

## Research

# Effect of salt reduction, mixture of salt with animal fat, and salt particle sizes on instrumental texture, yield properties and sensory characteristics of burgers

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## Abstract

This study aimed to investigate the impact of reduction of salt content (from 1.5 to 0.75%), the technique of mixing half of the salt content with animal fat, and the salt particle size on the instrumental texture, cooking losses, diameter reduction, overall liking, and sensory characteristics of burgers. The results showed that regardless of the types of micronized salt ( $MS < 250 \mu\text{m}$ ) incorporation (directly into the meat or the mixture of half of the MS with the meat and the other half with the fat), salt reduction decreased the salty perception and the instrumental hardness and chewiness. Thus, the mixture of MS with fat does not present sensory improvements nor overcome the texture effects of salt reduction. In a second experiment, the effect of different particle sizes (from  $< 177 \mu\text{m}$  to 1 mm) was evaluated, where it was observed that salt with particle size  $< 177 \mu\text{m}$  decreased the burgers' hardness, cooking losses, and diameter reduction. The salt particle sizes did not cause sensory changes in the burgers, and in both experiments, the overall liking was greater than 7 points on the 9-point hedonic scale. Salt  $< 177 \mu\text{m}$  could be a good option for reducing salt in burgers and possibly in other meat products.

**Keywords** Meat products · Micronized salt · Sensory properties · Sodium reduction · Technological properties

## 1 Introduction

Sodium chloride (NaCl, salt) is an indispensable ingredient in foods and the primary source of dietary sodium, but excessive sodium consumption is strongly linked to cardiovascular disease. It is estimated that 20% of dietary sodium intake comes from meat products [1], this is why the academy has been constantly contributing to the proposal of technological and sensory alternatives for the reduction of sodium in meat products. Recently, Wang et al. [2]

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proposed four strategies for sodium reduction in meat products: salt replacement with non-sodium salts, flavor and saltiness enhancers, processing technologies such as high pressure, ultrasound and microwave, and changing form and size of salt. While these strategies have advantages and disadvantages when applied in isolation, the combination of two or more of them could result in a more ideal effect [2]. However, it must be considered that for industrial applications any of the strategies implies an additional cost compared to the conventional product, and in this aspect, the reduction of the salt particle size using simple processes such as sieving may be the lowest cost [3].

In addition to reducing salt particle size, it has been proposed that in intermediate or high moisture products the salt should be mixed with oil or fat to improve the perception of saltiness. This complementary strategy to size reduction began with the patent of ConAgra Foods® in 2011, in which salt smaller than or equal to 20 µm was protected by a layer of oil or fat to improve the perception of the saltiness of foods [4]. Later, Rios-Mera et al. [5] applied the same principle in burgers, where half of the micronized salt content (salt < 250 µm) was mixed with animal fat (pork backfat), achieving a 33% reduction in salt content without affecting the sensory profile. Since then, several reports have shown the benefits of this strategy in meat products, with reductions of up to 50% in salt content [3, 6–8]; even using salt of different morphology, as reported by Soteras et al. [9], in the use of spherical salt in lamb meat burger.

The rationale behind implementing this approach is the enhancement of saltiness perception by small salt particles, but in moist products containing lipids, the lipid component must be used to protect the salt from aqueous solubilization, which can reduce the saltiness [10]. As a result, a reduced salt product and, unlike the use of salt replacers or flavor enhancers, a clean label product is obtained without significantly affecting saltiness and consumer acceptability.

While the reduction of salt by modifying the salt particle size has been reviewed and recommended by various authors [10–14], the potential advantages of incorporating salt into the fat of burgers have yet to be definitively established because the research cited earlier did not examine the effects of using the same salt particle size, with and without lipid mixing. In addition, the comparison of various salt particle sizes in meat products has not been reported. Defining the relevance of mixing salt with lipids before processing the meat product and choosing an ideal salt particle size can result in products with improved technological and sensory characteristics, so this approach can be a good option to reduce salt in burgers.

Reducing the particle size of salt and mixing it with fat or oil requires an additional unit operation in the production process, which can increase the production cost of the burger. To address this issue, this research investigates whether reducing salt and mixing with fat is feasible to reduce salt in burgers, as well as investigate other salt particle sizes that are more efficient in the technological and sensory characteristics of burgers. In this regard, the objective of this study was divided into two experiments: (1) to determine the effect of salt reduction and the mixture of salt with animal fat, and (2) to determine the effect of salt particle sizes in burgers. In both experiments, the parameters most affected by salt reduction in burgers were considered: instrumental texture, cooking losses, diameter reduction, and sensory characteristics.

## 2 Material and methods

### 2.1 Materials

Lean beef (*Quadriceps femoris*), pork backfat, table salt, and monosodium glutamate were obtained from the local market (Jaén, Cajamarca, Peru). Onion, garlic, and pepper powder were supplied by Alitecno (Lima, Peru). Sodium erythorbate was obtained from Frutarom Perú S. A. (Lima, Peru). The micronized salt (MS) was obtained from table salt (regular salt, RS), which was manually sieved using stainless steel sieves of 50 mesh (<297 µm), 60 mesh (<250 µm), 70 mesh (<210 µm), and 80 mesh (<117 µm). In addition, the residual salt, which was not sieved through the 50 mesh (1 mm coarse salt, CS), was used for burger processing. The size distribution was similar in each sieve and CS in terms of salt mass, making it representative of the RS used in this study.

### 2.2 Burger manufacture

The burgers were processed according to Rios-Mera et al. [5]. The ingredients used were beef (70%), pork backfat (20%), water (7.5%), salt, monosodium glutamate (0.28%), onion powder (0.28%), garlic powder (0.28%), white pepper powder (0.15%), and sodium erythorbate (0.01%). The study consisted of two experiments. In the first experiment, the effect of salt reduction and mixing salt with fat was studied, where the salt reduction ranged from 1.5 to 0.75%. In the second experiment, six salt

particle sizes were compared at 1.5%. For comparison purposes, the 1.5% salt concentration was chosen based on previous salt reduction studies in burgers using MS [3, 5, 7].

### 2.2.1 First experiment: salt reduction and mixing salt with fat

MS was used to reduce salt in the burgers from 1.5 to 0.75%. Additionally, a 1.5% RS treatment was manufactured for comparison with the MS treatments. MS was added to the burger dough in two forms: directly into the meat and a 1:1 meat: fat ratio of MS addition [5]. This ratio of MS addition to the meat and fat was evaluated by Rios-Mera et al. [3, 5], considering technological and sensory responses, with satisfactory results in reducing salt in burgers by up to 33%. It is important to mention that in previous studies the direct addition of MS to the meat was not evaluated [3, 5–7]. Therefore, the present study attempts to determine if there is a technological and sensory advantage of mixing half MS with fat.

In agreement with previous studies [3, 5–7], MS of 60 mesh (<250 µm) was used for the first experiment. These studies further suggest that the concentration of 0.75% in burgers can be considered the threshold so as not to negatively affect the texture, yield properties and sensory characteristics. In this line, five treatments were processed: 1.5% RS (RS1.5); 1.0% MS (MS1.0); 1.0% MS half in fat + half in meat batter (MS0.5+0.5); 0.75% MS (MS0.75); and 0.75% MS half in fat + half in meat batter (MS0.375+0.375).

For the processing of the burgers, the meat and fat were ground separately with a 0.8 cm disc, then salt was added to the meat or meat and fat (for MS0.5+0.5 and MS0.375+0.375 treatments) to be mixed manually for 2 min. Next, the other ingredients were added and mixed for 3 min. Then, 100 g of burger batter was molded into burger format using a 10 cm diameter and 1 cm thick plastic mold. The samples were frozen at –18 °C for 2 h to avoid deformation during vacuum packaging. Finally, they were stored at the same freezing temperature until analyses. To complete 100% of the formulation in the first experiment due to salt reduction, the meat content was slightly increased, from 70 to 70.75%.

### 2.2.2 Second experiment: salt particle sizes comparison

Six salt particle sizes were compared at a concentration of 1.5% in the burgers: RS, CS, <297 µm, <250 µm, <210 µm, and <117 µm). The processing followed the same procedure as the first experiment, but all salt sizes were added directly to the meat.

For both experiments, the processing was repeated three times in three separate batches, with 25 burgers produced for each treatment in each batch. The samples were kept at –18 °C for a maximum of one week. Before the analyses, they were refrigerated (4 °C) for two hours. Later, they were cooked at 150 °C on an electric plate. Both sides of the samples were cooked; on the first side, samples were expected to reach 37.5 °C to be turned over, and then on the second side, they were expected to reach 75 °C to be removed from the electric plate. The temperature was monitored with a puncture thermometer in the central area of the burgers. For sensory analysis, samples were cooled to 45 and 25 °C for instrumental texture and yield properties.

## 2.3 Yield properties

Yield properties were calculated by cooking losses and diameter reduction based on measuring the weights and diameters of burgers before and after cooking, respectively [15, 16]. Three burger samples were used in each analysis.

Cooking losses were determined according to Eq. 1:

$$\% \text{Cooking losses} = \frac{\text{Raw weight} - \text{Cooked weight}}{\text{Raw weight}} \times 100 \quad (1)$$

Diameters were measured using a vernier caliper and measurements were taken four times on each sample (vertically, horizontally and diagonally). The average of the measurements was then considered for determining the diameter reduction (Eq. 2):

$$\% \text{Diameter reduction} = \frac{\text{Raw diameter} - \text{Cooked diameter}}{\text{Raw diameter}} \times 100 \quad (2)$$

## 2.4 Texture profile analysis (TPA)

A TVT 6700 texturometer (Perkin Elmer, Australia) with a 50 kg load cell coupled to a 3.5 cm diameter cylindrical probe was used for the determination of hardness (Newton, N), springiness, cohesiveness, and chewiness (Newton, N). Three samples per treatment were used for TPA. The cooked samples were cut in a cylindrical format of 2.5 cm diameter and 1 cm height, using stainless steel cylindrical cutter of the same dimensions. According to Rios-Mera et al. [3], the samples were compressed twice up to 75% of their height at a constant speed of 20 cm/min. The pre-test and post-test speeds were 40 cm/min.

## 2.5 Sensory characterization and overall liking

### 2.5.1 Consumers

Participants were selected based on their availability and regular consumption of burgers. Other inclusion criteria were being over 18 years of age, without respiratory illnesses and without chronic diseases related to the consumption of any of the ingredients of the burger, which were informed by the research team. Consumers were selected by convenience and by snowballing, they were available on the campus of the Universidad Nacional de Jaén (Jaén, Peru).

In the first experiment, 79 participants (32 men, 46 women, and one who preferred not to declare sex) were in the range of 18 to 53 years. The frequency of burger consumption was: 3% ate burgers 3 to 1 times a week, 39% ate burgers every 15 days, 22% ate burgers once a month, and 37% rarely ate burgers. In the second experiment, the consumer panel comprised 77 participants (36 men and 41 women) between 18 and 51 years old. The frequency of burger consumption was: 4% ate burgers 3 to 1 times a week, 42% ate burgers every 15 days, 25% ate burgers once a month, and 29% rarely ate burgers.

Before participating in the study, consumers were explained about the product, the number of samples to be evaluated, and the estimated evaluation time (approximately 15–20 min). Then, consumers were required to read and sign a consent form approving their participation, which contained information on the research title, justification, objectives, methodology, risks, benefits, privacy statement, and contact information of the researchers. Finally, a brief training of 15 min was carried out on the correct use of the sensory sheet and the evaluation procedure, in addition to explaining the meaning of each sensory attribute evaluated.

**2.5.1.1 Procedure** The sensory analysis was conducted in individual sensory booths in a single session for each experiment. To describe the samples sensorially, the Check-All-That-Apply (CATA) method was used, with 15 descriptors provided by Rios-Mera et al. [3]. The sensory descriptors used in this study came from a previous study by Rios-Mera et al. [5]. They did not include hedonic terms, have implications for sensory differences between reduced-salt burgers, and were generated from the consumers' vocabulary through lemmatization and categorization with a Pivot profile task. The same ingredients were used in the same concentration in those previous studies, making the sensory words used to describe the burgers appropriate.

In both experiment sessions, samples in a quantity of ~10 g each sample were served monadically and balanced on plates coded with three-digit random numbers using a Williams Latin Square design [17]. First, consumers rated their overall liking using a 9-point hedonic scale, ranging from "extremely dislike" to "extremely like" [18]. After that, they were asked to select all sensory terms that applied to describe the samples (CATA questions). Water and unsalted crackers were provided to consumers to cleanse the palate between samples.

## 2.6 Data analysis

Data of instrumental texture and yield properties were analyzed by a mixed analysis of variance (ANOVA), considering treatments as a fixed effect and batch (3 independent burger processes performed in three days) as a random effect. In each processing, different batches of meat and fat were used, thus the variability of these ingredients was controlled and considered as the random effect. Mixed ANOVA was also used for overall liking, with treatment as a fixed factor and consumer and presentation order as random factors. Previously, normality of residuals (Shapiro–Wilk test), homogeneity

of variances (Bartlett test), and independence of residuals (Durbin-Watson test) at 5% significance were verified. When there were significant differences in the ANOVA, the Tukey's test was used for pairwise comparison at 5% significance.

A contingency table was elaborated to express the frequencies of selection of the sensory terms for each sample. Then, a  $\chi^2$  test per was conducted to compare the observed frequency with the theoretical value expected under the null hypothesis. This allowed us to identify significant deviations in sensory term selection across the samples, providing deeper insights into sensory differences among the products [19, 20].

XLSTAT 2015 (Addinsoft, New York, EEUU) and R software [21] were used for data analysis.

### 3 Results and discussion

#### 3.1 First experiment: salt reduction and mixing salt with fat

In the first experiment, the reduction in salt content resulted in a decrease in hardness and chewiness (Table 1), similar to the results of De Araújo et al. [7] and Rios-Mera et al. [3]. More crystal salts available means greater protein gel formation, which translates into greater firmness, hardness, and chewiness [3, 22]. In this sense, a lower salt concentration in the product means decreased salt action on the meat proteins, affecting the texture. However, the cooking losses and diameter reduction were no different ( $p > 0.05$ ) between treatments. On the contrary, Rios-Mera et al. [5] and De Araújo et al. [7] observed a significant decrease in cooking yield when salt was reduced in beef burgers. A possible explanation for discrepancies between studies is the difference in the quality of meat used to elaborate the burgers, which affects the action of salt on solubilization of myofibrillar proteins, resulting in retention of components of meat products during cooking [23]. In this regard, the observations in this experiment suggest that the solubilization of myofibrils by the action of MS was sufficient to obtain comparable cooking yield results even with up to 50% salt reduction.

Regarding the comparison of the two types of adding MS (directly in the meat and half in the fat), no differences ( $p > 0.05$ ) for texture and yield properties (Table 1) were observed between MS1.0 vs. MS0.5+0.5 and MS0.75 vs. MS0.375+0.375. However, Rios-Mera et al. [3] indicated that mixing half of the salt content with fat would result in less contact of salt with myofibrillar proteins, decreasing the hardness of burgers. Regarding yield parameters, MS was

**Table 1** Instrumental texture and yield properties (average  $\pm$  standard deviation) in burgers reduced in salt content and half of the content mixed with fat (first experiment) and with different salt particle size (second experiment)

Treatment	Instrumental texture properties				Yield properties	
	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)	Cooking losses (%)	Diameter reduction (%)
<i>First experiment<sup>1</sup>: salt reduction and mixing salt with fat</i>						
RS1.5	64.16 $\pm$ 3.93 <sup>a</sup>	0.80 $\pm$ 0.04 <sup>a</sup>	0.51 $\pm$ 0.03 <sup>a</sup>	26.21 $\pm$ 2.85 <sup>a</sup>	35.18 $\pm$ 2.39 <sup>a</sup>	27.34 $\pm$ 1.29 <sup>a</sup>
MS1.0	56.97 $\pm$ 3.82 <sup>ab</sup>	0.80 $\pm$ 0.06 <sup>a</sup>	0.53 $\pm$ 0.08 <sup>a</sup>	24.02 $\pm$ 3.39 <sup>ab</sup>	40.29 $\pm$ 4.24 <sup>a</sup>	31.84 $\pm$ 3.42 <sup>a</sup>
MS0.5+0.5	52.18 $\pm$ 1.26 <sup>bc</sup>	0.76 $\pm$ 0.04 <sup>a</sup>	0.53 $\pm$ 0.02 <sup>a</sup>	21.05 $\pm$ 2.02 <sup>ab</sup>	41.23 $\pm$ 0.58 <sup>a</sup>	31.67 $\pm$ 3.27 <sup>a</sup>
MS0.75	50.33 $\pm$ 3.72 <sup>bc</sup>	0.75 $\pm$ 0.05 <sup>a</sup>	0.50 $\pm$ 0.01 <sup>a</sup>	18.99 $\pm$ 2.25 <sup>ab</sup>	40.71 $\pm$ 0.45 <sup>a</sup>	31.60 $\pm$ 0.64 <sup>a</sup>
MS0.375+0.375	42.89 $\pm$ 6.61 <sup>c</sup>	0.79 $\pm$ 0.06 <sup>a</sup>	0.50 $\pm$ 0.04 <sup>a</sup>	17.16 $\pm$ 4.12 <sup>b</sup>	42.24 $\pm$ 4.06 <sup>a</sup>	31.70 $\pm$ 1.82 <sup>a</sup>
<i>Second experiment: salt particle size comparison</i>						
Regular salt, RS	51.86 $\pm$ 6.82 <sup>ab</sup>	0.86 $\pm$ 0.12 <sup>a</sup>	0.51 $\pm$ 0.05 <sup>a</sup>	22.63 $\pm$ 4.23 <sup>a</sup>	37.97 $\pm$ 1.81 <sup>ab</sup>	20.48 $\pm$ 2.38 <sup>b</sup>
Coarse salt, CS (1 mm) <sup>2</sup>	60.02 $\pm$ 1.28 <sup>a</sup>	0.82 $\pm$ 0.02 <sup>a</sup>	0.52 $\pm$ 0.03 <sup>a</sup>	25.62 $\pm$ 2.40 <sup>a</sup>	39.67 $\pm$ 2.01 <sup>ab</sup>	23.67 $\pm$ 1.63 <sup>a</sup>
<297 $\mu$ m	49.22 $\pm$ 1.46 <sup>b</sup>	0.84 $\pm$ 0.02 <sup>a</sup>	0.55 $\pm$ 0.01 <sup>a</sup>	22.88 $\pm$ 1.16 <sup>a</sup>	38.05 $\pm$ 0.81 <sup>ab</sup>	20.86 $\pm$ 0.89 <sup>b</sup>
<250 $\mu$ m	58.26 $\pm$ 2.82 <sup>ab</sup>	0.87 $\pm$ 0.13 <sup>a</sup>	0.54 $\pm$ 0.02 <sup>a</sup>	27.41 $\pm$ 5.39 <sup>a</sup>	40.62 $\pm$ 1.18 <sup>a</sup>	21.65 $\pm$ 1.15 <sup>ab</sup>
<210 $\mu$ m	57.39 $\pm$ 0.79 <sup>ab</sup>	0.86 $\pm$ 0.04 <sup>a</sup>	0.56 $\pm$ 0.04 <sup>a</sup>	27.61 $\pm$ 3.37 <sup>a</sup>	38.04 $\pm$ 2.18 <sup>ab</sup>	20.68 $\pm$ 4.50 <sup>b</sup>
<177 $\mu$ m	48.18 $\pm$ 3.16 <sup>b</sup>	0.78 $\pm$ 0.03 <sup>a</sup>	0.48 $\pm$ 0.02 <sup>a</sup>	18.28 $\pm$ 2.11 <sup>a</sup>	34.07 $\pm$ 2.54 <sup>b</sup>	18.28 $\pm$ 1.15 <sup>c</sup>

<sup>1</sup>Treatments in the first experiment: 1.5% regular salt (RS1.5); 1.0% micronized salt (MS1.0); 1.0% micronized salt half in fat + half in meat batter (MS0.5+0.5); 0.75% micronized salt (MS0.75); 0.75% micronized salt half in fat + half in meat batter (MS0.375+0.375). Micronized salt was <250  $\mu$ m of particle size

<sup>2</sup>Coarse salt was not sieved through the 50-mesh sieve

Different letters on the same column represent a significant difference ( $p < 0.05$ ) between treatments in each experiment, according to Tukey's test

efficient in the retention of burger components after cooking, which means that even with the interference of fat, MS has the ability to solubilize meat proteins. This was observed by Da Rosa et al. [6], who indicated that MS mixed with fat improved protein extraction than RS.

For sensory results, overall liking results were 7.32, 7.39, 7.27, 7.20, and 7.41 for RS1.5, MS1.0, MS0.5+0.5, MS0.75, and MS0.375+0.375, respectively. No significant differences ( $p > 0.05$ ) between treatments were observed. Based on the contingency table shown in Table 2, the  $\chi^2$  test per cell revealed that RS1.5 had a high frequency of *salty*, while the same was observed for *spicy* in MS0.5+0.5. However, the number of *spicy* frequencies for all treatments is too low to declare that the size and type of salt addition in the burger has an important impact for this sensory attribute. The result of *salty* differs from results observed in other studies, where MS mixed with fat was similar or superior in salty taste than RS [3, 5, 6]. A possible explanation for the differences in our results with those reported previously may be the cultural difference of consumers. While Brazilian consumers with a high frequency of burger consumption participated in the studies of [3, 5, 6], Peruvian consumers with a low frequency of burger consumption participated in the present study (see Sect. 2.5.1). In this regard, it has been reported that the perception of food is influenced by cultural aspects and familiarity with the product analyzed [24]. Then, by knowing well the analyzed product, a better perception of the sensory characteristics is expected.

In summary, does the mixture of MS with animal fat matter? From a sensory point of view for consumers who participated in this study, the answer is no, because it does not improve the salty perception and other sensory characteristics of the burger. Although the mixture of MS with fat has the same capacity to retain components after cooking as MS added directly to the meat, it is not enough to compensate for the effect of salt reduction, which regardless of the method of MS incorporation, reduced the salty perception, hardness, and chewiness. These results suggest the search for other salt particle sizes that may be more efficient in the technological and sensory characteristics of burgers.

### 3.2 Second experiment: salt particle sizes comparison

The instrumental texture and yield properties of the second experiment are shown in Table 1. There were significant differences in hardness, cooking losses, and diameter reduction between treatments, but only the burgers with the smallest salt size ( $<177 \mu\text{m}$ ) were significantly lower ( $p < 0.05$ ) than the other treatments for diameter reduction. Furthermore, this treatment obtained the lowest hardness and cooking losses, on the contrary, the burgers with coarser salt particles

**Table 2** Contingence table of the frequencies of the sensory attributes of burgers reduced in salt content and half of the content mixed with fat

Attribute	Burger treatments <sup>1</sup>				
	RS1.5	MS1.0	MS0.5+0.5	MS0.75	MS0.375+0.375
Aromatic	20	23	20	22	17
Beef	35	40	38	39	34
Characteristic	17	20	24	22	29
Compact	8	13	10	18	12
Dry	13	12	13	8	11
Fatty	17	18	14	17	16
Grilled	26	25	23	35	29
Hard	11	9	9	6	10
Juicy	24	32	29	29	26
Off-flavor	6	6	9	2	3
Salty	31 (+)	16	19	13	14
Seasoned	36	37	31	34	41
Spicy	1	2	6 (+)	3	2
Tasty	43	45	42	37	41
Tender	40	44	42	50	48

<sup>1</sup>Treatments: 1.5% regular salt (RS1.5); 1.0% micronized salt (MS1.0); 1.0% micronized salt half in fat + half in meat batter (MS0.5+0.5); 0.75% micronized salt (MS0.75); 0.75% micronized salt half in fat + half in meat batter (MS0.375+0.375). Micronized salt was  $<250 \mu\text{m}$  of particle size

Values with (+) presented frequencies higher than the expected theoretical value according to  $\chi^2$  test per cell at  $p < 0.05$

(CS) obtained the highest mean values of hardness and diameter reduction. Similarly, Rios-Mera et al. [3] observed a decrease in hardness for MS burgers by comparing 1.5% RS and 1.5% MS. Regarding cooking losses, similar results were observed by De Araújo et al. [7], where there was a decrease in cooking losses in burgers with 1.5% MS compared to 1.5% RS; the increase in cooking losses by using CS also aligns with the results of Gaudette et al. [8], who observed an increase in cooking losses as the proportion of 3 mm salt increased in burgers. However, there were no differences in diameter reduction in the reports by De Araújo et al. [7] and Rios-Mera et al. [5] comparing RS and MS at 1.5% in burgers. In those studies, MS had a particle size of  $168.86 \pm 1.66 \mu\text{m}$ , while in this study, the particle size of MS that caused significant differences with RS for diameter reduction was  $<177 \mu\text{m}$ , suggesting that the smaller the size of salt, the smaller diameter reduction will be obtained, in other words, it will have better cooking yield.

The action of  $<177 \mu\text{m}$  salt can be understood by its rapid penetration and action on meat proteins, an effect that was observed by Aheto et al. [25] in fresh pork belly cuts, where fine flake salt (0.55 mm) had rapid dissolution and penetration compared to medium flake (2.5 mm) and large flake (5 mm) salts. Then, salt solubilizes myofibrillar proteins, positively impacting the retention of components such as fat and water [21]. The action of CS can be understood as the opposite effect to that of finer salt. Still, it can also be interpreted that in CS fewer salt crystals are solubilized, so more crystals are available for the formation of the protein gel that occurs during cooking, which provides firmness in meat products, then greater hardness and chewiness are expected [3, 20]. Therefore, from a technological point of view, the smaller salt size presented an advantage over the other particle sizes evaluated.

Overall liking results were 7.22, 7.17, 7.56, 7.31, 7.48, and 7.14 for regular salt,  $<297 \mu\text{m}$ ,  $<250 \mu\text{m}$ ,  $<210 \mu\text{m}$ ,  $<117 \mu\text{m}$ , and CS, respectively. No significant differences ( $p > 0.05$ ) between treatments were observed. The contingency table presented in Table 3 reveals that none of the sensory attributes had a significant high or low frequency of mention by consumers, which means that the salt particle sizes used in this experiment did not cause sensory changes in the burger. Regarding the *salty* taste, its decrease was expected at a smaller salt particle size, due to rapid solubilization in water compared to larger particle sizes, a hypothesis raised in products with intermediate to high moisture [3, 5, 10, 26, 27], which suggests more research to explain these discrepancies, considering the effects of the matrix, the evaluation of saltiness perception kinetics [10], and as a suggestion by the authors of this study, the cultural differences in consumption of the participants who evaluate the product.

Finally, the technological characteristics suggest the use of salt  $<117 \mu\text{m}$ , which could be a good option to reduce salt in burger and possibly in other meat products. This is reinforced by the idea that both experiments in this study showed that overall liking does not vary by salt reduction, mixing of salt with fat, and salt particle size.

**Table 3** Contingence table of the frequencies of the sensory attributes of burgers with different salt particle size

Attribute	Burger treatments					
	Regular salt, RS	CS (1 mm) <sup>1</sup>	$<297 \mu\text{m}$	$<250 \mu\text{m}$	$<210 \mu\text{m}$	$<177 \mu\text{m}$
Aromatic	32	33	33	33	28	27
Beef	39	46	42	41	46	39
Characteristic	28	32	28	30	29	30
Compact	14	13	13	15	18	13
Dry	12	10	7	13	13	15
Fatty	22	21	25	26	21	20
Grilled	29	29	34	33	31	27
Hard	5	7	6	7	8	4
Juicy	33	35	41	41	38	36
Off-flavor	3	5	5	5	5	5
Salty	18	19	21	25	22	20
Seasoned	51	53	46	52	46	52
Spicy	6	3	3	3	5	6
Tasty	43	40	47	43	51	45
Tender	52	44	48	47	44	47

<sup>1</sup>Coarse salt was not sieved through the 50-mesh sieve

## 4 Conclusion

The results suggest that salt reduction decreases the instrumental hardness and chewiness and the salty taste, but does not affect the yield properties. Mixing half the micronized salt with the fat does not improve the sensory characteristics of the burger. The choice of salt particle size does matter if the goal is to have a desired texture without negatively affecting the yield properties after cooking the burgers. Salt particles  $<117\ \mu\text{m}$  would be the most appropriate for this goal. The salt particle sizes did not affect the sensory characteristics evaluated, and in both experiments, the overall liking was greater than 7 points for all treatments. For industrial purposes, processors should consider that micronization of salt involves an additional step in the manufacturing of burgers, which, although simple, could have some implications on the cost of production. Therefore, the burger processor will choose to apply this strategy.

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**Data availability** The datasets generated during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate** All procedures performed in the sensory analysis were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Approval was granted by the Ethics Committee of University of Jaén on October 20, 2023 (OFICIO N° 04-2023/VPI-UNJ/CE).

**Informed consent** Informed consent was obtained from all individual participants included in the study.

**Competing interests** The authors declare no competing interests.

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