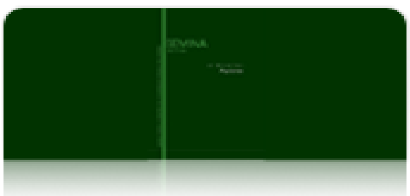

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Partial substitution of sodium chloride in Toscana sausages and the effect on product characteristics

Substituição parcial de cloreto de sódio em linguiça Toscana e os efeitos nas características do produto

Diogo Seganfredo[1]; Sidnei Rodrigues[1]; Daneysa Lahis Kalschne[2]; Cleonice Mendes Pereira Sarmento[3]; Cristiane Canan[3*]

Abstract

High sodium intake has been linked with problems of hypertension and in Brazil, it still has above that recommended by the World Health Organization. Meat products contribute 20–30% of sodium intake in the diet, indicating the necessity of reducing the amount of sodium added. The aim of this study was to reduce the sodium content in Toscana sausages by partial replacement of sodium chloride with PuraQ Arome NA4 substitute, and to evaluate the effect on physico-chemical and microbiological parameters and sensory acceptability. Three formulations – one control (T1), and one with 20% (T2) and another with 30% (T3) sodium reduction compared with the control – were produced. For comparative purposes, the physico-chemical, microbiological and sensory parameters were determined. In the proposed formulations with 20% and 30% reduction, the sodium contents were 857.3 mg 100 g^{-1} (T2) and 790.3 mg 100 g^{-1} (T3), compared with 926.7 mg 100 g^{-1} in T1. The produced samples were in accordance with the physico-chemical (moisture, lipid, protein and calcium) and microbiological (*Salmonella*, coagulase-positive *Staphylococcus*, and sulphite-reducing *Clostridium* and Coliforms at 45°C) parameters stipulated by Brazilian law. The analysis of lightness and hue indicated that the sample T3 had a more intense red colour, while T1 had a less intense red colour. In the shear force evaluation, no difference was observed between the samples. The sample T2 was the most preferred in the ordering of preference test; however, in the hedonic scale, there was no difference between the means of sensory values for roast colour, aroma, texture, flavour and overall impression, indicating that all samples had adequate sensory acceptance. Acceptability levels were greater than 74.6% for all attributes evaluated in T1, T2 and T3.

Key words: Fresh sausage. Ordering of preference. Sensory acceptance. Sodium reduction. Sodium substitute.

Resumo

O consumo elevado de sódio tem sido relacionado com problemas de hipertensão arterial e, no Brasil, ainda tem-se um consumo acima do recomendado pela Organização Mundial da Saúde. Os produtos cárneos têm contribuído com 20 a 30% do sódio ingerido na dieta, indicando a necessidade de redução no sódio adicionado. O objetivo do presente estudo foi reduzir o teor de sódio em linguiça Toscana por meio da substituição parcial do cloreto de sódio (NaCl) pelo substituto PuraQ Arome NA4 e avaliar

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o efeito deste aditivo na aceitação sensorial da linguiça Toscana. Foram elaboradas três formulações, uma controle (T1), uma com 20% (T2) e outra com 30% (T3) de redução de sódio, em comparação à primeira (T1). Para efeitos comparativos, os parâmetros físico-químicos, microbiológicos e sensoriais foram determinados. Nas formulações com proposta de 20% e 30% de redução, o teor de sódio foi 857,3 mg 100 g^{-1} (T2) e 790,3 mg 100 g^{-1} (T3), comparados com 926,7 mg 100 g^{-1} em T1. As formulações elaboradas atenderam os critérios físico-químicos (umidade, lipídio, proteína e cálcio) e microbiológicos (*Salmonella*, *Staphylococcus* coagulase positiva, *Clostridium* sulfito redutor e Coliformes a 45 ºC) estipulados na legislação brasileira. A análise dos parâmetros luminosidade e tonalidade cromática indicaram que a amostra T3 foi a de cor vermelha mais intensa, enquanto T1 a de cor vermelha menos intensa. Na avaliação da força de cisalhamento, não foi verificada diferença entre as amostras. A amostra T2 foi a mais preferida no teste de ordenação da preferencia, entretanto na escala hedônica não houve diferença entre os valores sensoriais médios para a cor assada, aroma, textura, sabor e impressão global, indicando que todas as amostras foram sensorialmente aceitas. Os índices de aceitabilidade foram superiores a 74,6% para todos os atributos avaliados em T1, T2 e T3.

Palavras-chave: Linguiça frescal. Ordenação da preferência. Aceitação sensorial. Redução de sódio. Substituto de sódio.

Introduction

Pork sausages are the oldest meat processed products and are enjoyed by millions of consumers worldwide (WENJIAO et al., 2014). Pork fresh sausages alone, in Brazil in 2011, represented 32.8% of pork meat purchases (ABIPECS, 2012). Toscana sausages are defined as a raw and cured product that is composed exclusively of pork meat, pork fat and ingredients (BRASIL, 2000), and is one of the main sausages prepared with this meat.

Meat products are an important source of sodium in the human diet, representing 20% to 30% of the daily intake (WIRTH, 1991; HENDERSON et al., 2003). In sausages, additions exceeding 2 g sodium chloride (NaCl) per 100 g^{-1} of sausage are used (JIMÉNEZ-COLMENERO et al., 2001). Bernardi and Roman (2011a) reported sodium levels of between 1100 and 2657 mg 100 g^{-1} in Toscana sausages.

In Brazil, the daily average sodium intake is 4.1 g sodium per person (SARNO et al., 2013), which is higher than the maximum level of 2 g sodium (equivalent 5 g NaCl) per person that is recommended by the World Health Organization (WHO) (WHO, 2012). These data are worrisome, considering that high sodium intake is associated with increased blood pressure (ZHAO et al., 2011; WHO, 2012), stroke, left ventricular hypertrophy and kidney disease (HE; MACGREGOR, 2010).

NaCl is an important ingredient in meat processing because it increases flavour and texture, and it contributes to the extraction of myofibrillar proteins, thus increasing the water retention capability, gel and emulsion formation, and osmotic pressure, and inhibiting microbial growth, thus avoiding deterioration of the meat product (STRASBURG et al., 2010), and therefore cannot be eliminated completely. However, intake in the diet must be reduced, and for this purpose several ingredients have emerged that keep the saltiness characteristics of NaCl, called sodium substitutes. The NaCl is largely replaced by potassium chloride (KCl). However, the addition of KCl in certain amounts may cause undesirable sensory changes, such as a metallic or bitter taste and astringency (GOU et al., 1996; DESMOND, 2006; MA et al., 2013).

Besides the KCl, other ingredients such as $CaCl_2$ (MA et al., 2013; SANTOS et al., 2015), phosphates (RUUSUNEN; PUOLANNE, 2005), transglutaminases (TSENG et al., 2000) and lactate (GOU et al., 1996) have been reported.

Recently, a sodium substitute called PuraQ Arome NA4 (Corbion-Purac) was released, which consists of sugars, salts of organic acids and aromas obtained from the controlled fermentation of sugarcane. The PuraQ Arome NA4 is considered a natural flavour that is able to mimic the taste of meat and to control the water activity, which reduces the rate of microbial growth (WILSON et al., 2012).

Considering the high consumption of meat sausages, studies of sodium-content reduction are important to improve the quality of the population's diet (CARRARO et al., 2012). However, NaCl is an essential ingredient in the meat industry, and a reduction in the content cannot occur without a detailed evaluation of the effects on sensory acceptance and microbiological stability. The aim of this work was to reduce the sodium content in Toscana sausages through partial substitution of NaCl with PuraQ Arome NA4, and to evaluate the physico-chemical, microbiological and sensory qualities of the elaborated formulations.

Materials and Methods

The Toscana sausage formulations (Table 1) were prepared in a slaughterhouse located in the West of Paraná. In preparing the curing salt, NaCl, condiment, cochineal carmine and PuraQ Arome NA4 were added to water. The pork meat and fat were ground into 10 mm discs and added to the brine, and mixed for 3 min. The emulsifier and sodium erythorbate were added to the dough and mixed for 3 min. The final dough temperature was 6 ± 1°C, and remained curing for 6 h in a cold room at 8 ± 1°C. The sausages were embedded in natural pork casings of 30-34 mm diameter, and packaged in sealed polyethylene packages of 1 kg. The packages went into the freezing tunnel to reach –18°C internally, and then were placed in cold storage at –18°C until analysis.

Table 1. Formulations of control (T1), and formulations with 20% (T2) and 30% (T3) reduced sodium.

Raw materials/Ingredients	T1 (%)	T2 (%)	T3 (%)
Lean pork retail[1]	70.29	69.75	69.99
Fat pork retail[2]	15.00	15.00	15.00
Fat of pork leg and belly	8.00	8.00	8.00
Water	3.00	2.00	2.00
PuraQÒ Arome NA4 (Corbion-Purac)	-	2.00	2.00
Salt – NaCl (Diana)[3]	1.50	1.04	0.80
Sausage condiment (Fuchs)[4]	0.50	0.50	0.50
Curing salt (Kerry)[5]	0.50	0.50	0.50
Sodium erythorbate (Kerry)	0.20	0.20	0.20
Sausage emulsifier (Kerry)	1.00	1.00	1.00
Cochineal carmine (Kerry)	0.01	0.01	0.01
Total formulation	100.00	100.00	100.00
Total NaCl (theoretical)	2.33	1.87	1.63

1: Average of 25% lipid; 2: average of 50% lipid; 3: 99.2% NaCl; 4: 70% NaCl; 5: 97% NaCl and 3% sodium nitrite; Total theoretical NaCl added to each formulation was based on the sum of NaCl present in the salt, condiment and curing salt.

The weight loss after thawing (WLT) was performed by weighing samples frozen at –18ºC (W1) and after 20 h of equilibration of temperature in the refrigerated chamber at 8ºC (W2). The analysis was performed in triplicate, and the calculation was performed according to the equation: WLT = (W1-W2) / W1 * 100. Weight loss on cooking (WLC) was performed by weighing samples before (W3) and after cooking (W4) in a preheated electric oven at 250°C (model 10537-13368, Fisher, Brusque, BR) for 75 min, ensuring that the temperature at the geometric centre of the product reached at least 72°C. The analysis was performed in triplicate, and the calculation was performed according to the equation: WLC = (W3-W4) / W3 * 100.

The moisture content, lipid, protein, calcium, chloride and pH were analysed according to the methodologies of Normative Instruction (NI) n° 20 of 06/21/1999 (BRASIL, 1999), and sodium (INSTITUTO ADOLFO LUTZ, 2005) was analysed by atomic emission spectroscopy using a flame photometer (FC-180 model, Celm, São Paulo, BR). Water activity (Aw) was determined using a water activity meter (model DCG-40530, Decagon, WA, USA). All the analyses were performed in triplicate.

The colour measurements were performed on the surface of thawed raw sausages and by reading at five different points per sample using a colorimeter (model CR400, Konica Minolta, NJ, USA) with an integrating sphere and 45° viewing angle (lighting d/45 and illuminating D). The values obtained were lightness (L*), chroma (C*), which refers to colour saturation, and hue (hº).

The instrumental texture analysis was performed in a texturometer (model TA.XT/Plus/50, Stable Micro System, Godalming, UK) calibrated with a 5 kg load cell. The samples were cut into 12 cylinders of 20 mm in length and subjected to shear force determination (probe: HDP/WBV; test speed: 2.0 mm s^{-1}; penetration into the sample: 30 mm; applied force: 5 g). To evaluate the resistance to bite, 21 sausages were standardised with 10 mm long (probe: HDP/VB; test speed: 2.0 mm s^{-1}; sample penetration: 25 mm; applied force: 5 g).

Microbiological analyses were performed in triplicate at the beginning of the period of validity for the count of mesophilic aerobic bacteria, moulds and yeasts, coagulase-positive *Staphylococcus*, and sulphite-reducing *Clostridium* following NI n° 62 of 08/26/2003 (BRASIL, 2003) and the count of Coliforms 45°C was performed with Petrifilm methodology approved by AFNOR (3M-01/2-09/89/C). *Salmonella* spp. research test was performed according to the methodology approved by AFNOR (BIO-12/16-09/05).

Sensory analysis was performed according to the ethical precepts (CEP-UEL, CAAE 13086413.5.0000.5547, project 243.376) in individual booths with 60 untrained judges. The samples were thawed and baked (as indicated in WLT and WLC), cut into rings of approximately 1 cm thick, and served heated in white plastic plates coded with three random digits. Mineral water was served between samples to eliminate the aftertaste and for cleaning of the palate. The ordering of preference test was used, which asked the judges to evaluate the three samples and to indicate a preference in descending order (from most to least preferred). The test of hedonic scale ranged from "extremely disliked" (1) to "like extremely" (9) and was applied to evaluate the attributes of colour, appearance, texture, flavour and overall impression by a monadic evaluation of samples. The acceptability index (AI) was calculated according to the equation (TEIXEIRA et al., 1987): AI = average grade / highest score * 100. An experimental randomised block design considering the samples and the judges as a source of variation was used.

The results were analysed by ANOVA and Tukey test (Statistica 8.0, Statsoft Inc., Tulsa, OK, USA). The ordering of preference test was analysed according to a Christensen Table (DUTCOSKY, 2013), where to get a significant difference between samples, the sum of grades assigned for each sample should have a minimum difference of 22 when considering 60 assessments ($p \leq 0.05$).

Results and Discussion

Physico-chemical quality

Formulation T1 had the lowest WLT, while the largest WLT was observed for T2 ($p \leq 0.05$). The WLC was statistically similar for the three formulations ($p \geq 0.05$; Table 2). The ability to bind, immobilise and retain endogenous and exogenous water in the processed meat is assigned to myofibrillar proteins, which are influenced by the meat ingredients (STRASBURG et al., 2010). NaCl is an essential ingredient, which stands between the myofibrillar proteins while keeping the myofibrils spaced, allowing greater water retention (PEREDA et al., 2005). Due to the effect of NaCl, higher water retention was expected in T1 formulation (without reduction of NaCl).

Maia Junior (2013) produced fresh sausages with sheep meat with 31% lipid-content reduction and, at the same time, 25% and 50% sodium reduction by substituting NaCl for KCl, compared with a formulation without reduction that contained 2.20% NaCl. The control formulation WLC was 26.47%, which was lower than the 33.64% and 30.68% reported for the formulations with 25% and 50% sodium reduction, respectively.

Table 2. Results of the physico-chemical analyses of the formulation control (T1), and formulations with 20% (T2) and 30% (T3) reduced sodium.

Physico-chemical parameter	Legislation[1]	T1	T2	T3
WLT (%)[2]	-	$0.3^{a} \pm 0.1$	$0.8^{b} \pm 0.1$	$0.6^{ab} \pm 0.2$
WLC (%)[3]	-	$39.3^{a} \pm 2.4$	$41.4^{a} \pm 1.9$	$43.4^{a} \pm 2.3$
Moisture (%)	Max. 70%	$62.5^{b} \pm 0.8$	$66.3^{a} \pm 0.4$	$67.5^{a} \pm 0.4$
Lipid (%)	Max. 25%	$19.6^{a} \pm 1.0$	$13.6^{b} \pm 0.2$	$12.2^{b} \pm 0.6$
Protein (%)	Min. 12%	$13.6^{c} \pm 0.4$	$15.3^{b} \pm 0.2$	$16.3^{a} \pm 0.2$
Chloride (%)	-	$2.3^{a} \pm 0.1$	$2.1^{ab} \pm 0.1$	$1.9^{b} \pm 0.2$
Sodium (mg 100 g^{-1})	-	$926.7^{a} \pm 22.0$	$857.3^{ab} \pm 44.5$	$790.3^{b} \pm 27.7$
Aw	-	$0.967^{b} \pm 0.004$	$0.982^{a} \pm 0.006$	$0.970^{b} \pm 0.003$
Calcium (dry base) (%)	Max. 0.1%	$0.05^{a} \pm 0.01$	$0.05^{a} \pm 0.03$	$0.03^{a} \pm 0.01$
pH	-	$5.88^{a} \pm 0.02$	$5.81^{b} \pm 0.02$	$5.82^{b} \pm 0.02$
L*	-	$61.0^{a} \pm 2.2$	$55.7^{b} \pm 1.5$	$49.8^{c} \pm 2.3$
C*	-	$14.2^{a} \pm 1.9$	$15.4^{a} \pm 2.5$	$14.9^{a} \pm 2.1$
h^0	-	$42.0^{a} \pm 2.9$	$36.2^{b} \pm 3.2$	$28.5^{c} \pm 2.4$
Resistance to bite (N)	-	$10.1^{a} \pm 1.6$	$11.8^{b} \pm 2.0$	$11.3^{ab} \pm 1.9$
Shear force (N)	-	$24.9^{a} \pm 2.7$	$26.0^{a} \pm 3.6$	$24.8^{a} \pm 3.1$

1: NI n° 4 of 03/31/2000 (BRASIL, 2000); 2: weight loss after thawing; 3: weight loss on cooking; Mean ± standard deviation (n=3; except for L*, C* and h^0 n=5; resistance to bite n=21; and shear force n=12). Means with different superscript letters on the same line have significant difference ($p \leq 0.05$).

The moisture contents of T2 and T3 were higher than that of T1, while the lipid contents of T2 and T3 were lower than that of T1 (Table 2). The protein content was higher in formulation T3, followed by T2 and T1 (Table 2). Variations in moisture, lipid and protein content are likely correlated with variations in the raw material.

In Toscana-type sausage samples, Paulino et al. (2006) reported a moisture content of 52.65% for the control and 59.10% for a sample with 25% sodium and lipid reduction. For the same formulations, the lipid content was 28.43% and 19.08%, while the protein content was 16.11% and 17.28%, respectively. The moisture reported by these authors was lower than that obtained in the present work, while the lipid content and protein values were higher.

The chloride content was higher in formulation T1, followed by T2 and T3, but only the T3 content was statistically different from T1. A higher content of chloride was expected for T1, because T2 and T3 had a gradual reduction in NaCl, and the sodium substitute employed did not have chloride in its composition. Similarly, Aaslyng et al. (2014) reported a significant decrease in chloride content of sausages with reduced NaCl. Control formulation had 2.19% chloride, while formulations containing 0.5% and 1% less NaCl had 1.74% and 1.23% chloride, respectively.

The sodium content of T1 and T2 was similar (926.7 and 857.3 mg 100 g^{-1}, respectively), whereas the sodium content of T3 was statistically lower than T1 (790.3 mg 100 g^{-1}). Theoretically, the sodium level was reduced by 20% (T2) and 30% (T3), but in fact, there was a reduction of 7.5% (T2) and 14.7% (T3) compared with T1 considering the results of analyses for sodium. Triki et al. (2013) reported 38% sodium reduction in fresh Merguez sausages (a kind of sausage of North Africa) when comparing a control formulation (630.7 mg 100 g^{-1}) with a formulation whose NaCl was partially substituted by a mixture of KCl, calcium chloride and magnesium chloride (391.0 mg 100 g^{-1}). The sodium reduction obtained by these authors was higher than that reported in the present work, but the type of sausage and the sodium substitute employed were different.

Aw was higher in formulation T2, which differed from T1 and T3. Many sodium substitutes can give a salty taste, though not all act by reducing Aw as NaCl does. The PuraQ Arome NA4 is supposed to give a salty taste and to ensure the reduction of Aw (CORBION-PURAC, 2013); however, T2 had a higher Aw than T1. Silva et al. (2014) reported lower Aw values in Toscana sausages (0.952 to 0.968) than those determined in this work. Differences in Aw can be directly linked to food product composition.

The calcium content was similar for all formulations (Table 2), and all met the Brazialian legislation (BRASIL, 2000). In Toscana sausage manufacture, mechanically deboned meat is prohibited (BRASIL, 2000), and so it is important to analyse calcium content to identify potential fraud, because according to Souza et al. (2003), how much mechanically deboned meat is added higher is the calcium content of meat products.

The pH of the formulation T1 (5.9) was higher than that of T2 and T3 (both 5.8). Results of pH that were slightly higher than determined in this work were reported by Silva et al. (2014) in Toscana sausage samples, ranging from 6.07 to 6.10 on the first day after manufacture.

The lightness (L*) was higher in formulation T1, followed by T2 and T3. How lower L* is, more dark the samples are, than T3 and T2 had lower L*, which corresponds to an intense red colour. Bradley et al. (2011) reported lower L* values (47.6 to 50.4) than those obtained in the present work, indicating fresh pork sausage samples produced by them had a more intense red colour.

The chroma (C*) is the colour saturation, and was similar between samples. The hue (h^0) was lower in the formulation T3, followed by T2 and T1. At angles of 0° and 90°, the predominant colour is red and yellow, because h^0 reported for T3 is the closest to 0° there was a greater amount of red in this sample, followed by T2 and T1. Therefore, sample T3 had a more intense red colour, while T1 had a less intense red colour. As mentioned above, the pH of T2 and T3 was lower than that of T1 and, according to Milani et al. (2003), the pH of the sausage exerts direct influence on their conservation and colour.

The instrumental evaluation of texture showed that T2 had a greater resistance to bite than T1, but not T3. However, the shear force was similar between formulations (Table 2). Similarly, Araújo (2012) reported no significant difference ($p>0.05$) in shear force between control fresh sausage samples of chicken and samples with different levels of substitution of NaCl by KCl and a mix of basil, oregano and rosemary.

Microbiological quality

All formulations analysed met the microbiological criteria of Brazilian legislation (Table 3) (BRASIL, 2001). *Salmonella* spp. was not detected on the formulations. The count of coagulase-positive *Staphylococcus* was $<10^2$ CFU g^{-1}, while the count of sulphite-reducing *Clostridium* and Coliforms at 45°C were $<10^1$ CFU g^{-1} for T1, T2 and T3. Similarly, Bernardi and Roman (2011a) reported no *Salmonella,* and counts of *Staphylococcus aureus* and Coliforms at 45°C were $<1.0x10^1$ CFU

g^{-1} in Toscana sausages without NaCl, and with 0.67% NaCl. Maia Junior et al. (2013) produced fresh pork sausages with addition of 1.8% NaCl (control) and with 1.8% of light salt (NaCl/KCl). They found no presence of *Salmonella* spp. and no growth of *Staphylococcus aureus*, sulphite-reducing *Clostridium* and Coliforms at 45°C in the samples.

The count of mesophilic aerobic bacteria was $1.2x10^3$ CFU g^{-1} in sample T1, followed by $3.0x10^3$ CFU g^{-1} in T2 and $5.0x10^3$ CFU g^{-1} in T3. Similarly, Bernardi and Roman (2011a) obtained $3.0x10^3$ CFU g^{-1} of mesophilic aerobic bacteria in Toscana sausages without added NaCl and $2.4x10^3$ CFU g^{-1} in the sausages with 0.67% NaCl.

The count of moulds and yeasts was $<10^2$ CFU g^{-1} for T1, T2 and T3. Aaslyng et al. (2014) evaluated the effect of NaCl reduction in meat products stored at 5°C. They reported counts of mould and yeasts of $<10^1$ CFU g^{-1} for samples of sausage, ham and salami after 29, 28 and 60 days of storage, respectively. These results suggest there was no growth of this group of microorganisms due to the NaCl reduction.

Table 3. Results of microbiological analyses of control formulation (T1), and formulations with 20% (T2) and 30% (T3) reduced sodium.

Microbiological parameters	Legislation[1]	T1	T2	T3
Salmonella spp. (in 25 g)	Absence	Absence	Absence	Absence
Coagulase-positive *Staphylococcus* (CFU g^{-1})[2]	$5x10^3$	$<10^2$	$<10^2$	$<10^2$
Sulphite-reducing *Clostridium* (CFU g^{-1})	$3x10^3$	$<10^1$	$<10^1$	$<10^1$
Coliform at 45ºC (CFU g^{-1})	$5x10^3$	$<10^1$	$<10^1$	$<10^1$
Mesophilic aerobic bacteria (CFU g^{-1})	-	$1.2x10^3$	$3.0x10^3$	$5.0x10^3$
Moulds and yeasts (UFC g^{-1})	-	$<10^2$	$<10^2$	$<10^2$

1: RDC n° 12 01/02/2001 (BRASIL, 2001); 2: colony-forming unit per gram of sample. Results expressed as mean (n=3).

Sensory quality

The ordering of preference test showed that T2 was the most preferred sample, and significantly differed from T1 and T3 ($p \leq 0.05$). In contrast, the formulations did not differ ($p \leq 0.05$) when evaluated by hedonic scale for the attributes of roast colour, aroma, texture, flavour and overall impression (Table 4). The acceptability index was greater than 74.6% for all attributes evaluated in T1, T2 and T3, indicating that all samples were sensorially acceptable, because the minimum limit for AI is 70% for sensory acceptance (TEIXEIRA et al., 1987). As the sample T2 had the highest average values in the sensory acceptance test, T2 also obtained the highest AI.

Bernardi and Roman (2011b) obtained AI values of 81%, 82%, 83% and 85% for flavour, aroma, colour and texture of Toscana sausages with 0.67% NaCl added. These AI values were similar to those obtained for the T2 formulation (with 1.87% NaCl added), i.e. 82.6%, 80.2%, 78.2% and 83.9% for flavour, aroma, colour and texture.

Table 4. Results of sensory analyses of control formulation (T1), and formulations with 20% (T2) and 30% (T3) reduced sodium.

Sensory parameters	T1	T2	T3
		Ordering of preference test	
Sum	110^{b}	139^{a}	111^{b}
		Hedonic scale	
Roasted colour	$6.7^{a} \pm 1.5$	$7.0^{a} \pm 1.4$	$7.0^{a} \pm 1.3$
Aroma	$6.9^{a} \pm 1.7$	$7.2^{a} \pm 1.3$	$7.0^{a} \pm 1.5$
Texture	$7.3^{a} \pm 1.5$	$7.6^{a} \pm 1.0$	$7.1^{a} \pm 1.6$
Flavour	$7.1^{a} \pm 1.5$	$7.4^{a} \pm 1.2$	$7.1^{a} \pm 1.2$
Overall impression	$7.2^{a} \pm 1.4$	$7.4^{a} \pm 1.3$	$7.2^{a} \pm 1.3$
		Acceptability index	
Roasted colour	74.6%	78.2%	77.6%
Aroma	76.1%	80.2%	77.6%
Texture	81.3%	83.9%	78.7%
Flavour	78.7%	82.6%	78.3%
Overall impression	79.4%	82.4%	79.6%

Ordering of preference test: sums with different letters superscript in the same line have a statistical difference ($p \leq 0.05$); Hedonic scale: mean of sensory values ± standard deviation (n=60); means with different superscript letters on the same line have a significant difference ($p \leq 0.05$).

Conclusions

The sodium content was significantly lower ($p \leq 0.05$) in sausages with reduced NaCl. However, the formulations with a theoretical 20% and 30% sodium reduction, in fact, led to only a 7.5% and 14.7% reduction compared with the control. All formulations met the physico-chemical and microbiological criteria of Brazilian legislation. Sensory acceptance was obtained for all samples, but the sample with a theoretical 20% reduction in sodium was the most preferred. Therefore, the PuraQ Arome NA4, when applied at a concentration of 2% and combined with a 20% reduction in the NaCl added, allowed to obtain a product with reduced sodium content that met the legal criteria and was sensorially accepted by consumers.

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