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Inovação

Effect of NaCl replacement on physicochemical and sensory properties of the traditional cured coppa

Efeito da substituição de NaCl nas propriedades físico-químicas e sensoriais de Copa curada tradicional

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ABSTRACT: This study aimed to reduce sodium content in pork coppa without affecting consumer acceptance. NaCl reduction, partial replacement with KCl, and reduction in salting process time were evaluated. Six treatments were performed: Standard – 100% NaCl with a 2-day salting process and a 5-day re-salting process; T1 – a mixture of 70% NaCl/30% KCl; T2, T3, T4 – mixtures of 85% NaCl/15% KCl; T5 – 100% NaCl. T1 to T5 applied a 2-day salting process and a 2-day re-salting process. All treatments complied with Brazilian sodium guidelines. No statistically significant difference in consumer acceptance was observed. A reduction of 4 days in salting and re-salting processes maintained sensory characteristics and reduced sodium content by 50%. Even with reduced salt content, no changes in physicochemical parameters or effects on product preservation and microbiological quality were observed. NaCl reduction and replacement up to 30% KCl did not affect coppa characteristics or acceptance.
Keywords: Coppa, Sodium reduction, NaCl, KCl, Acceptance.

RESUMO: *Este estudo teve como objetivo reduzir o teor de sódio em Coppa suína sem afetar a aceitação do consumidor. Foram avaliadas a redução de NaCl, a substituição parcial por KCl e a redução do tempo de processo de salga. Foram realizados seis tratamentos: Padrão – 100% NaCl com processo de salga de 2 dias e processo de re-salga de 5 dias; T1 – mistura de 70% NaCl/30% KCl; T2, T3, T4 – misturas de 85% NaCl/15% KCl; T5 – 100% NaCl. T1 a T5 aplicou-se um processo de salga de 2 dias e um processo de re-salga de 2 dias. Todos os tratamentos cumpriram as diretrizes brasileiras de níveis de sódio. Não houve diferença estatisticamente significativa na aceitação do consumidor. Uma redução de 4 dias nos processos de salga e re-salga manteve as características sensoriais e reduziu o teor de sódio em 50%. Mesmo com teor reduzido de sal, não foram observadas alterações nos parâmetros físico-químicos ou efeitos na preservação do produto e na qualidade microbiológica. A redução e substituição de NaCl até 30% KCl não afetaram as características ou aceitação do Coppa.*
Palavras-chave*: Copa, Redução de sódio, NaCl, KCl, Aceitabilidade.*

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INTRODUCTION

The processed foods and changes in the population's eating habits resulted in increased sodium consumption, exceeding the limit recommended by the World Health Organization (World Health Organization [WHO], 2016). In many countries, about 80% of dietary sodium is obtained from the consumption of processed foods. The daily recommendation is less than 5 g of salt per day, whereas Brazil has an average consumption of 12 g per day (Nilson et al., 2017; WHO, 2016). In fact, in many cases, hypertension is related to changes in salt intake, causing blood pressure increase (Koç & Baysal, 2019). Thus, the food industry recognizes the need to respond to consumer demands to reduce the level of sodium in processed products (Pan American Health Organization [PAHO], 2015).

Salt (NaCl) is an important ingredient in meat products and is responsible for some technological properties such as the ability to solubilize the myofibril, leading to better adhesion and cohesiveness of dry-cured products (matured) (Inguglia et al., 2017). It impacts flavor and texture and mainly acts as a preservative, reducing water activity (Aw) (Pretorius & Schönfeldt, 2018; Yotsuyanagi et al., 2016). The reduction of sodium content in sausages may cause lipid oxidation, texture loss, and sensory characteristics changes. Therefore, the choice of the method used for this reduction must be carefully evaluated (Inguglia et al., 2017; Wong et al., 2019).

Strategies to reduce sodium content in meat products must be carefully evaluated including the use of metallic salt, salt reducer, salt replacer, and flavor enhancer. Sodium chloride can be replaced with other salts such as potassium chloride, potassium lactate, magnesium chloride and sulfate, and calcium chloride. However, potassium chloride (KCl) is the most used because its sodium chloride has similar properties and it is not associated with the development of cardiovascular or chronic disease (Inguglia et al., 2017; Triki et al., 2017). However, the use of KCl is still limited due to negative sensory attributes (Gaudette & Pietrasik, 2017; Stanley et al., 2017). Replacing up to 50% with KCl could introduce a bitter taste to the final product (Wong et al., 2019).

Moreover, some studies demonstrated that sodium reduction affects the dry-cured meat products characteristics in terms of sensory and physicochemical aspects (Gan et al., 2019) and microbiological changes may reduce the shelf life and acceptance by consumers (Pretorius & Schönfeldt, 2018).

Sodium occurs naturally in beef, pork, and poultry at concentrations ranging from 50 to 70 mg per 100 g, consequently, processed meat products contain high sodium levels in their formulations (Wong et al., 2019). In this context, coppa is a cured, matured, and smoked product, obtained from the entire pork neck, which is subjected to the curing process through the addition of curing salts and a high sodium chloride concentration during salting and re-salting processes (Di Domenico et al., 2020; Taddei et al., 2020).

As salt is one of the main coppa preservatives, its high concentrations, increase the sodium content, which is harmful to consumers' health and intensify the salty taste. The challenge faced by the food industry concerns the consumers who accept less the highly salt meat products or the even slightly salty. On the other hand, reducing salt content makes the products more microbiological and physicochemical changes vulnerable (Aaslyng et al., 2014). The coppa is not yet included in the Brazilian agreement for the reduction of sodium in industrialized products (Instituto Brasileiro de Defesa do Consumidor [IDEC], 2014).

Previous studies showed that the salting and resalting time reduction and partial NaCl replacement by KCl was efficient in coppa technological process and the sensory evaluation complies with consumer expectations (Di Domenico et al., 2020). In order to configure the technological process, this work aimed to consolidate the salting process time and NaCl reduction by salt substitution while maintaining the physicochemical and sensory quality of Coppa.

MATERIALS AND METHODS

Experimental design and coppa manufacture

Coppa samples were manufactured on an industrial scale according to the protocols of the swine slaughterhouse located in Chapecó (Santa Catarina, Brazil). Each treatment consisted of a batch of 80 kg of pork neck. The weight of each pork neck ranged from 0.900 kg to 1.400 kg. It was previously established that the ideal sample of coppa would be that subjected to 4 days salting process and re-salting process with 35% NaCl replacement with KCl (IBRAC®) (Di Domenico et al., 2020). From these data, a centroid simplex mixtures design was performed, resulting in five different formulations (Table 1). T2, T3 and T4 consisted the center point and repetition, respectively. A standard formulation was also used as a control, which is currently prepared in the company where this study was conducted. The independent factors were NaCl (0–100%) and KCl (0–30%). The response variables mensurated were sodium content, lipid oxidation, lipids, protein, moisture, Aw, pH, nitrate and nitrite content, texture, and acceptance hedonic test. All measures were performed in triplicate.

Table 1

Real and codified independent variables according simplex-centroid mixture design.

Formulation Runs	Salting and re-salting processes (days)	Pseudo-component		Real values**	
		% NaCl (x_1)	% KCl (x_2)	% NaCl (x_1)	% KCl (x_2)
Standard	7	-	-	100	0
T1	4	0.00	1.00	70	30
T2*	4	0.50	0.50	85	15
T3*	4	0.50	0.50	85	15
T4*	4	0.50	0.50	85	15
T5	4	1.00	0.00	100	0

Standard treatment, the usual factory process, was used to compare to the others treatment; * Centroid point and Repetition; ** Percent of the ingredient in the mix of these ingredients.

Each treatment was obtained according to the experimental design (Table 1). The process consisted of subjecting the neckpieces to the dry salting process, using a blend containing commercial salt, sugar, nitrate, nitrite, clove, cinnamon, pepper, monosodium glutamate, ascorbic acid, and starters. Based on the experimental design, commercial salt was partially replaced with KCl (IBRAC®). The samples were stored in a cold chamber for 2 days/13 ºC. Then, the neckpieces were subjected to a dry re-salting process, using the same blend as the first step, except for starter culture. The samples were stored again in a cold chamber at 13 °C for more than 2 days.

Afterward, all pieces were washed in a chiller containing water at 30 to 40 °C to remove the blend of salty ingredients adhered to the surface. Subsequently, the pieces were embedded in an artificial collagen casing and subjected to natural smoking for 20 hours. Then they were kept in a maturation room for 30 days. Finally, the product was washed, casing removed, vacuum-packed, and stored at 22 °C.

Physicochemical analyses

The analyses were performed at the end of the maturation period (30 days). Therefore time 0 is after the end of maturation. Analyses of Sodium, Protein, Fat, Nitrite, Nitrate were performed only at time 0 (after the maturation period) to show reduction of NaCl and some minimum quality parameters. The analysis of moisture, oxidation Degree (TBARS), pH, Aw and texture were performed at time 0, 45, 90 and 105 days to demonstrate the behavior of these quality parameters during storage time.

All the analyses were performed in triplicate from independent samples obtained from each treatment. The coppa samples were analyzed for sodium content by the method of optical emission spectrometry with inductively coupled plasma (Association of Officiating Analytical Chemists [AOAC], 2005). The analysis was carried out using Shimadzu® equipment (Model ICPE-9000) with a reading at a wavelength of 589–592 nm. The results were expressed as mg of sodium 100 g^{-1}.

The oxidation degree was determined by the 2-thiobarbituric acid reactive substances test (TBARs). The TBARs value was estimated using a double beam UV-VIS spectrophotometer at a wavelength of 532 nm (ELICO SL-218, Andhra Pradesh, India). The results were expressed as mg of MDA (malondialdehyde) kg^{-1} (Koniecko, 1985).

Moisture was determined according to the gravimetric method in a drying oven at 105°C (AOAC, 2005). Fat content was assessed by the Soxhlet extractor method. Protein content was determined through the Kjeldahl method, converted to crude protein using the 6.25 factor (AOAC, 2005).

The nitrate and nitrite contents were determined using a spectrophotometer at 540 nm (AOAC, 2005) at storage time zero. The nitrate was converted into nitrite by reduction on a spongy cadmium column. All nitrite was quantified by the Griess-Ilosvay reaction. The results were evaluated according to the maximum concentrations allowed by Brazilian legislation and were expressed as mg kg^{-1} (Brasil, 2019).

The Aw was measured in AquaLab equipment (4TE, Decagon Devices) and pH was determined using a micro-processed bench analyzer AK 96 (AKSO). The analysis was carried out at 0, 45, 90, and 105 days after coppa maturation.

Texture profile analysis (TPA) was performed using six replicates from each treatment (cubes of 20 mm × 20 mm × 20 mm), using a texture analyzer TA.XT (Stable Microsystems Ltd., Surrey, England). Hardness, cohesiveness, elasticity, and chewiness were analyzed at 0, 45, 90, and 105 days after coppa maturation. The samples were compressed to 50% of their original height by 4 mm s^{-1} in two cycles, five seconds between the cycles, using an aluminum cylinder probe (P/40).

For microbiological analysis, thermotolerant coliforms, coagulase-positive Staphylococcus, Salmonella sp. and Listeria monocytogenes were analyzed according to methods described by APHA (Vanderzant et al., 1992).

Sensory analysis was performed by 100 untrained judges in the laboratory of the Federal University of Technology Parana. Before the test, participants read and signed an informed consent form. A 9-point structured hedonic scale was used (1 = I did not like it much; 9 = I liked it very much) to evaluate color, flavor, texture, and overall acceptability attributes (Dutcosky, 2019). The product was analyzed at 0, 45, and 90 days of storage (the time estimated for distribution and commercialization of this type of product). This study was approved by the Research Ethics Committee of the Federal University of Technology Paraná (Approval No. 02153618.0.0000.5547).

Statistical analysis

The physicochemical and sensory data were analyzed by ANOVA and Tukey test, with a 5% significance level, using the Statistica software, version 7.0 (Stat Soft Inc., Tulska OK, USA). The results were expressed as mean ± standard deviation. The response surface method was also used to assess the influence of NaCl and KCl on the responses of physicochemical parameters. To verify the correlations between the samples and the sensory data, the data set of acceptance tests was assessed using principal components analysis (PCA), and the attributes were used as variables, applying covariance = n-1, in the XLSTAT® 2014 software.

RESULTS AND DISCUSSION

Sodium content was significantly different ($p<0.05$) for all treatments in comparison with the standard. T5 and T1 had sodium concentration reduction by 50 and 36%, respectively (Table 2). These results demonstrate that the partial NaCl replacement with KCl and the salting and re-salting processes time reduction (Di Domenico et al., 2020) contributed to these results. In products such as hot dog sausage, ham, salami, and bacon, NaCl reductions between 20% and 50% caused a proportional decrease in sodium content (Aaslyng et al., 2014). NaCl Replacements of 70% and 50% with KCl in cured products such as loin and ham, respectively, were also reported (Armenteros et al., 2009).

The standard treatment showed the highest values of lipid oxidation at time 0 (Table 2). This fact may be related to their higher NaCl concentration, which possibly acted as a pro-oxidant agent (Cluff et al., 2016). Lipid oxidation increased in all treatments, except for the standard. T5 had the lowest lipid oxidation at the end of the storage period. Products often become rancid during prolonged storage (Argemí-Armengol et al., 2019).

Table 2
Physicochemical analyses, protein, fat, nitrite, nitrate, moisture, pH, Aw, Sodium content and lipid oxidation (TBARS) after 30 days of coppa maturation.

	Day	S	T1	T2	T3	T4	T5
Sodium (mg/kg)	0	3069.33 ±5.03^{a}	1972.26±143.27^{bc}	2463.68±482.58^{ab}	2189.62±134.72^{bc}	2114.12±497.35^{bc}	1504.94±170.04^{c}
Protein	0	31.95 ± 1.69^{a}	35.74 ± 2.37^{a}	31.37 ± 5.27^{a}	35.81 ± 5.50^{a}	36.47 ± 2.69^{a}	33.29 ± 2.70^{a}
Fat	0	21.00 ± 0.86^{a}	17.19 ± 2.53^{a}	18.50 ± 4.23^{a}	17.03 ± 3.14^{a}	16.44 ± 2.96a	18.22 ± 5.25a
Nitrite	0	4.14 ± 14.70^{a}	10.44 ± 5.99^{a}	6.50 ± 3.25^{a}	10.28 ± 6.72^{a}	6.21 ± 0.85a	11.52 ± 10.27a
Nitrate	0	12.59 ± 14.70^{a}	6.46 ± 1.59^{a}	14.54 ± 6.48^{a}	12.05 ± 5.68^{a}	31.83 ± 27.22^{a}	8.87 ± 5.50^{a}
Moisture	0	33.04 ± 8.93^{a}	42.11 ± 1.75^{a}	39.66 ± 1.91^{a}	38.39 ± 3.26^{a}	36.70 ± 0.27^{a}	38.46 ± 1.56^{a}
	45	37.09 ± 4.30^{a}	40.76 ± 0.82^{a}	35.97 ± 1.20^{a}	38.22 ± 2.73^{a}	36.40 ± 0.24^{a}	41.21 ± 2.15^{a}
	90	38.50 ± 1.00^{a}	39.90 ± 0.01^{a}	25.27 ± 19.03^{a}	40.48 ± 0.01^{a}	39.10 ± 0.00^{a}	39.06 ± 0.02^{a}
	105	36.76 ± 0.02^{d}	33.78 ± 0.02^{e}	40.64± 0.02^{a}	40.58 ± 0.01^{a}	39.06 ± 0.01^{b}	38.10 ± 0.02^{c}
TBARS (mg of MDA/Kg)	0	0.18 ± 0.01^{a}	0.11 ± 0.00^{b}	0.11 ± 0.01^{b}	0.09 ± 0.00^{d}	0.11 ± 0.00^{b}	0.10 ±0.01^{c}
	105	0.17 ± 0.01^{b}	0.17 ± 0.02^{b}	0.22 ± 0.01^{a}	0.17 ± 0.01^{b}	0.17 ± 0.01^{b}	0.12 ± 0.01^{c}
Aw	0	0.82 ± 0.00^{b}	0.827 ± 0.01^{b}	0.859 ± 0.01^{a}	0.812± 0.00^{b}	0.848 ± 0.00^{a}	0.862 ± 0.00^{a}
	45	0.873 ± 0.01^{a}	0.843 ± 0.00^{c}	0.835 ± 0.00^{cd}	0.799 ± 0.00^{e}	0.825 ± 0.00^{d}	0.861 ± 0.00^{b}
	90	0.837 ± 0.00^{b}	0.819± 0.00^{c}	0.807 ± 0.00^{e}	0.785 ± 0.01^{f}	0.815 ± 0.00^{d}	0.846 ± 0.00^{a}
	105	0.834 ± 0.00^{a}	0.834 ± 0.00^{a}	0.825 ± 0.00^{b}	0.808 ± 0.00^{d}	0.815 ± 0.00^{c}	0.831 ± 0.00^{a}
pH	0	5.79 ± 0.05^{a}	5.79 ± 0.08^{a}	5.87 ± 0.17^{a}	5.89 ± 0.14^{a}	5.67 ± 0.12^{a}	5.63 ± 0.08^{a}
	45	5.81 ± 0.14^{a}	6.15 ± 0.19^{a}	5.94 ± 0.17^{a}	6.11 ± 0.22^{a}	6.13 ± 0.14^{a}	5.88 ± 0.15^{a}
	90	6.16 ± 0.00^{bc}	6.34 ± 0.01^{a}	6.10 ± 0.03^{c}	6.12 ±0.03^{bc}	6.13 ±0.03^{bc}	6.18 ± 0.01^{b}
	105	6.19 ± 0.42^{a}	6.37 ± 0.06^{a}	6.15 ± 0.23^{a}	5.63 ± 0.46^{a}	6.00 ± 0.16^{a}	5.91± 0.08^{a}

S= Standard (NaCl 100% + 7 days of salting); T1 – (NaCl 70% + 30% KCL 4 days of salting); T2 – (NaCl 85% + 15% KCl + 4 days of salting); T3 – (NaCl 85% + 15% KCl + 4 days of salting); T4 – (NaCl 85% + 15% KCl + 4 days of salting); T5 – (NaCl 100% + 4 days of salting). Mean rates (n = 3) followed by their standard deviation. Means followed by the same small letter in the same column do not statistically differ at 5% significance by Tukey test ($p < 0.05$). MDA = malondialdehyde. x_1: NaCl; x_2:KCl.

A Scheffé model was obtained in the ANOVA, with an adjusted coefficient of determination (R^2aj) of 86.41 for sodium content, i.e., the model explained 86.41% (Supplementary data 1). Beholden the coefficients x_1 (NaCl) and x_2 (KCl), x_1 showed a higher contribution to the sodium content, although both showed interaction in the final sodium content of the produced coppa. For lipid oxidation, the lack of adjustment was significant for the models; however, the mean square value was equal to zero for both models, indicating that the lack of adjustment is not relevant. According to the equation, for lipid oxidation at 105 days storage, the model explained 66.90% and showed that NaCl had a higher contribution to oxidation than KCl and that their interaction had more effect on oxidation than KCl (Supplementary data 1).

The coppa nitrite and nitrate levels at the beginning of storage were no significantly different (p>0.05) between treatments (Table 2) and met the maximum limit established by Brazilian legislation (Brasil, 2019). The models obtained from ANOVA were not significant (p>0.05) and the lack of adjustment for the other analyses was not relevant, as the mean square of the pure error was equal to zero for all parameters (Supplementary data 1). The fact that the lack of fit was significant should not be considered relevant when the average square of the pure error is low (Box & Draper, 1987); therefore, the total residuals from the model are decomposed in pure error and lack of fit (Bruns et al., 2005). Nitrite and nitrate are curing salts classified as preservative substances, with the function of preventing or delaying microbial or enzymatic activity. In addition, they promote color fixation, flavor development, and aroma typical of cured meat products (Iamarino et al., 2015).

Protein and fat content had no significant difference between treatments (Table 2), corroborating studies that used KCl to NaCl replace in cured sausages (Tejada et al., 2021), cured bacon (Wu et al., 2015), and cured leg (Domínguez et al., 2016; Ferreira et al., 2009).

NaCl and KCl did not affect protein, nitrate, and nitrite, which is justified by the lack of adjustment of the model and the low value of the coefficient of determination (R^2). This fact may be related to the coppa characteristics, as each sample unit consisted of different pieces, which had high variability in the cut characteristics (pork neck cut) (Supplementary data 1).

The moisture results were not significant ($p>0.05$) between treatments up to 90 days storage and may be related to the smoking process and maturation conditions (Table 2). The maturation area conditions and the intrinsic characteristics of the raw material, due to the differences in the percentage of intramuscular fat, interfere in the loss of moisture (Price et al., 1994). There was a significant difference in moisture content between treatments at 105 days storage, and T2 and T3 lost less moisture. The standard treatment presented the lowest moisture content, indicating that higher NaCl content promotes greater coppa dehydration. Similar behavior was observed for bacon, in which the treatment added with KCl had the highest moisture value (46.1%), whereas the product containing 100% NaCl had a moisture value of 42.29% (Wu et al., 2015). These differences may occur due to the faster penetration of salt mixtures containing KCl, preventing water from leaving the meat (Aliño et al., 2009) however, for cured loin, this behavior was not observed (Armenteros et al., 2012).

There were significant differences in Aw values between treatments and met the reference value established by Brazilian legislation (≤0.90) during the storage period (Brasil, 2022b) (Table 2). The salting process contributes to reducing Aw by changing the osmotic pressure, favoring coppa stability and preservation, due to the inhibition of the development of microorganisms (Vignoto et al., 2010). The ANOVA model was not significant ($p>0.05$) and there was a lack of adjustment; however, it is of little relevance as the mean square of the pure error was zero (Supplementary data 1). NaCl and KCl had no direct correlation with this parameter. This evidences that the NaCl replacement with KCl had no negative effect on the water activity, and that the obtained values are related to the parameters of humidity, temperature, and ventilation of the room where the product was exposed, during the maturation period.

The coppa pH was not affected by the NaCl reduction and replacement with KCl ($p>0.05$) (Table 2), similarly to cured products such as bacon (Delgado-Pando et al., 2018). However, in smoked pork loin, samples with higher NaCl content had lower pH (Haddad et al., 2018). The pH values subjected to ANOVA showed that the model was not significant ($p>0.05$) and that the NaCl and KCl addition and interaction had little effect on this parameter (Supplementary data 1).

Regarding texture, the replacement of NaCl with KCl and the reduced salting time did not affect the coppa hardness (Table 3). There was only a significant difference ($p<0.05$) at 105 days of storage, comparing the treatments to the standard. Cohesiveness did not significantly differ ($p>0.05$) between treatments; however, there was a significant difference ($p<0.05$) for chewiness (45 and 105 days of storage) and elasticity (45 days of storage) (Table 3). Texture variations are strongly related to the drying and maturation of the coppa due to the loss of water during these processes and the formation of crust on the product. The reduction of NaCl in coppa, similarly to other meat products, may have increased proteolysis, leading to an increase in tenderness (Toldrá, 2007). Similar behavior of reduced hardness and chewiness was observed in cooked ham when NaCl was replaced with a salt mixture containing potassium chloride and ammonium chloride (O' Neill et al., 2018). According to the ANOVA the model was not significant ($p>0.05$) and there was a lack of adjustment ($p>0.05$); however, the mean square of the pure error was equal to zero for all parameters at all times. For hardness and chewiness, there was no difference between the effects generated by the addition of NaCl and KCl, whereas cohesiveness and elasticity did not correlate with the salts (Supplementary data 2).

Table 3

Texture profile of reduced sodium pork coppa at 0, 45, 90 and 105 days of storage period.

Source	days	S	T1	T2	T3	T4	T5
Hardness	0	8226.00 ± 1850.22[a]	8481.41 ± 1891.47[a]	7454.52 ± 1213.82[a]	8399.97 ± 2574.72[a]	8584.84 ± 2070.65[a]	8640.59 ± 1786.39[a]
	45	8480.67 ± 1933.40[a]	6912.28 ± 2263.66[a]	6552.09 ± 1570.61[a]	6428.27 ± 2116.01[a]	8944.37 ± 2983.99[a]	6357.53 ± 3267.05[a]
	90	7555.95 ± 806.30[a]	7543.69 ± 1413.54[a]	8870.34 ± 1893.94[a]	9096.83 ± 1047.14[a]	8764.44 ± 1829.23[a]	7307.45 ± 1755.07[a]
	105	7803.01 ± 2808.58[a]	3109.48 ± 1183.12[b]	3773.62 ± 1580.31[b]	4693.47 ± 2086.03[b]	5481.31 ± 2130.04[ab]	3971.83 ± 1822.94[b]
Cohesiveness	0	0.62 ± 0.05[a]	0.57 ± 0.06[a]	0.60 ± 0.04[a]	0.50 ± 0.21[a]	0.58 ± 0.24[a]	0.56 ± 0.02[a]
	45	0.60 ± 0.03[a]	0.60 ± 0.06[a]	0.56 ± 0.07[a]	0.55 ± 0.02[a]	0.58 ± 0.03[a]	0.53 ± 0.07[a]
	90	0.60 ± 0.06[a]	0.60 ± 0.04[a]	0.63 ± 0.08[a]	0.59 ± 0.04[a]	0.57 ± 0.05[a]	0.63 ± 0.05[a]
	105	0.51 ± 0.21[a]	0.52 ± 0.05[a]	0.56 ± 0.03[a]	0.53 ± 0.05[a]	0.54 ± 0.07[a]	0.58 ± 0.05[a]
Chewiness	0	4186.66 ± 979.17[a]	3623.68 ± 1205.44[a]	3226.77 ± 659.19[a]	3533.31 ± 638.29[a]	4331.64 ± 487.73[a]	3573.48 ± 539.10[a]
	45	4205.43 ± 1050.35[a]	3373.55 ± 1327.26[abc]	2682.30 ± 795.77[bc]	2687.97 ± 2116.01[bc]	3960.30 ± 936.55[ab]	2025.39 ± 647.75[c]
	90	3351.84 ± 983.69[a]	3661.17 ± 593.69[a]	3629.66 ± 1782.01[a]	4094.52 ± 737.40[a]	3934.47 ± 801.07[a]	3672.68 ± 1007.35[a]
	105	2487.10 ± 1198.02[a]	1058.67 ± 350.55[b]	1401.79 ± 529.10[ab]	1480.12 ± 624.72[ab]	1877.66 ± 830.33[ab]	1661.96 ± 754.94[ab]
Elasticity	0	0.83 ± 0.26[a]	0.73 ± 0.03[a]	0.71 ± 0.08[a]	0.67± 0.27[a]	0.71 ± 0.29[a]	0.74 ± 0.06[a]
	45	0.81 ± 0.04[a]	0.79 ±0.07[ab]	0.71 ± 0.06[bc]	0.76 ±0.06[ab]	0.79 ±0.05[ab]	0.66 ± 0.06[c]
	90	0.72 ± 0.14[a]	0.80 ± 0.04[a]	0.68 ± 0.28[a]	0.75 ± 0.06[a]	0.78 ± 0.07[a]	0.79 ± 0.05[a]
	105	0.60 ± 0.26[a]	0.65 ± 0.04[a]	0.66 ± 0.06[a]	0.60 ± 0.04[a]	0.64 ± 0.11[a]	0.71 ± 0.05[a]

S= Standard (NaCl 100% + 7 days of salting); T1 – (NaCl 70% + 30% KCL 4 days of salting); T2 – (NaCl 85% + 15% KCl + 4 days of salting); T3 – (NaCl 85% + 15% KCl + 4 days of salting); T4 – (NaCl 85% + 15% KCl + 4 days of salting); T5 – (NaCl 100% + 4 days of salting). Mean rates (n = 3) followed by their standard deviation. Means followed by the same small letter in the same column do not statistically differ at 5% significance by Tukey test (p < 0.05).

Microbiological results of thermotolerant coliforms, coagulase-positive Staphylococcus, Salmonella sp. and Listeria monocytogenes attended the limits established for microbiological sanitary Brazilian standards for food (Brasil, 2022a, 2022b).

Concerning sensory analysis, there was no significant difference between treatments for color, flavor, texture, and overall impression (Table 4). This evidences that the NaCl reduction and its replacement with KCl by up to 30% and the reduced salting process time did not interfere with the acceptance of the coppa evaluated by the panelists (Table 4). According to the ANOVA performed for T1, T2, T3, T4, and T5, the models had no significant difference (p>0.05) for the parameters and times evaluated, except for color at 45 days storage (Supplementary data 3). For the parameters color, flavor, texture, and overall impression at all times, there was a lack of adjustment to the model (p≥0.05). In the case of significant difference (p<0.05), the model should be used with caution; however, the mean square error was equal to zero, which makes the lack of adjustment a little relevant.

The PCA graph (Figure 1) shows that each vector corresponds to the independent variable and the vertices represent the dependent variables. The first main component resulted in two distinct groups. The first one is located to the left of the figure and included the independent variables color (90), texture (0), flavor (45), overall impression, and the dependent variable days of salting. Thus, the variation of salting days had a higher effect on these independent variables. The second group, on the right, included the dependent variable KCl, consequently, KCl content has a small positive influence on the dependent variables presented in the first quadrant. The second main component discriminated the independent variables in the role of NaCl content in the treatments, with 47.70% of the variation between the treatments applied. The NaCl content resulted in more positive scores represented by the sensory attributes of color, flavor, texture, and overall impression. The first main component accounted for 25.23% of the variation, which explains that the KCl content used in this study, although presenting negative scores for most of the sensory attributes, showed no significant difference (Table 4) for the sensory attributes evaluated.

Table 4

Sensory parametrs of reduced sodium pork coppa at 0, 45, 90 days of storage period.

Source	days	S	T1	T2	T3	T4	T5
Color	0	7.25 ± 1.21[a]	7.40 ± 1.22[a]	7.47 ± 1.01[a]	7.2 ± 1.37[a]	7.51 ± 1.07[a]	7.28 ± 1.32[a]
	45	7.38 ± 1.17[a]	7.57 ± 1.08[a]	7.30 ± 1.34[a]	7.07 ± 1.23[a]	7.50 ± 1.02[a]	7.28 ± 1.29[a]
	90	7.61 ± 1.14[a]	7.38 ± 1.45[a]	7.69 ± 1.00[a]	7.58 ± 1.36[a]	7.61 ± 0.93[a]	7.60 ± 1.14[a]
Flavor	0	7.25 ± 1.37[a]	7.23 ± 1.24[a]	7.3 ± 1.20[a]	6.94 ± 1.40[a]	7.05 ± 1.56[a]	6.95 ± 1.56[a]
	45	7.19 ± 1.37[a]	7.05 ± 1.56[a]	7.37 ± 1.20[a]	6.84 ± 1.47[a]	7.28 ± 1.38[a]	7.37 ± 1.26[a]
	90	7.43 ± 1.17[a]	7.17 ± 1.27[a]	6.95 ± 1.44[a]	7.15 ± 1.35[a]	7.27 ± 1.27[a]	7.05 ± 7.06[a]
Texture	0	7.00 ± 1.44[a]	6.97 ± 1.57[a]	7.33 ± 1.11[a]	6.8 ± 1.56[a]	7.16 ± 1.45[a]	7.13 ± 1.37[a]
	45	7.25 ± 1.29[a]	7.28 ± 1.31[a]	7.24 ± 1.29[a]	7.07 ± 1.35[a]	7.38 ± 1.31[a]	7.25 ± 1.33[a]
	90	7.08 ± 1.45[a]	7.25 ± 1.34[a]	7.06 ± 1.28[a]	7.06 ± 1.58[a]	7.16 ± 1.16[a]	7.05 ± 1.35[a]
Overall Liking	0	7.00 ± 1.34[a]	7.23 ± 1.19[a]	7.35 ± 1.09[a]	6.87 ± 1.34[a]	7.12 ± 1.31[a]	6.98 ± 1.39[a]
	45	7.09 ± 1.33[a]	7.07 ± 1.53[a]	7.10 ± 1.51[a]	6.83 ± 1.31[a]	7.12 ± 1.32[a]	7.18 ± 1.16[a]
	90	7.29 ± 1.06[a]	7.12 ± 1.31[a]	7.09 ± 1.16[a]	7.28 ± 1.33[a]	7.14 ± 1.23[a]	7.01 ± 1.30[a]

S= Standard (NaCl 100% + 7 days of salting); T1 – (NaCl 70% + 30% KCL 4 days of salting); T2 – (NaCl 85% + 15% KCl + 4 days of salting); T3 – (NaCl 85% + 15% KCl + 4 days of salting); T4 – (NaCl 85% + 15% KCl + 4 days of salting); T5 – (NaCl 100% + 4 days of salting). Mean rates followed by their standard deviation. Means followed by the same small letter in the same column do not statistically differ at 5% significance by Tukey test ($p < 0.05$).

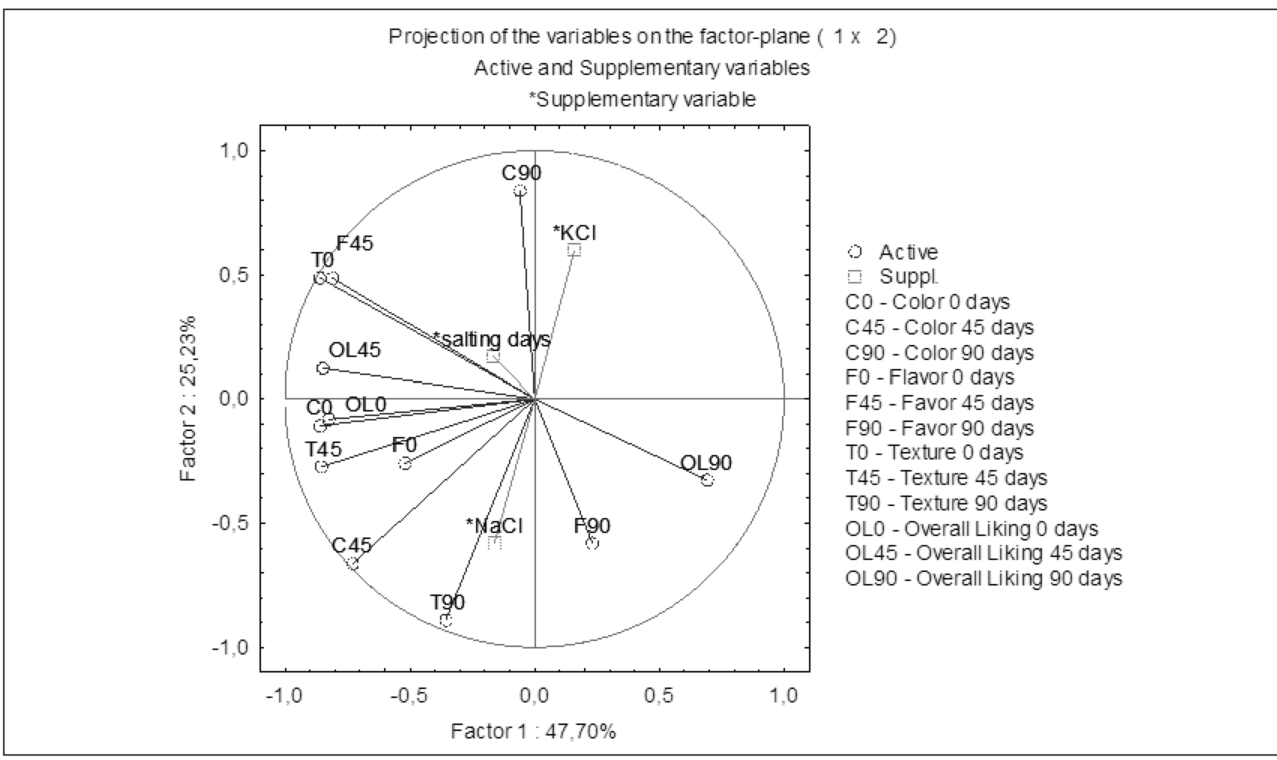

Figure 1

Principal component analysis of sensory parameters from reduced sodium pork coppa at 0, 45, 90 days of storage period

In ready-to-eat frozen roasted meat, NaCl replacement with 30% KCl showed no difference in sensory acceptance and did not affect the microbiological stability of the product (Bis et al., 2016). In bacon, up to 40%, KCl replacement had no negative effects on sensory quality, whereas the NaCl replacement with 60% KCl resulted in a less salting taste, but a bitter taste was perceived (Li et al., 2016). In Italian salami, no significant differences ($p>0.05$) were found between the formulations for color, odor, and texture; however, the tasters detected a bitter taste from KCl (Fieira et al., 2018). Products with reduced sodium content have a reduced ability to suppress the bitter taste of KCl (Gaudette & Pietrasik, 2017).

CONCLUSION

This study demonstrates the alteration of the standard process of 7 days and NaCl substitution provided a 50% reduction in sodium content in the final product. The time of 4 days in which the product was exposed to salt was effective to reduce the sodium content. The reduced NaCl content did not interfere with Coppa Aw and moisture, important parameters for the microbiological conservation of the product. There were no differences in the acceptance of Coppa swine as to its color, flavor, texture and overall impression. This demonstrates that the reduction of NaCl and its replacement by up to 30% of KCl did not affect the sensory parameters of Coppa.

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Supplementary data 1. ANOVA models for proximal composition, pH, Aw, nitrate and nitrite concentration during the storage period of reduced sodium pork coppa.

Parameter	Time (days)	Equation	R^2_{adj} (%)	p	Lack of fit (p)
Moisture	0	$ymoisture0 = 42.11 x_1 + 38.46x_2 - 8.14x1x_2$	41.53	0.27	0.00
	45	$ymoisture45 = 40.76x_1 + 41.21x_2 - 16.49x_1x_2$	87.72	0.12	0.00
	90	$ymoisture90 = 39.90x_1 + 39.06x_2 -18.12x_1x_2$	15.00	0.05	0.00
	105	$ymoisture105 = 33.78x_1 + 38.10x_2 - 16.16x_1x_2$	94.93	0.84	0.00
Protein	0	$yprotein= 35.74x_1 + 33.29x_2 + 0.14x_1x_2$	16.27	0.83	0.00
Fat		$yfat = 10.19x_1 + 18.22x_2 + 12.46x_1x_2$	95.14	0.04	0.00
Nitrate		$ynitrate = 6.47x_1 + 8.87x_2 + 47.22x_1x_2$	42.31	0.57	0.00
Nitrite		$ynitrite = 10.45x_1 + 11.53x_2 - 13.28x_1x_2$	57.52	0.42	0.00
Aw	0	$yaw0 = 0.83x_1 + 0.86x_2 - 0.02x_1x_2$	79.58	0.65	0.00
	45	$yaw45 = 0.84x_1 + 0.86x_2 - 0.13 x_1x_2$	67.22	0.33	0.00
	90	$yaw90 = 0.84x_1 + 0.84x_2 - 0.16x_1x_2$	79.58	0.20	0.00
	105	$yaw105 = 0.83x_1 + 0.83x_2 - 0.01x_1x_2$	69.40	0.30	0.00
pH	0	$ypH0 = 5.79x_1 + 5.63x_2 + 0.39x_1x_2$	45.62	0.54	0.00
	45	$pH45 = 6.15x_1 + 5.88x_2 + 0.25x_1x_2$	57.81	0.42	0.00
	90	$ypH90 = 6.34x_1 + 6.18 x_2 - 0.56x_1x_2$	98.14	0.02	0.00
	105	$ypH105 = 6.37x_1 + 5.91x_2 - 0.84 x_1x_2$	52.53	0.47	0.00

x_1: NaCl; x_2:KCl; R^2adj: Adjusted R Squared, p: ($p < 0.05$); Lack of fit (p): ($p < 0.05$)

Supplementary data 2. ANOVA models for texture profile of reduced sodium pork coppa at 0, 45, 90 and 105 days of storage period.

Parameter	Time (days)	Equation	R^2_{adj} (%)	p	Lack of Fit (p)
Hardness	0	$y_{hardness0} = 8484x_1 + 8640x_2 - 1658x_1x_2$	22.94	0.77	0.00
	45	$Y_{hardness45} = 6912x_1 + 6357x_2 + 2693x_1x_2$	14.78	0.85	0.00
	90	$Y_{hardness90} = 7543x_1 + 7307x_2 + 5939x_1x_2$	97.89	0.02	0.00
	105	$Y_{hardness105} = 3109x_1 + 3971x_2 + 4435x_1x_2$	55.84	0.44	0.00
Cohesiveness	0	$Y_{cohesiveness0} = 0.57x_1 + 0.56x_2 - 0.02x_1x_2$	18.50	0.98	0.00
	45	$y_{cohesiveness45} = 0.60x_1 + 0.53x_2 - 0.00x_1x_2$	85.58	0.14	0.00
	90	$y_{cohesiveness90} = 0.60x_1 + 0.63x_2 - 0.07x_1x_2$	26.50	0.73	0.00
	105	$y_{cohesiveness105} = 0.53x_1 + 0.59x_2 - 0.03x_1x_2$	72.74	0.27	0.00
Chewiness	0	$Y_{chewiness0} = 3623x_1 + 3573x_2 + 394x_1x_2$	19.50	0.98	0.00
	45	$Y_{chewiness45} = 3373x_1 + 2025x_2 + 1642x_1x_2$	50.62	0.49	0.00
	90	$Y_{chewiness90} = 3661x_1 + 3672x_2 + 877x_1x_2$	34.12	0.66	0.00
	105	$Y_{chewiness105} = 1058x_1 + 1661x_2 + 904x_1x_2$	65.15	0.35	0.00
Elasticity	0	$y_{elasticity0} = 0.73x_1 + 074x_2 - 0.13x_1x_2$	50.83	0.50	0.00
	45	$y_{elasticity45} = 0.79x_1 + 0.66x_2 + 0.13x_1x_2$	72.84	0.27	0.00
	90	$y_{elasticity90} = 0.80x_1 + 0.79x_2 - 0.23x_1x_2$	44.23	0.55	0.00
	105	$y_{elasticity105} = 0.66x_1 + 0.71x_2 - 0.19 x_1x_2$	68.98	0.31	0.00

x_1: NaCl; x2:KCl; R^2_{adj}: Adjusted R Squared, p: ($p < 0.05$); Lack of fit (p): ($p < 0.05$)

Supplementary data 3. ANOVA models for sensory parametrs of reduced sodium pork coppa at 0, 45, 90 days of storage period.

time (days)	equation	R^2_{adj} (%)	p	Lack of Fit (p)
0	$y_{color0} = 7.39x_1 + 7.27x_2 + 0.22x_1x_2$	16.37	0.84	0. 00
	$Y_{flavor0} = 6.95x_1 + 7.23x_2$	37.52	0.27	0.97
	$y_{texture0} = 7.13x_1 + 6.97x_2 + 0.19x_1x_2$	95.00	0.91	0.00
	$y_{overall\ impression0} = 6.99x_1 + 7.3x_2$	20.68	0.44	0.96
45	$y_{color45} = 7.28x_1 + 7.40x_2 + 0.21x_1x_2$	15.73	0.00	0.59
	$Y_{flavor45} = 7.34x_1 + 7.02x_2$	23.85	0.41	0.87
	$y_{texture45} = 7.25x_1 + 7.28x_2 - 0.014\ x_1x_2$	38.30	0.96	0.00
	$Y_{overall\ impression45} = 7.06x_1 + 7.07x_2 - 0.019x_1x_2$	51.60	0.72	0.00
90	$Y_{color90} = 7.6x_1 + 7.38x_2 + 0.55x_1x_2$	75.63	0.13	0.00
	$Y_{flavor90} = 7.06x_1 + 7.17x_2$	12.06	0.57	0.94
	$Y_{texture90} = 7.06x_1 + 7.22x_2$	54.04	0.09	0.39
	$Y_{overral\ impression90} = 7.01x_1 + 7.12x_2 + 0.42x_1x_2$	49.84	0.50	0.00

x_1: NaCl; x_2:KCl; R^2_{adj}: Adjusted R Squared, p: ($p< 0.05$); Lack of fit (p): ($p < 0.05$)