on dry basis) compared to the control, except without any significant differences. Although emulsion-type sausages are not similar with burger-type products, it is worth mentioning that Powell et al. [14] and Magalhães et al. [39] reported higher hardness values (with no yield changes) when using 0.5–1% and 2.5–5% of citrus fibre (76.1% of total fibre) and bamboo fibre, respectively, as phosphate replacements in Bologna sausage. Moreover, Savadkoohi et al. [40] reported a progressive increase in hardness and higher chewiness values (compared to control) when adding 3–7% of tomato pomace (39.11% of fibre content) in beef frankfurters. These data indicate that a potentially progressive increase in hardness and chewiness could be associated with the amounts of fibre source of higher than 2%, depending on the fibre content and composition (insoluble/soluble), meat system, and the salt/phosphate content.

Table 4. Results of texture profile analysis.

	CON	TP5	TP10	TP20
Hardness (N)	11.98 ± 1.27 [a]	14.27 ± 1.60 [b]	13.82 ± 1.61 [b]	14.55 ± 1.20 [b]
Adhesiveness (N*s)	−0.26 ± 0.13 [a]	−0.28 ± 0.14 [a]	−0.35 ± 0.13 [a]	−0.29 ± 0.18 [a]
Springiness	0.835 ± 0.027 [a]	0.854 ± 0.031 [a]	0.830 ± 0.034 [a]	0.841 ± 0.033 [a]
Cohesiveness	0.674 ± 0.065 [a]	0.693 ± 0.038 [a]	0.684 ± 0.056 [a]	0.697 ± 0.035 [a]
Chewiness (N)	6.76 ± 1.15 [a]	8.42 ± 0.91 [b]	7.87 ± 1.32 [b]	8.55 ± 1.10 [b]

[a–b] Values (mean ± SD) in the same row with different superscripts are significantly different ($p < 0.05$); CON—control treatment; TP5—treatment with 5 g/kg of TP; TP10—treatment with 10 g/kg of TP; TP20—treatment with 20 g/kg of TP.

Dietary fibres possess the ability to form gels, immobilize water, and emulsify fat [41]. The data indicate that insoluble fibres can alter food texture by forming a three-dimensional network that can modify rheological properties and increase hardness and chewiness, as reported in several studies on the addition of dietary fibre to emulsified meat products [13,14,39] and burger-type meat products [31,35].

The addition of different TP amounts in the ćevapi formulation did not change adhesiveness, springiness, and cohesiveness, although higher values of all three parameters were observed in the TP treatments. López-Vargas et al. [35] and Polizer-Rocha et al. [31] also reported no significant differences in the beef burgers compared to control when adding passion fruit albedo-fibre powder and pea fibre, respectively. However, Stajić et al. [13], Magalhães et al. [39], and Powell et al. [14] obtained lower and/or significantly lower values of springiness and cohesiveness in emulsion-type sausages with dietary fibre used as phosphate replacements. This indicates that the effect of the use of dietary fibre depends on the meat system and the content of other ingredients.

3.5. Sensory Evaluation

The results of the sensory evaluation presented in Figure 1 indicate that there were no significant differences between CON and the TP treatments regarding any examined sensory properties. It is worth mentioning that in terms of appearance and colour, TP20 received the lowest grades, about 0.5 lower compared to CON and TP5 (significantly lower than TP5 in terms of colour). This could indicate that when tomato pomace powder is added in amounts of higher than 20 g/kg, we can expect lower acceptance (of appearance and colour) of such products, bearing in mind that progressively higher values of b* and ΔE* values were observed in the grilled ćevapi with the increase in TP amount. Though significant differences in cooking loss, hardness, and chewiness were found between CON and the TP treatments, the assessors gave similar ($p > 0.05$) grades of hardness and juiciness. This indicates that, if differences were observed, this was not perceived as a negative influence. Also, the addition of TP powder did not influence odour, taste, and saltiness perception. It is also worth noting that TP10 received about grades that were 0.5 lower compared to CON in terms of hardness, odour, and saltiness perception, which probably influenced its lower grade (about 0.5 to CON) in terms of overall acceptance.

The addition of 5% of passion fruit albedo-fibre powder in burgers did not have an adverse effect on sensory quality [31]. Rather, the burgers with 2.5% of passion fruit albedo-fibre powder received significantly higher grades compared to control in terms of flavour, taste intensity, and overall acceptability. The authors also found that significantly higher values of instrumental hardness and chewiness were not confirmed in sensory analysis, which is similar to our research. Research on the influence of tomato pomace on sensory quality meat products is scarce. Savadkoohi et al. [40] reported that the addition of up to 5% of tomato pomace could increase the sensory quality of beef frankfurters, while a higher percentage could reduce sensory quality. The authors pointed out that the influence of tomato pomace addition is product-type dependent, since the reduction in the sensory quality of beef ham occurred with the addition of 3% tomato pomace.

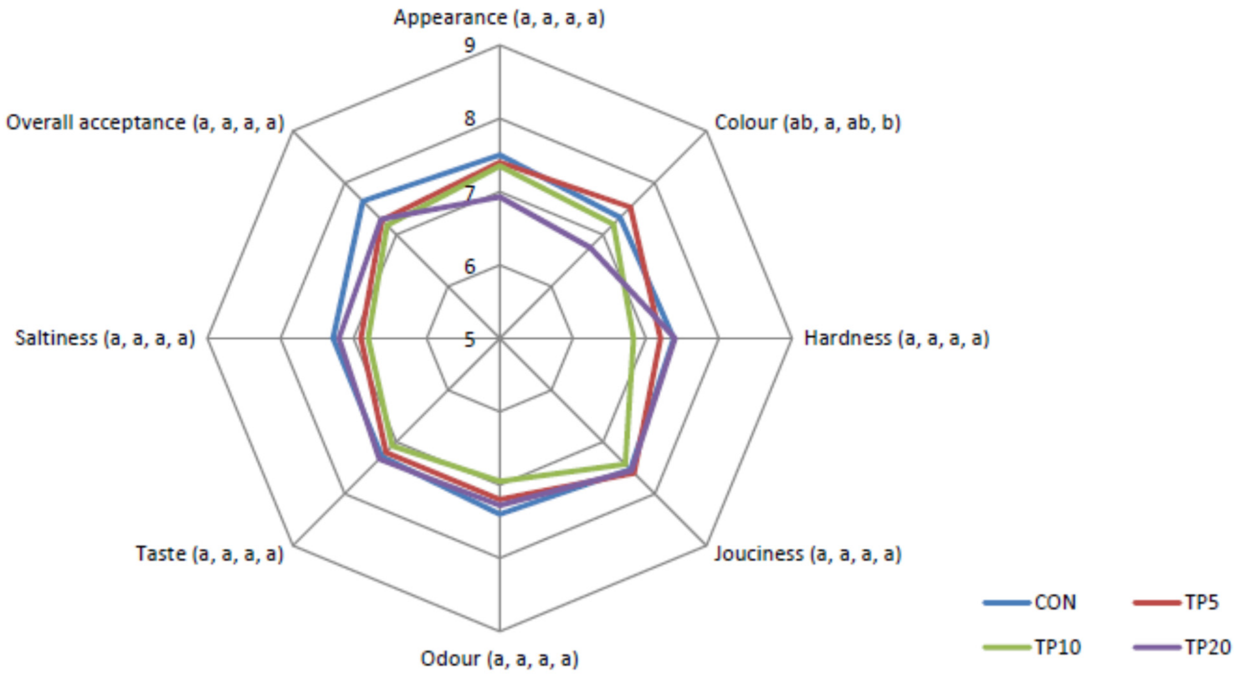

Figure 1. Results of sensory evaluation. CON—control treatment; TP5—treatment with 5 g/kg of TP; TP10—treatment with 10 g/kg of TP; TP20—treatment with 20 g/kg of TP; different small letters in brackets after each sensory property indicates a significant difference $p < 0.05$. Every letter is dedicated to one treatment in the following order: CON, TP5, TP10, and TP20.

4. Conclusions

The addition of tomato pomace in the amounts of 10 and 20 g/kg in the formulation of the traditional Serbian minced meat product, ćevapi, significantly reduced cooking loss and, in turn, increased water retention and processing yield. However, instrumental hardness and chewiness were also significantly increased, while other parameters of instrumental texture were not influenced. Adding 5 g/kg of TP and more appeared to progressively and significantly ($p < 0.05$) increase the yellow tones (b* and h values) in the raw ćevapi while in the grilled product, we observed significantly higher redness and yellowness when 10 g/kg and more of TP was added. The values of total colour differences indicate that the colour differences of the modified treatments could be perceptible. However, the sensory evaluation results indicate that there were no significant differences between CON and the TP treatments in terms of any examined sensory properties. Therefore, consumers probably did not negatively perceive the established differences in instrumental texture and colour.

Since salt and meat content are of great importance to the technological properties (production yield and instrumental texture) and sensory quality, and because the addition of TP reduces cooking loss and increases instrumental hardness and chewiness (and potentially cohesiveness), this opens up the possibility of reducing the salt and/or meat content in these products. This could be one of the goals in further research. Another one could be the examination of oxidative stability during freeze storage since TP contains compounds with antioxidative properties.

Author Contributions: Conceptualization, S.S. and M.K.; methodology, S.S.; validation, S.S., I.T. and V.K.; formal analysis, B.P., S.Đ., P.S. and I.T.; investigation, S.S., P.S. and S.Đ.; data curation, S.Đ., P.S., I.T. and S.S.; writing—original draft preparation, S.S., S.Đ. and P.S.; writing—review and editing, V.K. and M.K.; supervision, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Science, Technological Development and Innovation of The Republic of Serbia, grant numbers: 451-03-65/2024-03/200116 and 451-03-66/2024-03/200088.

Data Availability Statement: Data may be obtained from the authors, upon reasonable request.

Acknowledgments: The authors thank Marija Stajić for performing the English proofreading.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Laufenberg, G.; Kunz, B.; Nystroem, M. Transformation of vegetable waste into value added products: (a) the upgrading concept; (b) practical implementations. *Bioresour. Technol.* **2003**, *87*, 167–198. [CrossRef] [PubMed]
2. Moshtaghian, H.; Bolton, K.; Rousta, K. Challenges for upcycled foods: Definition, inclusion in the food waste management hierarchy and public acceptability. *Foods* **2021**, *10*, 2874. [CrossRef] [PubMed]
3. Spratt, O.; Suri, R.; Deutsch, J. Defining upcycled food products. *J. Culin. Sci. Technol.* **2021**, *19*, 485–496. [CrossRef]
4. Zuorro, A.; Fidaleo, M.; Lavecchia, R. Enzyme-assisted extraction of lycopene from tomato processing waste. *Enzyme Microb. Technol.* **2011**, *49*, 567–573. [CrossRef] [PubMed]
5. Elbadrawy, E.; Sello, A. Evaluation of nutritional value and antioxidant activity of tomato peel extracts. *Arab. J. Chem.* **2016**, *9*, S1010–S1018. [CrossRef]
6. Lu, Z.; Wang, J.; Gao, R.; Ye, F.; Zhao, G. Sustainable valorisation of tomato pomace: A comprehensive review. *Trends Food Sci. Technol.* **2019**, *86*, 172–187. [CrossRef]
7. Eslami, E.; Carpentieri, S.; Pataro, G.; Ferrari, G. A comprehensive overview of tomato processing by-product valorization by conventional methods versus emerging technologies. *Foods* **2023**, *12*, 166. [CrossRef]
8. Bianchi, A.R.; Vitale, E.; Guerretti, V.; Palumbo, G.; De Clemente, I.M.; Vitale, L.; Arena, C.; De Maio, A. Antioxidant characterization of six tomato cultivars and derived products destined for human consumption. *Antioxidants* **2023**, *12*, 761. [CrossRef]
9. Górecka, D.; Wawrzyniak, A.; Jędrusek-Golińska, A.; Dziedzic, K.; Hamułka, J.; Kowalczewski, P.Ł.; Walkowiak, J. Lycopene in tomatoes and tomato products. *Open Chem.* **2020**, *18*, 752–756. [CrossRef]
10. Osman, S.F.; Irwin, P.; Fett, W.F.; O'Conno, J.V.; Parris, N. Preparation, isolation, and characterization of cutin monomers and oligomers from tomato peels. *J. Agric. Food Chem.* **1999**, *47*, 799–802. [CrossRef]
11. Skwarek, P.; Karwowska, M. Fatty acids profile and antioxidant properties of raw fermented sausages with the addition of tomato pomace. *Biomolecules* **2022**, *12*, 1695. [CrossRef] [PubMed]
12. Šojić, B.; Pavlić, B.; Tomović, V.; Kocić-Tanackov, S.; Đurović, S.; Zeković, Z.; Belović, M.; Torbica, A.; Jokanović, M.; Urumović, N.; et al. Tomato pomace extract and organic peppermint essential oil as effective sodium nitrite replacement in cooked pork sausages. *Food Chem.* **2020**, *330*, 127202. [CrossRef] [PubMed]
13. Stajić, S.; Tomasevic, I.; Tomovic, V.; Stanišić, N. Dietary fibre as phosphate replacement in all-beef model system emulsions with reduced content of sodium chloride. *J. Food Nutr. Res.* **2022**, *61*, 277–285.
14. Powell, M.J.; Sebranek, J.G.; Prusa, K.J.; Tarté, R. Evaluation of citrus fiber as a natural replacer of sodium phosphate in alternatively-cured all-pork bologna sausage. *Meat Sci.* **2019**, *157*, 107883. [CrossRef] [PubMed]
15. Salehi, F. Textural properties and quality of meat products containing fruit or vegetable products: A review. *J. Food Nutr. Res.* **2021**, *60*, 187–202.
16. Ruusunen, M.; Puolanne, E. Reducing sodium intake from meat products. *Meat Sci.* **2005**, *70*, 531–541. [CrossRef] [PubMed]
17. Karwowska, M.; Stadnik, J.; Stasiak, D.M.; Wójciak, K.; Lorenzo, J.M. Strategies to improve the nutritional value of meat products: Incorporation of bioactive compounds, reduction or elimination of harmful components and alternative technologies. *Int. J. Food Sci. Technol.* **2021**, *56*, 6142–6156. [CrossRef]
18. Chaouch, M.A.; Benvenuti, S. The role of fruit by-products as bioactive compounds for intestinal health. *Foods* **2020**, *9*, 1716. [CrossRef] [PubMed]
19. *AOAC 934.06:1996*; Moisture in Dried Fruits. Aoac Official Methods of Analysis, 17th ed. Association of Official Analytical Chemists: Arlington, VA, USA, 2000.
20. *ISO 1871:2009*; Food and Feed Products—General Guidelines for the Determination of Nitrogen by the Kjeldahl Method. International Organization for Standardization: Geneva, Switzerland, 2009.
21. *NMKL Method No.160:1998*; Fat, Determination in Foods. Nordic Committee on Food Analysis. Institute of Marin Research, NMKL NordVal International: Bergen, Norway, 1998.
22. *NMKL Method No.173:2005*; Fat, Determination in Foods. Nordic Committee on Food Analysis. Institute of Marin Research, NMKL NordVal International: Bergen, Norway, 2005.
23. *AOAC 985.29:1986*; Total Dietary Fiber in Foods, Enzymatic–Gravimetric Method. Aoac Official Methods of Analysis, 17th ed. The Association of Official Analytical Chemists: Arlington, VA, USA, 2000.
24. *Gafta Method 10.1:2018*; Sugar—Luff Schoorl Method. GAFTA Analysis Methods, The Grain and Feed Trade Association: London, UK, 2018.
25. *AOAC 986.25:1988*; Proximate Analysis of Milk-Based Infant Formula. Aoac Official Methods of Analysis, 17th ed. The Association of Official Analytical Chemists: Arlington, VA, USA, 2000.
26. Tomasevic, I.; Tomovic, V.; Milovanovic, B.; Lorenzo, J.; Đorđević, V.; Karabasil, N.; Djekic, I. Comparison of a computer vision system vs. Traditional colorimeter for color evaluation of meat products with various physical properties. *Meat Sci.* **2019**, *148*, 5–12. [CrossRef]

27. Del Valle, M.; Cámara, M.; Torija, M.-E. Chemical characterization of tomato pomace. *J. Sci. Food Agric.* **2006**, *86*, 1232–1236. [CrossRef]
28. Djekic, I.; Stajic, S.; Udovicki, B.; Siladji, C.; Djordjevic, V.; Terjung, N.; Heinz, V.; Tomasevic, I. Quality and oral processing characteristics of traditional serbian ćevap influenced by game meat. *Foods* **2023**, *12*, 2070. [CrossRef]
29. Kurćubić, V.S.; Stajić, S.B.; Miletić, N.M.; Petković, M.M.; Dmitrić, M.P.; Đurović, V.M.; Heinz, V.; Tomasevic, I.B. Techno-functional properties of burgers fortified by wild garlic extract: A reconsideration. *Foods* **2023**, *12*, 2100. [CrossRef] [PubMed]
30. Patinho, I.; Selani, M.M.; Saldaña, E.; Bortoluzzi, A.C.T.; Rios-Mera, J.D.; da Silva, C.M.; Kushida, M.M.; Contreras-Castillo, C.J. *Agaricus bisporus* mushroom as partial fat replacer improves the sensory quality maintaining the instrumental characteristics of beef burger. *Meat Sci.* **2021**, *172*, 108307. [CrossRef] [PubMed]
31. Polizer-Rocha, Y.J.; Lorenzo, J.M.; Pompeu, D.; Rodrigues, I.; Baldin, J.C.; Pires, M.A.; Freire, M.T.A.; Barba, F.J.; Trindade, M.A. Physicochemical and technological properties of beef burger as influenced by the addition of pea fibre. *Int. J. Food Sci. Technol.* **2020**, *55*, 1018–1024. [CrossRef]
32. Grasso, S.; Goksen, G. The best of both worlds? Challenges and opportunities in the development of hybrid meat products from the last 3 years. *LWT Food Sci. Technol.* **2023**, *173*, 114235. [CrossRef]
33. Piñero, M.P.; Parra, K.; Huerta-Leidenz, N.; Arenas de Moreno, L.; Ferrer, M.; Araujo, S.; Barboza, Y. Effect of oat's soluble fibre (β-glucan) as a fat replacer on physical, chemical, microbiological and sensory properties of low-fat beef patties. *Meat Sci.* **2008**, *80*, 675–680. [CrossRef] [PubMed]
34. Angiolillo, L.; Conte, A.; Del Nobile, M.A. Technological strategies to produce functional meat burgers. *LWT Food Sci. Technol.* **2015**, *62*, 697–703. [CrossRef]
35. López-Vargas, J.H.; Fernández-López, J.; Pérez-Álvarez, J.Á.; Viuda-Martos, M. Quality characteristics of pork burger added with albedo-fiber powder obtained from yellow passion fruit (passiflora edulis var. Flavicarpa) co-products. *Meat Sci.* **2014**, *97*, 270–276. [CrossRef]
36. Calvo, M.M.; García, M.L.; Selgas, M.D. Dry fermented sausages enriched with lycopene from tomato peel. *Meat Sci.* **2008**, *80*, 167–172. [CrossRef]
37. Candogan, K. The effect of tomato paste on some quality characteristics of beef patties during refrigerated storage. *Eur. Food Res. Technol.* **2002**, *215*, 305–309. [CrossRef]
38. Ramírez-Navas, J.S.; Rodríguez De Stouvenel, A. Characterization of colombian quesillo cheese by spectrocolorimetry. *Vitae* **2012**, *19*, 178–185. [CrossRef]
39. Magalhães, I.M.C.; Paglarini, C.d.S.; Vidal, V.A.S.; Pollonio, M.A.R. Bamboo fiber improves the functional properties of reduced salt and phosphate-free bologna sausage. *J. Food Process. Preserv.* **2020**, *44*, e14929. [CrossRef]
40. Savadkoohi, S.; Hoogenkamp, H.; Shamsi, K.; Farahnaky, A. Color, sensory and textural attributes of beef frankfurter, beef ham and meat-free sausage containing tomato pomace. *Meat Sci.* **2014**, *97*, 410–418. [CrossRef] [PubMed]
41. Tungland, B.C.; Meyer, D. Nondigestible oligo- and polysaccharides (dietary fiber): Their physiology and role in human health and food. *Compr. Rev. Food Sci. Food Saf.* **2002**, *1*, 90–109. [CrossRef] [PubMed]