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Exploring Chia Mucilage as a Potential Additive for Salt Reduction in Traditional Balkan Minced Meat Product "Ćevap"

Running title: Chia Mucilage as a Salt Reducer in Balkan "Ćevap"

Sanja Đurđević[1*], Igor Tomašević[1,2], Steva Lević[3], Nikola Stanišić[4], Vladimir Kurćubić[5] and Slaviša Stajić[1]

[1]Department of Animal Source Food Technology, Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11080 Belgrade, Serbia
[2]German Institute of Food Technologies (DIL), 49610 Ouackenbruck, Germany
[3]Department of Food Technology and Biochemistry, Faculty of Agriculture, University of Belgrade, 11080 Belgrade, Serbia
[4]Institute for Animal Husbandry, Belgrade-Zemun, Autoput Beograd-Zagreb 16, 11000 Belgrade, Serbia
[5]Department of Food Technology, Faculty of Agronomy, University of Kragujevac, Cara Dušana 34, 32102 Čačak, Serbia

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SUMMARY

Research background. The food industry is constantly searching for solutions to reduce the sodium content in meat products as the world is facing an increased risk of diseases caused by a greater intake of sodium from salt through processed foods, including minced meat products.

Experimental approach. The aim of this work was to determine potential use of chia mucilage in different concentration (2 and 4 %) in traditional products with reduced salt content (15 and 30 %) and to evaluate its impact on technological properties, color, texture, and sensory parameters of minced meat product "Ćevap". Given its water-binding and gelling properties, chia mucilage may exert

[*]Corresponding author

E-mail: sanja.djurdjevic@agrif.bg.ac.rs

a similar functional effect as salt in minced meat products, particularly in improving water retention and texture.

Results and conclusions. Findings showed that replacement of sodium chloride with chia mucilage did not have a significant effect on some technological properties, such as pH and cooking loss, but textural parameters were affected, producing softer and stickier product in general. A treatment with 15 % sodium chloride reduction and 2 % chia mucilage addition were preferred as for appearance, juiciness, and overall acceptability, while higher chia mucilage concentrations led to lower scores in taste and saltines perception as shown in sensory analysis.

Novelty and scientific contribution. As a conclusion it was established that chia mucilage can help reduce the salt content with the careful reformulation, so it do not change the sensory qualities.

Keywords: meat product; minced meat; chia mucilage; salt reduction

INTRODUCTION

In recent years, the world has faced an increased risk of diseases caused by a greater intake of sodium from salt through processed foods, including minced meat products (*1*). The recommended daily consumption for adults is less than 2000 mg of sodium, which is equivalent to less than 5 g of salt (*2*).

For this reason, the food industry is constantly searching for solutions to reduce the sodium content in meat products such as sausages, burgers, and meatballs. However, given that salt plays a key role in meat products by enhancing flavor, affecting texture, as well as inhibiting microbes, reducing the salt content in meat products without compromising sensory attributes poses a significant challenge, and alternatives are difficult to find (*3*). Meat products, especially those made from minced meat (*e.g.* burgers), must be aligned with certain regulations, and for this reason the use of nitrites and phosphates are prohibited by some national regulations for some types of this product (*4*). Although nitrites contribute to microbiological safety, color stabilization and specific taste, and phosphates improve water binding and texture, their prohibition in certain formulations emphasizes the key role of salt. This leads us to the fact that salt remains one of the main technological factors in the extraction and activation of myofibrillar proteins, improving the water binding capacity, as well as defining taste and maintaining shelf life and safety of minced meat products (*5,6*). Lowering salt concentration reduces the extracted and solubilized myofibrillar proteins, which in turn affects the technological and sensory properties of the meat system (*7*).

Recent research has shown that the incorporation of natural additives such as chia seed mucilage (CM) offers promising solutions (*3*). CM is defined as a water-soluble polysaccharide obtained from the seeds of the *Salvia hispanica L.* plant through three processes: hydration, extraction, and recovery (*8,9*). Chia seeds contain a significant amount of dietary fiber, antioxidants including phenolic compounds, increased protein content with a balanced proportion of essential amino acids, and are rich in polyunsaturated fatty acids, especially linolenic acid (*10*). Mucilage obtained from chia seeds (CM) comprises moisture, carbohydrates, protein, fat, ash, and uronic acids, and has a high content of soluble dietary fibers, primarily composed of polysaccharides such as mucilage and pectin, whose presence can have health benefits in the form of lowering cholesterol and helping intestinal functions (*11-13*). Due to the properties of its components, CM has a potential use in different food systems as a functional “clean label” (free from artificial additives, preservatives, colors, or flavours) ingredient, *e.g.* texture modifier, fat replacer, stabilizer, emulsifier, and others (*12*).

Until now, chia seed derivatives in meat products have been studied as a potential replacement for the proportion of saturated fat (*10*). Due to its high content of dietary fibres, CM can be potentially used in meat products where fibers were used as phosphate or/and salt replacements (*14,15*). Such composition contributes to the ability to form a gel, which improves water retention and affects texture modification and binding capacity in food products. In addition, it exhibits emulsifying properties, which can improve the stability and homogeneity of minced meat formulations (*10*). CM, with its hydrocolloid substances and water-holding capacity, could be a promising solution for minced meat products such as patties, meatballs, and burgers. The amount of connective tissue, along with fat content, degree of cooking, and type of heat treatment, affects texture and flavor, and the use of hydrocolloid components such as CM can be crucial given that cooking cause water loss and by extension mass loss, as well as shrinkage in minced meat products (*13,16*). Minced meat is a widely utilized raw material in the production of processed meat products, including burgers, hamburgers, sausages, meatballs, also traditional Balkan dishes such as “Ćevap” and “Pljeskavica” (*5,17*). “Ćevap” (pronounced/t͡ɕěʋaːp/), belongs to the category of minced meat heat treated by grilling or barbecuing before consumption. This type of heat treatment affects the final product and results in changed shape, color, and taste (*5,6*). Given its high global consumption, there is a continuous need to enhance the quality, functionality, and nutritional profile of these products. This paper investigates the application of CM as a potential ingredient in a traditional minced meat product from the Balkan due to its exceptional gelling properties, potential health benefits, and its potential salt replacement while preserving color, texture, and sensory parameters.

MATERIALS AND METHODS

Chia Seed Mucilage preparation

Chia seed mucilage (CM) was extracted from chia seeds (*Salvia hispanica* L.) (purchased at the local market, imported from the Netherlands) using cold extraction by distilled water for 2 h as explained by Hovjecki *et al.* (*18*). Extraction involved the separation of chia mucilage using a SJE 741SS juicer (SENCOR, Tokyo, Japan), followed by mixing it with 5 % *m*/*V* inulin (Cosucra, Warcoing, Belgium) as a drying aid. The mixture was dried in a laboratory oven (UF 55, Memmert, Schwabach, Germany) at 70 °C until completely dry. The dried mucilage was collected, vacuum packed, and stored at 4 °C. It was ground in grinder Bosch KM-13 (Robert Bosch GmbH, Munich, Germany) to a powdered product, which was added to meat pieces and mixed by hand with other ingredients.

"Ćevap" preparation and analysis

The "Ćevap" production process was the same as explained by Stajić *et al.* (*4*). Briefly, beef, pork (shoulder muscles) and back fat (cut into small pieces) were weighed, manually mixed with other ingredients, and ground (separately) through an 8 mm plate (82H, Laska, Traun, Austria).Control treatment (CON) and four experimental treatments were prepared using 34 % of beef (moisture (73.01±0.86) %, protein (21.29±0.93) %, and fat (3.77±0.48) %; *N*=4 (2x2)), 34 % of pork (moisture (75.10±0.83) %, protein (19.63±0.91) %, and fat (4.38±0.69) %; *N*=4 (2x2)), 18 % of back fat, water (11.5 %), sodium bicarbonate (0.5 %), and dextrose (0.5 %). CON was prepared with 1.5 % of salt while experimental treatments were prepared as CON with the reduction of NaCl in the amounts of 15 % and 30 % and the addition of CM in the amounts of 2 and 4 % (CM15/2: 15 % NaCl reduction and 2 % CM addition; CM15/4: 15 % NaCl reduction and 4 % CM addition; CM30/2: 30 % NaCl reduction and 2 % CM addition; CM30/4: 30 % NaCl reduction and 4 % CM addition). Câmara *et al.* (*10*) used chia mucilage powder in the amounts of 2 % and 4 % as phosphate replacer in emulsion-type sausage. Use of phosphates in "Ćevap" (and similar types of minced meat products) is not allowed by Serbian national regulations. Therefore, we used CM powder in the amounts of 2 and 4 %, as potential partial salt replacement, considering that phosphates enhance protein solubility by disrupting the actin-myosin complex. This disruption amplifies the functional effects of salt and added water on protein extraction and solubilization, which CM may partially mimic through its water-binding and gelling properties. The salt amounts were based on earlier studies in which the effect of cooking loss on overall sodium content had been considered (*19-23*).

After refrigerating for 24 h, batches of all treatments were ground again (separately) through a 4.5 mm plate and "Ćevap" were formed using manual sausage feeder equipped a 20 m funnel into cylindrical shapes about 6–8 cm in length and 2 cm in diameter. After shaping, "Ćevap" were grilled (electric grill IEG-820 Guangzhou Ideal Catering Equipment Co., Ltd., Guangzhou, China) at 250 °C (75 °C in the centre), cooled at ambient temperature, and kept in the refrigerator 24 h. A total of two independent production batches were prepared, with each treatment weighted at 1 kg. Between 20 and 25 individual "Ćevap" were obtained within each treatment (100–125 individual "Ćevap" for all treatments in one batch), with the average mass of (24.1±1.0) g (*N*=60; 30 per batch). The experiment was conducted in two replications on different days.

Technological properties

pH values were determined on 12 individual "Ćevap" per treatment (6 per batch) using Testo 206 pH2 (Testo, Lenzkirich, Germany) pH-meter with penetration probe. pH-meter was calibrated before each measurement at pH=4.0 and 7.0 using standard buffer solutions. pH values were determined on both, raw and grilled products.

Six individual "Ćevap" per treatment (3 per batch) were used to determine water activity (a_w). This was carried out using the a_w-meter LabSwift-aw (Novasina, Lachen, Switzerland).

Ten individual "Ćevap" per treatment (5 per batch) were used to determine cooking loss (cL), which was calculated as the mass difference (in %) of raw and grilled products cooled to room temperature.

Ten individual "Ćevap" per treatment (5 per batch) were used to determine length reduction (lR), which was calculated as the length difference (in %) of raw and grilled products cooled to room temperature. Digital nonius (with a 0.01 mm precision ratio) was used for measuring the length of each individual "Ćevap".

Instrumental color and texture analysis

Instrumental color was determined on both, raw products (*N*=12; 6 per batch) and grilled products (*N*=12; 6 per batch) cooled to room temperature. Color measurements were conducted using the Computer Vision System (CVS) (*24*) with the equipment and under conditions as described by

Tomasevic *et al.* (*25*). RAW photographs (files with uncompressed and unprocessed image data) of each individual "Ćevap" surface were used to determine *L**, *a**, and *b** values of meat parts (avoiding fat parts), using a Photoshop Average Color Sampler Tool. From each individual Ćevap three readings were taken on measuring area of 5 x 5 pixels. 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:

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

$$h=\arctan b^*/a^* \qquad /2/$$

Total color difference (Δ*E**) represents the quantification of the overall difference between two colors, *e.g.* modified treatments vs. CON. Δ*E** was calculated using the standard equation:

$$\Delta E^* = \sqrt{(L^*_{MA} - L^*_{CON})^2 + (a^*_{MA} - a^*_{CON})^2 + (b^*_{MA} - b^*_{CON})^2} \qquad /3/$$

where CM is "Ćevap" with chia mucilage, and CON is control.

Texture profile analysis was performed on grilled "Ćevap" with the equipment (TA.XT Plus; Stable Micro System, Ltd., Godalming, UK) and under the same conditions as described by Stajić *et al.* (*4*). Six individual "Ćevap" per treatment (3 per batch) were held for equilibration to ambiental temperature, two samples, 10 mm in height and 12 mm in radius were taken from the center of each individual "Ćevap". Hardness, adhesiveness, springiness, cohesiveness, and chewiness were evaluated and obtained using Exponent software (Stable Micro Systems, Godalming, UK).

Sensory analysis

A preliminary sensory analysis was performed using Smart Sensory Solutions software (Smart Sensory Solutions S.r.I., Sassari, Italy) (*26*). Twenty untrained assessors (aged 21–60, 35 % male, 65 % female) participated in the sensory analysis and were selected based on their frequency of "Ćevap" or "Pljeskavica" consumption (at least once a week, or once every two weeks, based on their answers). Assessors were students (age 21–30, 70 %) and staff members (age 31–60, 30 %) at the Faculty of Agriculture, University of Belgrade. Given that this type of product is usually consumed warm, the samples were heated in a microwave (Samsung GE82N-B, Malaysia) for 20 s at 650 W, about 50 °C in the center before tasting. As the sensory analysis could not be performed on the same day the products were prepared (by grilling), but rather the next day, heating before serving was necessary to stimulate real consumption conditions. Prior to sensory evaluation, a half of "Ćevap" from each treatment were coded with a randomly selected three-digit number, heated and served in broad daylight, randomly (*N*=5). The assessors evaluated the appearance, surface color, hardness, juiciness, odor, taste, saltiness, and overall acceptability using a nine-point hedonic scale (1 – extremely unacceptable; 5 – neither like nor dislike; 9 – extremely acceptable). Assessors used water (at room temperature) to cleanse their palates between samples. The sensory evaluations were performed in two time-separated assessments (replicates). Instructions for evaluation were briefly presented before each assessment. Due to the limited number of assessors and the preliminary nature of this analysis, the results are not shown and should be interpreted with caution.

Statistical analysis

Statistical data processing and analysis were performed using the IBM SPSS (Statistical Package of Social Science Inc., Chicago, IL, USA) software version 17.0 (*27*). A one-way analysis of variance (ANOVA) and Tukey's post hoc was performed to determine significant differences among treatment groups. A level of 0.05 was used for the threshold value of significance. Results are presented as the mean±standard deviation (S.D.).

RESULTS AND DISCUSSION

Effect of chia addition on techno-functional characteristics

Based on the statistical analysis of pH values pre- and post-heat treatment, as presented in Table 1, it can be inferred that the incorporation of CM alongside a concomitant decrease in sodium chloride did not yield a statistically significant ($p > 0.05$) impact on pH values compared to the control. Antonini *et al.* (*28*) and Paula *et al.* (*29*) came to the conclusion, that the addition of chia seeds does not have a statistically significant effect on the pH of meat burgers, (similar meat products as "Ćevap"), while reduced sodium chloride content has no effect on pH values up to 33 % (*21*). These results are consistent with the research conducted by Fernández-López *et al.* (*30*), where the addition of different forms of chia seeds in frankfurters did not have a statistically significant effect on the change in the pH value. Minor variations observed between control and treated samples may be attributed to the dissociation of ions and bioactive compounds naturally present in the CM, which can influence the hydrogen ion concentration in the system (*10*). However, these variations were not statistically significant ($p>0.05$). Water activity values (a_w) in raw samples of all treatments were higher than those observed in the control group; however the difference was not significant ($p>0.05$). The observed increase in a_w may be attributed to the hydrophilic nature of CM, though the effect was not sufficient to produce a statistically meaningful change. Other authors reported no significant differences in a_w values, either with the same or with similar types of products (*4,10,29-31*).

Minced meat products, including burgers, undergo shape deformation during heat treatment. Consequently, the cooking loss and reduction in the diameter play crucial roles as technological aspects in the production of these products. Notably, in the case of a Balkan product, "Ćevap", the reduction in diameter is substituted by a length reduction, owning to its distinctive cylindrical shape (*4,5*). The reduction of sodium chloride content with the addition of CM had no statistically significant effect on cooking loss, but affected the length reduction. As shown in Table 1, the result for the CM15/4 treatment for cooking loss show a modest variation compared to the control group, a phenomenon likely influenced by the presence of CM and dietary fiber content, which have a positive effect on water retention in the product (*3,28,32-34*). In contrast, in the CM30/4 treatment, despite the inclusion of 4 % CM, the two-fold reduction in sodium chloride could not be fully compensated, indicating that the degree of sodium chloride reduction is the limiting factor in this case. Research on beef patties with less sodium, where a different amount and size of salt was applied and its effect on cooking loss was examined, showed that the application of more coarse salt lead to increased cooking loss, as a consequence of the lower availability of sodium ions (*35*). The reduction in length during cooking, though small, was statistically significant ($p<0.05$), suggesting that changes in formulation can affect product shrinkage. This may be linked to the limited ability of CM to compensate for the reduced NaCl, which plays a crucial role in protein solubilization and structure formation.

Instrumental evaluation of color and texture parameters

Instrumental color analysis of "Ćevap" revealed significant variation among treatments, associated with the concentration of CM, as presented in Table 2. In raw samples, the *L** value (lightness) increased in all CM treatments compared to the control (CON), with a statistically significant difference observed in CM15/4, CM30/2 and CM30/4 ($p < 0.05$). This variation is attributed to the inherent color of CM, which, in its powdered form, ranges from white to gray (*36*). Furthermore, the tabular data indicate lower *a** (redness) and *b** (yellowness) values in treatments with salt reduction and CM addition. Among all treatments, CM30/4 exhibited the lowest *a** and *b** values, corresponding to the highest CM concentration and greatest salt reduction.

After heat treatment, all CM samples showed lower *L** values compared to CON, indicating a darker appearance (Table 2). The analysis reveals a statistically significant difference ($p<0.05$) between CM15/2 and the remaining treatments, among which no statistically significant differences were detected. The results differ from earlier research that looked at the use of CM as a supplement or substitute for various meat components. Specifically, research demonstrated that the inclusion of CM as a fat replacer in beef patties showed that lightness (*L**) and yellowness (*b**) increased with the higher percentage of fat replaced with CM (*13,33*), however, there was a decrease in redness (*a**) when the addition of CM resulted in a less red product (*13*). Research with Bologna sausages and a model system emulsion led to a reduction in *L** and *a** color values (*10*). Similarly, Pintado *et al.* (*3*) and Fernández-López *et al.* (*30*) observed comparable outcomes, noting that the incorporation of chia flour resulted in decreased *L** and *a** values. The observed color changes in other types of products are likely associated with variations in moisture and fat content, which influence light reflectance and, consequently, the brightness of the product. However, this phenomenon does not apply to the current research, as there are no variations in the composition of the treatments. Furthermore, the variation in cooking loss is minimal and does not impact the chemical composition. The observed decrease in *L** and *a** values may be attributed to the unique chemical composition of chia seeds, which enhances their water-binding capacity (*30*). Although *a** values (redness) do not display a statistically significant variation, it is noteworthy that samples with higher CM content, specifically CM15/4 and CM30/4, exhibit numerically lower *a** values, indicating reduced redness. Moreover, the *b** values (yellowness) demonstrate statistically significant differences between samples with the highest CM content and CON, with the former displaying lower *b** values and thus appearing less yellow (Table 2).

The *ΔE** values, which indicate total color difference of modified treatments compared to CON, show that raw CM treatments with 4 % of CM powder added are more different compared to CON than treatments with 2 % of CM powder. On the other side, this was not the case after grilling, considering that all Δ*E** values were within a narrow range, between 7 and 8. Salt reduction did not influence Δ*E** values in both raw and grilled "Ćevap". The established Δ*E** values were not higher than 10, which indicates that color differences of modified treatments (compared to CON) will probably be noticeable considering that Djekic *et al.* (*37*) highlighted the perceptible difference within the 2–10 range.

Textural properties are crucial in determining the quality and sensory characteristics of food products. Table 3 presents the results of texture profile analysis for "Ćevap" samples formulated with a reduced sodium content (15 and 30 %) and varying levels (2 and 4 %) of added CM, highlighting the impact on parameters such as hardness, cohesiveness, springiness, chewiness, and resilience. The presented results indicate that the reduction of the salt content with the simultaneous addition of CM had an effect on the reduction of hardness. Namely, all modified treatments had a lower hardness value and did not differ statistically from CON. Research on beef patties showed similar results, where the addition of chia seeds resulted in reduced hardness and chewiness of these products (*13,32*). Fernández-López *et al.* (*30*) came to the same results with the frankfurter experiment, where the addition of CM in the form of flour caused a less hard product. Similar results were also reported by Arifin *et al.* (*38*) and Barros *et al.* (*39*). Addition of other plant based ingredients, such as pitahaya peel flour, were also negatively impacted textural parameters, by reducing values of hardness, chewiness and gumminess, in same type product (*40*). The analysis shows that only CM15/2 had no significant differences compared to CON. Therefore, it can be concluded that the addition of CM powder even in higher amounts could not compensate for the reduction of the salt content. The decrease in hardness may be due to the gel matrix of the CM, namely the hydrophilic proteins and soluble fibers in the mucilage that keep water bound and result in softer structure (*13,32*). CM30/4 demonstrates significantly the highest value for adhesiveness, indicating it is the stickiest of the treatments. Conversely, CON shows the lowest adhesiveness, suggesting that salt reduction affects the increase in the stickiness of the samples. The reduction of the salt content may result in decreased springiness values, as demonstrated in this research. Specifically, greater levels of salt reduction were associated with lower springiness values, and the addition of CM was insufficient to counteract this effect. Câmara *et al.* showed that the concentration of 5 % CM decreases springiness and cohesiveness of the meat model system, potentially because of dietary fibers inhibiting the aggregation of myosin globular heads, which is the initial stage in the protein gelation process that occur high temperatures (*31*). CM15/2 exhibits the highest springiness among all treatments, although the difference is minor. CM15/4 and CM30/4 exhibit the lowest cohesiveness (*31,33*), indicating poorer internal cohesion after the addition of 4 % of CM. Also, the same amount of added CM in CM15/4 and CM30/4 showed the lowest resilience, reflecting reduced recovery after deformation. Chewiness was also significantly affected, with all CM-enriched and salt-reduced treatments showing lower values and reflecting a softer and less cohesive texture. The results indicate that all four treatments consistently exhibit lower values across most textural parameters, suggesting the samples with the additions are softer, stickier and less cohesive.

Descriptive sensory evaluation

A preliminary sensory evaluation was conducted to provide indicative insight into the acceptability of products with different levels of sodium chloride (NaCl) reduction and CM addition across attributes such as appearance, color, hardness, juiciness, odor, taste, saltines, and overall acceptability. Due to the small number of assessors, the results are not shown and should be interpreted only as an initial orientation, not conclusive findings (data not shown).

The appearance scores indicated that the formulation with 15 % reduction in NaCl coupled with 2 % CM achived the most desirable rating. This suggests that such a combination may enhance the visual appeal of the meat product, potentially due to the mucilage's ability to improve moisture retention and binding properties (*12*). In contrast, both formulations, which entail a 4 % CM addition, received lower scores. Although there is a distinction between CM15/2 and CM15/4, we cannot conclude that salt reduction with the simultaneous addition of CM may considerably modify the exterior appearance. Color ratings were consistent, remaining high across all samples, with no significant differences observed ($p>0.05$). This indicates that the incorporation of CM, regardless of the NaCl reduction, does not affect the color adversely, which is essential for perception of freshness and quality in meat products. The same data for color were obtained using a gel emulsion prepared with chia seeds and olive oil in beef patties (*33*). Hardness scores were similarly consistent, with no significant differences among the samples. This suggests that the structural integrity of the meat products is maintained, even with the addition of CM, which is crucial since texture is a key determinant of sensory panel acceptance and preference. Sensory panel rated the treatment with a lower level of NaCl reduction and lower CM content, particularly in CM15/2, highest in terms of juiciness, although hardness and cohesiveness are reduced. However, the flavor profile appears to be compromised in CM30 formulations, where we see a decline in juiciness scores. The results indicate that either the sensory panel did not notice the differences determined by instrumental texture measurement or if they did, they did not consider them to be negative. Yüncü *et al.* (*32*) and Arifin *et al.* (*38*) reported an increase in juiciness scores, which is not in correlation with other authors (*29*). This indicates that while CM can enhance perceived juiciness, higher salt reduction may lead to a less palatable experience when combined with excessive mucilage. Odor scores remained high and consistent, suggesting that the addition of CM does not affect the aromatic profile of the meat products negatively, which is in agreement with Liu *et al.* (*33*). This is an important finding, as the olfactory properties of meat significantly impact overall consumer acceptability. Taste perception varied notably, with CM15/2 and CM30/2 maintaining higher scores. In contrast, both samples with 4 % CM addition exhibited lower taste ratings, particularly CM30/4. This suggests that while reducing NaCl can be beneficial for health considerations, excessive reduction paired with higher CM may lead to an undesirable taste profile, potentially due to the distinct flavor or texture of mucilage altering the inherent taste of meat (*30,32,33*). Saltiness perception was highest in the control and CM15/4, and decreased in the CM30 formulations, particularly in CM30/4. This finding underscores the importance of salt in flavor enhancement and may suggest that while CM can help reduce sodium content, it does not replicate the taste impact of salt effectively at higher mucilage concentrations. Overall acceptability mirrored the trends observed in other sensory attributes, with CM15/2 achieving the highest score and CM30/4 the lowest. This illustrates that while CM offers an innovative means of reducing sodium content in meat products, the optimal formulation must balance health benefits with sensory quality.

CONCLUSIONS

Adding 2 and 4 % of chia mucilage (CM) powder and simultaneously salt reduction (15 and 30 %) in Balkan minced meat product ćevap, altered examined technological properties. Treatments with higher salt reduction and higher amounts of CM powder were more prone to deformation during grilling. Raw modified treatments were lighter and less red and yellow compared to control. However, this was not observed after grilling. Regarding instrumental texture, adding CM powder could not compensate for salt reduction / modified treatments had lower hardness and chewiness and were less elastic and cohesive. Although a preliminary sensory analysis was conducted, the small number of assessors limits the strength of conclusion. Nevertheless, early indications suggest that altered technological properties, either not always noticeable or were not perceived negatively. Notably, the optimal balance appears to be achieved with a 15 % reduction in salt coupled with a 2 % addition of CM, enhancing overall acceptability without compromising flavor or texture. Thus, this study underscores the potential of natural additives like chia seed mucilage in reformulating traditional minced meat products and promoting healthier consumption while respecting culinary traditions. Future research should further investigate the long-term effects of such formulations on product stability and consumer preferences, paving the way for broader applications in the meat industry.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTION

S.Đ. and S.S. were responsible for the conceptualization, methodology, formal analysis and investigation. S.Đ. also handles the software and data analysis, as well as writing original draft. S.S. contributed to the review and editing of the manuscript. I.T. developed the methodology for instrumental color analysis and sensory analysis. S.L. prepared the chia seed mucilage material. N.S. and V.K. were involved in validation, supervision, and manuscript review.

ORCID ID

S. Đurđević https://orcid.org/0009-0003-3619-5575

I. Tomašević https://orcid.org/0000-0002-1611-2264

S. Lević https://orcid.org/0000-0001-8337-3475

N. Stanišić https://orcid.org/0000-0002-4316-7332

V. Kurćubić https://orcid.org/0000-0003-2016-7345

S. Stajić https://orcid.org/0000-0001-5287-8956

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Table 1. Technological properties

Property	CON	CM15/2	CM15/4	CM30/2	CM30/4
pH (raw)	(6.82±0.13)[a]	(6.88±0.08)[a]	(6.81±0.10)[a]	(6.82±0.08)[a]	(6.83±0.15)[a]
pH (grilled and cooled)	(7.16±0.06)[a]	(7.17±0.08)[a]	(7.14±0.10)[a]	(7.19±0.07)[a]	(7.17±0.17)[a]
cL/%	(19.65±1.88)[a]	(21.91±2.87)[a]	(19.83±2.96)[a]	(21.02±2.79)[a]	(22.48±2.74)[a]
lR/%	(16.33±2.02)[a]	(19.32±3.90)[ab]	(20.07±2.85)[b]	(23.76±2.96)[c]	(24.27±1.93)[c]
a_w	(0.962±0)[a]	(0.963±0)[ab]	(0.964±0)[b]	(0.963±0)[ab]	(0.964±0)[b]

a–c Values (mean±S.D.) in the same row with different superscripts are significantly different (p<0.05); CON: control sample; CM15/2: 15 % NaCl reduction and 2 % chia seed mucilage addition; CM15/4: 15 % NaCl reduction and 4 % chia seed mucilage addition; CM30/2: 30 % NaCl reduction and 2 % chia seed mucilage addition; CM30/4: 30 % NaCl reduction and 4 % chia seed mucilage; cL: cooking loss; lR: length reduction after grilling; a_w: water activity

Table 2. Differences in the values of instrumental color parameters

Raw	CON	CM15/2	CM15/4	CM30/2	CM30/4
*L**	(52.97±1.54)^{a}	(55.37±1.21)^{ab}	(58.43±2.00)^{c}	(57.40±1.99)^{bc}	(57.64±3.75)^{bc}
*a**	(42.37±1.70)^{c}	(40.20±1.15)^{bc}	(37.17±1.61)^{a}	(39.07±1.41)^{ab}	(36.90±2.46)^{a}
*b**	(14.20±1.76)^{b}	(13.13±1.04)^{ab}	(13.03±1.38)^{ab}	(12.67±1.14)^{ab}	(12.37±0.90)^{a}
C	(44.72±2.01)^{c}	(42.31±1.36)^{b}	(39.41±1.80)^{a}	(41.09±1.49)^{ab}	(38.94±2.34)^{a}
h	(18.45±1.82)^{a}	(18.03±1.03)^{a}	(19.26±1.64)^{a}	(17.94±1.44)^{a}	(18.57±1.75)^{a}
Δ*E**	/	5.57±1.83	9.18±2.79	6.63±2.76	9.55±4.59
Grilled					
*L**	(52.40±2.29)^{b}	(47.20±2.01)^{a}	(49.77±4.31)^{ab}	(50.00±3.71)^{ab}	(49.23±3.90)^{ab}
*a**	(15.93±1.43)^{a}	(14.77±1.47)^{a}	(14.33±1.62)^{a}	(14.53±0.84)^{a}	(14.37±1.54)^{a}
*b**	(22.30±0.85)^{b}	(21.00±1.46)^{ab}	(19.73±2.12)^{a}	(20.90±1.01)^{ab}	(20.40±1.23)^{a}
C	(27.47±1.40)^{b}	(25.74±1.37)^{ab}	(24.25±1.78)^{a}	(25.49±1.15)^{a}	(25.02±1.53)^{a}
h	(22.30±0.85)^{a}	(21.00±1.46)^{a}	(19.73±2.12)^{a}	(20.90±1.01)^{a}	(20.40±1.23)^{a}
Δ*E**	/	7.57±2.17	7.17±2.37	7.27±1.17	8.09±2.04

a–c Values (mean±S.D.) in the same row with different superscripts are significantly different ($p < 0.05$); CON: control sample; CM15/2: 15 % NaCl reduction and 2 % chia seed mucilage addition; CM15/4: 15 % NaCl reduction and 4 % chia seed mucilage addition; CM30/2: 30 % NaCl reduction and 2 % chia seed mucilage addition; CM30/4: 30 % NaCl reduction and 4 % chia seed

Table 3. Results of the texture profile analysis

Property	CON	CM15/2	CM15/4	CM30/2	CM30/4
Hardness/N	(1887.16±198.85)^{c}	(1745.09±152.53)^{bc}	(1439.29±83.77)^{a}	(1572.71±110.96)^{ab}	(1566.37±219.77)^{ab}
Adhesiveness/(N·s)	(-13.54±7.91)^{a}	(-8.85±8.45)^{ab}	(-9.42±7.61)^{ab}	(-7.78±6.94)^{ab}	(-3.95±6.39)^{b}
Springiness	(0.87±0.02)^{bc}	(0.88±0.03)^{c}	(0.83±0.04)^{a}	(0.84±0.02)^{ab}	(0.84±0.04)^{ab}
Cohesiveness	(0.67±0.03)^{b}	(0.64±0.06)^{b}	(0.55±0.05)^{a}	(0.57±0.05)^{a}	(0.55±0.03)^{a}
Chewiness/N	(1104.45±120.05)^{b}	(981.04±141.57)^{b}	(664.05±94.45)^{a}	(748.88±63.93)^{a}	(716.14±97.99)^{a}
Resilience	(0.31±0.02)^{b}	(0.28±0.03)^{b}	(0.23±0.03)^{a}	(0.24±0.03)^{a}	(0.23±0.02)^{a}

a–c Values (mean±S.D.) in the same row with different superscripts are significantly different ($p < 0.05$); CON: control sample; CM15/2: 15 % NaCl reduction and 2 % chia seed mucilage addition; CM15/4: 15 % NaCl reduction and 4 % chia seed mucilage addition; CM30/2: 30 % NaCl reduction and 2 % chia seed mucilage addition; CM30/4: 30 % NaCl reduction and 4 % chia seed