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Sodium and nitrite reduction in ham by home hydric methods

SALINAS- Tania†`, FRANCO- Talía`, NAVARRO- Gerardo`, PAREDES- Adriana`, RODRÍGUEZ- Lizbeth`, ROSAS- Mariana`, SALCEDO- Patricia`, GÁLVEZ- Javier*`, GALLEGOS- Saúl``

` Centro Universitario de Ciencias de la Salud. Universidad de Guadalajara.
`` Centro Universitario de Ciencias Exactas e Ingenierías. Universidad de Guadalajara.

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Ham is a product highly consumed by society; however it contains some elements that make it a non-recommended food. Thus, it has been attempted to eliminate or reduce those components. Materials and methods: To compare sodium and nitrites contents after processes of washing, soaking, simple cooking and double cooking applied to turkey and pork ham samples in a cross-sectional analytical experimental study. The processed samples were analyzed by triplicate. Atomic emission technique was used to determine sodium and the method described by the NOM-213-SSA1-2002 was utilized to determine nitrites. In addition, sensory acceptance of the samples was evaluated through a 4 point sensory acceptance test. For quantitative variables 1-way ANOVA test with Bonferroni post hoc test was used and for qualitative variables x2 was utilized. The value of $p \leq 0.001$ was considered statistically significant for both tests. Results: All processes applied to both types of ham reduced sodium and nitrites. The double cooking was the most effective due to the sodium reduction was about 94.1% for turkey and 99.6% for pork, in the case of nitrites the reduction was 90.8% and 89.8% respectively. Reduction of sodium was statistically significant for both types of hams. A positive relation was observed between less sodium content and rejection in the sensory evaluation. Conclusions: Soaking is recommended because it reduced sodium and nitrites significantly and is the most accepted sensory. It is necessary to implement microbiological test to determine the sanitation of the techniques.

Sodium, Nitrites: Ham, Sensory Evaluation, Nitrosamines

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* Correspondence to Author (email: galvez1975@hotmail.com)
† Researcher contributing first author.

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Introduction

One of the meat products widely accepted by society is ham due to it is easy to prepare and consume; besides it has a considerable shelf life (1). Thus, ham is defined as a food product made with animal cuts suitable for human consumption. In its elaboration this product is subjected to various processes such as healing, where salts such as sodium chloride (NaCl), nitrites, nitrates and other food additives are added in order to preserve the quality and sanitary of the product (2). Sodium chloride plays an important role on the functionality, sensory properties and microbiological stability of these products due to it improves the binding characteristics of water and fat which contribute to the formation of stable gel structure within the meat products; also it acts as a conservative by reducing water activity and microbial growth. Finally, the salty taste improves the flavor perception of meat which is an important factor of acceptability (3). Moreover, nitrite salts used in sausages have an inhibitory effect on the growth of Listeria monocytogenes (4). Furthermore, nitrite salts are potent inhibitor of microorganisms such as *Clostridium* species. Added to this, nitrite salts are essential in the development of the product color and taste, stability against lipids oxidation and enrichment of the texture (5).

Eighty percent of sodium intake comes from processed food; specifically 7% comes from sandwiches and processed meats (6, 7). Some authors and institutions have determined that processed meats are the major source of sodium in the Western diet (8, 9). The amount of sodium in hams is usually from 1500 to 1800 milligrams (mg) per 100 grams (g) of product (10). In contrast, Recommended Daily Intake (RDI) of sodium is about 1000 to 1500 mg (11).

The maximum limit admitted of nitrite in meat product is 15.6 mg per 100 g (12) and the Joint Committee of Food and Agriculture Organization-World Health Organization (FAO-WHO) establishes an Acceptable Daily Intake (ADI) of less than 0.09 mg of sodium nitrite per kilogram (kg) of body weight (13). Thus, an adult with 60 kg of body weight could get an amount of 5.4 mg of residual nitrite but it is permitted to have an amount of 15.6 mg per 100 of product. This would be more than double of the quantity allowed by FAO-WHO (14).

It has demonstrated a positive correlation between excessive sodium intake and some diseases as high blood pressure and obesity. Because of the high content of sodium in sausages, their consumption have been limited in metabolic diseases (15, 16) and patients with renal disease due to they are unable to excrete the amount of sodium ingested (17, 18). Recently, consumption of low sodium foods has been included within a healthy lifestyle and several countries have adopted strategies to reduce sodium intake (19). Furthermore, nitrites could contribute to the formation of nitrosamines. Nitrosamines are chemicals with potent toxic, mutagenic and carcinogenic effects (20) which increase the risk of cancer development, methemoglobinemia and impaired lung function (21, 22, 23, 24). It is believed that nitrosamines are formed due to residual nitrites existed in cured meat products and it has found higher levels than the permitted in these products (25). It is important to know that the level of nitrosamines tolerated for humans is 5-10 micrograms (µg) per kg of body weight (23).

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Because of this problem, some industries have done many studies trying to reduce the amount of these substances in the preparation of sausages, where the organoleptic characteristics have suffered alterations (26, 27, 28). Other researches have suggested the use of substitutes of salt in the preparation of hams with moderately positive results (29). However, studies where the reduction was made after marketing the product and at the time of consumption were not found. This could improve the acceptability without increase the microbiological risk.

Therefore, the objective of this study is to propose an alternative way of ham consumption in the population, especially people with hypertension, renal failure and obesity through the reduction of sodium and nitrites by home hydric methods as washing (W), soaking (S), simple cooking (SC) and double cooking (DC).

Material and methods

The present study is cross-sectional analytical experimental. The mark of the sample was selected by intentional non-probabilistic method based on frequency of use, good quality and standardized presentation established in a Mexican Federal Consumer study (30). We chose the variety of pork ham with an average of 16% protein without soy and starch added and the variety of turkey ham with added soy and an average of 16% protein.

Techniques that showed reduction of similar elements were chosen (17, 31). Two packages with 250 g (one of pork ham and one of turkey ham) were fractionated in five parts, one was destined for blank (B) and the rest for the home hydric methods: washing (W), soaking (S), simple cooking (SC) and double cooking (DC).

Regarding to W technique, the sample was exposed to a constant fall of water at room temperature (approximately 20°C) for 1 minute with rubbing of hands. Respecting to S technique, the sample was immersed on 1 liter of cold water (5-7°C) maintaining the same temperature for 2 hours. For SC technique, the sample was submerged on 1 liter of water, it heated and when it reached boiling point it was cooked for 10 minutes. DC technique consists of immersing the sample on 1 liter of water, it heated and when it reached boiling point it was cooked for 10 minutes, water was replaced for 1 liter of fresh water it heated again and when it reached boiling point it was cooked for 10 minutes again. All samples were dried at room temperature before determination of sodium and nitrites. Quantitative analysis of each technique of both types of ham was made by triplicate obtaining a total of 60 samples.

Sodium determination was performed with atomic emission technique. Flame Photometer model 06-0202126 was used. We utilized the procedures carried out by Hart and Carballo (32, 33), using 5 g of sample without added hydrochloric acid, ammonium chloride or lithium oxalate to the wet ash. Calculations were made from the emission obtained to express the sodium content in mg/g of sample.

The method for the determination of nitrite was based on the Mexican norm NOM-213-SSA1-2002 (2). The calibration curve was performed to cured products. The results are expressed in parts per million (ppm) which were calculated from the absorbance recorded by the spectrophotometer.

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Added to this, organoleptic characteristics of the processed samples were evaluated through an acceptance test of 4 points applied to 19 people selected by intentional non-probabilistic method. Texture, flavor and color were evaluated.

Quantitative variables are expressed as mean and standard deviation. Comparison of sodium and nitrites between blank and the home hydric methods were performed by one-way ANOVA in addition to Bonferroni post hoc test. Value of $p < 0.001$ was considered statistically significant. Organoleptic characteristics reported by the study group were evaluated and are expressed as frequency and percentage. Subsequently the results of sodium reduction process of each home hydric method and each type of ham were clustered according to categories of sodium content established at NOM-086-SSA1-1994 (34). Finally these categories were correlated with sensory acceptance through statistical test x^2. Value of $p < 0.001$ was considered statistically significant.

Results

Based on the analysis of 60 samples, the average content of sodium and nitrite belonging to turkey and pork ham with their respective home hydric method were calculated. DC demonstrated greater percentage of sodium reduction in turkey and pork ham (94.1% and 99.6% respectively) and nitrite (90.8% and 89.8% respectively); in contrast, W reduced less sodium in both types of hams (70.5% for turkey and 28.6% for pork) and nitrite (35.2% and 42.4% respectively). All processes reduced sodium statistically significant compared to the blank sample ($p \leq 0.001$). The reduction of nitrites was not considered statistically significant (Figure 1).

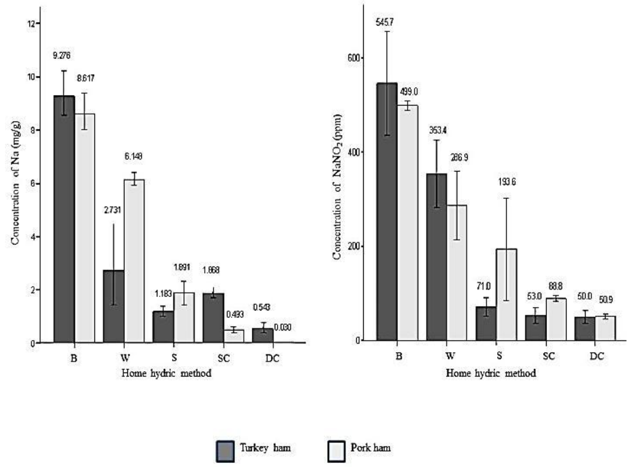

Figure 1 Concentration of sodium and nitrite. Data are reported as mean ± standard deviation. A decrease in the concentration of both components in all the process is observed. Sodium concentration in both types of hams is significantly different between blank and the home hydric methods applied $p \leq 0.001$.

Results of sensory evaluation of both types of ham (taste, color and texture) showed poor acceptance by respondents, however W was the technique most accepted. In contrast, DC was not accepted (Table 1).

	Blank		Washing		Soaking		Simple Cooking		Double Cooking	
	P (%)	T (%)	P (%)	T (%)	P (%)	T (%)	P (%)	T (%)	P (%)	T (%)
TASTE										
Very good taste	10 (52.6%)	9(47.45%)	4 (21.1)	3 (15.8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Good taste	5 (26.3%)	8 (42.1%)	9 (47.4)	8 (42.1%)	6 (31.6%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Regular taste	3 (15.8%)	2 (10.5%)	6 (31.6)	8 (42.1%)	7 (36.8%)	6 (31.6%)	1 (5.3%)	0 (0%)	0 (0%)	0 (0%)
Undesirable taste	1 (5.3%)	0 (0%)	0 (0)	0 (0%)	6 (31.6%)	13 (68.4%)	18 (94.7%)	19 (100%)	19 (100%)	19 (100%)
COLOR										
Very good color	10 (52.6%)	2 (10.5%)	7 (36.8%)	2 (10.5%)	4 (21.1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Good color	4 (21.1%)	11 (57.9%)	8 (42.1%)	8 (42.1%)	11 (57.9%)	4 (21.1%)	2 (10.5%)	0 (0%)	0 (0%)	0 (0%)
Regular color	4 (21.1%)	5 (26.3%)	3 (15.8%)	5 (26.3%)	2 (10.5%)	7 (36.8%)	4 (21.1%)	4 (21.1%)	1 (5.3%)	4 (21.1%)
Undesirable color	1 (5.3%)	1 (5.3%)	1 (5.3%)	4 (21.1%)	2 (10.5%)	8 (42.1%)	13 (68.4%)	15 (78.9%)	18 (94.7%)	15 (78.9%)
TEXTURE										
Very good texture	11 (57.9%)	9 (47.4%)	7 (36.8%)	4 (21.1%)	5 (26.3%)	1 (5.3%)	0 (0%)	1 (5.3%)	1 (5.3%)	0 (0%)
Good texture	4 (21.1%)	5 (26.3%)	10 (52.6%)	9 (47.4%)	8 (42.1%)	5 (26.3%)	2 (10.5%)	0 (0%)	1 (5.3%)	1 (5.3%)
Regular texture	3 (15.8%)	5 (26.3%)	2 (10.5%)	6 (31.6%)	5 (26.3%)	9 (47.4%)	5 (26.3%)	5 (26.3%)	3 (15.8%)	2 (10.5%)
Undesirable texture	1 (5.4%)	0 (0%)	0 (0%)	0 (0%)	1 (5.3%)	4 (21.1%)	12 (63.2%)	13 (68.4%)	14 (73.7%)	16 (84.2%)

P: pork ham
T: turkey ham
Values are expressed in frequency and percentage.

Table 1 Sensory evaluations of pork and turkey ham after being treated by home hydric methods

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Sodium content of each samples were classified in reference to the Mexican norm NOM-086-SSA1-1994 (34) in order to analyze the relationship between sodium reduction and sensory acceptance. This norm establishes nutritional specifications which modified foods must keep. Thus, the NOM-086-SSA1-1994 establishes sodium concentrations allowed for "low sodium", "very low sodium" and "sodium free" products. We added "not significant" category when the sample does not fit into any standard classification. Categories of sodium were correlated with sensory evaluation. According to this classification, B turkey ham was designated as "not significant", W, S and SC were designated as "low sodium" and DC as "very low sodium". With respect to pork ham, B and W were classified as "not significant", S as "low sodium", SC as "very low sodium" and DC as "sodium free". Correlation between less quantity of sodium and less sensory acceptance was positive $p < 0.001$ (Table 2).

Sensory evaluation	TURKEY HAM			PORK HAM			
	*Category of sodium reduction**			*Category of sodium reduction**			
	Very low	Low	Not significant	Free	Very low	Low	Not significant
TASTE							
Very good taste	0 (0%)	3(5%)	9(47%)	0 (0%)	0 (0%)	0 (0%)	14 (37%)
Good taste	0 (0%)	8 (14%)	8 (42%)	0 (0%)	0 (0%)	6 (32%)	14 (37%)
Regular taste	0 (0%)	14 (25%)	2 (11%)	0 (0%)	1 (5%)	7 (37%)	9 (24%)
Undesirable taste	19 (100%)	32 (56%)	0 (0%)	19 (100%)	18 (95%)	6 (32%)	1 (2%)
COLOR							
Very good taste	0 (0%)	2 (4%)	2 (11%)	0 (0%)	0 (0%)	4 (21%)	17 (45%)
Good taste	0 (0%)	12 (21%)	11 (58%)	0 (0%)	2 (11%)	11 (58%)	12 (32%)
Regular taste	4 (21%)	16 (28%)	5(26%)	1 (5%)	4 (21%)	2 (11%)	7 (18%)
Undesirable taste	15 (79%)	27 (47%)	1 (5%)	18 (95%)	13 (68%)	2 (11%)	2 (5%)
TEXTURE							
Very good taste	0 (0%)	6 (11%)	9 (47%)	1 (5%)	0 (0%)	5 (26%)	18 (47%)
Good taste	1 (5%)	14 (25%)	5(26%)	1 (5%)	2 (11%)	8 (42%)	14 (37%)
Regular taste	2 (11%)	20 (35%)	5(26%)	3 (16%)	5 (26%)	5 (26%)	5 (13%)
Undesirable taste	16 (54%)	17 (30%)	0 (0%)	14 (74%)	12 (63%)	1 (5%)	1 (3%)

$p \leq 0.001$
* NOM-086-SSA1-1994
Values are expressed in frequency and percentage.

Table 2 Correlation between sodium quantity and sensory acceptance.

Discussion

The number of health conscious consumers has increased in recent years; therefore, demand of low fat and sodium foods has increased. Food processing industries are searching for new ways to generate products with low content of salts, particularly sodium chloride which plays an important role in flavoring and preservation. Furthermore sodium chloride lows water activity in meat products influencing its shelf life. (35) Other problem additive is sodium nitrite. Nitrites are indispensable in the meat industry due to it improves safety and sets the characteristic color of smoked and cured meats (23, 36).

In industrialized countries sodium intake exceeds the nutritional recommendations by 60%. It has implications in elevated blood pressure, development of hypertension and positive association with mortality and CHD risk. Given this, it has promoted recommendation programs to reduce the intake of sodium without conclusive results (37). On the other hand, nitrites represents another risk to the health of consumers due to it is absorbed by diffusion through the gastric mucosa and gut wall and in certain absorption levels, nitrite reacts with hemoglobin and could cause methemoglobinemia, decreased oxidative phosphorylation, inhibition of microsomal enzymes and other toxic effects which could eventually cause death (22, 23, 36). Scientific evidence suggests that frequent consumption of meat products with high concentrations of nitrite is associated with obstructive lung function by causing nitrosative stress experimentally (24, 28).

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Furthermore, reaction of nitrites with amines could cause the formation of N-nitroso compounds such as nitrosamines, highly reactive and responsible of causing embryopathy mutagenic effects. Children are especially susceptible to these effects due to their low body weight, immature enzyme system and weakness in gastric system (23, 39).

Consumption of 60 g of ham covers more than one third of the RDI of sodium for an adult. It represents 37% of RDI in turkey ham and 34% of RDI in pork ham. This percentage decreases with the home hydric methods: turkey ham could contain only 2.1% to 10.9% of the RDA and pork ham could contain 0.1% to 24.6% of the RDA.

One finding of this research is the difference found in the concentrations of sodium and nitrites between turkey and pork ham. Sodium and nitrite concentration was higher in turkey ham against pork ham (9.28 mg and 8.62 mg in the case of sodium and 545.72 ppm and 498.99 ppm in the case of nitrites). The above information becomes relevant because it could influence the choice of meat product based on the health of the consumer.

Nowadays there are not recommendations scientifically validated to processes sausages in home and easily in order to reduce concentrations of sodium and nitrite. However, Burrowes, *et al*. conducted a similar study in which they reduced potassium in some potato varieties. Results revealed that SC and DC processes decreased significantly this mineral (31).

Other experimental alternatives have been performed to reduce sodium concentration during product development, as reported by Stopfoth *et al*. They used potassium lactate on the formulation, decreasing 42% of the sodium content (37). Lavieri *et al*. used nitrites of plant origin in combination with high hydrostatic pressure with the objective to inhibit L. monocytogenes growing having favorable results (4). The same author has worked with other natural or organic methods with promising results (40). One of these methods is natural vegetable juice which has proved quality and usefulness comparable with conventional curing methods (41). Meat products with organic or natural additives without nitrites or nitrates are good alternative of consumption (42). However several low-sodium meats obtained by physical and chemical methods have failed in sanity quality, sensory perception and consumer acceptance (43). Thus home hydric methods applied at the time of consumption could become an economic and acceptable alternative.

In our study DC reduced more quantity of sodium in turkey and pork ham with 94.1% and 99.6% respectively, and nitrites with 90.8% and 89.8% respectively. In contrast, W process reduced less quantity of sodium (70.5% for turkey ham and 28.6% for pork ham) and nitrite (35.2% and 42.4% respectively). Respect to the organoleptic properties, we found that the processes in which heat is applied and therefore reduced sodium and nitrites significantly were the least accepted sensory. In contrast, those in which heat were not applied were mostly accepted. Rejection of low sodium technics is due to use of sodium and nitrites are essential to improve sensory characteristics as well as they are important agents emulsifiers, flavor enhancers, color enhancers, water and fat binder and microorganisms controller (44).

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It is important to know that determination methods used in the study are validated (2, 32, 33). Further, analyses were performed integrally including sodium quantity, nitrite quantity, organoleptic characteristics and their correlation. We obtained a statistical significance of $p \leq 0.001$ in reducing sodium in both ham and in the correlation of sensory acceptance and the categories of reduction. Nitrites content was affected by home hydric methods but not significantly. However, it is difficult to extrapolate these results, since the sample of sensory evaluation is insufficient and was not determined probabilistically and only one trademark of ham was analyzed. It is also necessary to assess the sanity of the product after applying the home hydric methods.

More researches in other type of sausages are needed. It is necessary to analyze the loss of water soluble nutrients, to determine changes in the fat content and to quantify the microbial content of the product after applying reduction processes. In addition to this, it is important to investigate whether the interaction of nitrite during cooking generates N-nitroso components such as nitrosamines.

Conclusions

We concluded the application of the processes W, S, SC and DC in turkey and pork ham reduced sodium and nitrite. The most significant reduction of sodium was shown with SC and DC processes. However, they didn´t have sensory acceptation. On the other hand, S represents a good alternative to turn ham as acceptable food for people with hypertension, renal disease, obesity and general population, besides it could contribute to cancer prevention because it reduced the amount of sodium and nitrites. S technique was the most accepted organoleptically. All the home hydric methods reduced sodium in statistically significant way.

We observed nitrites reduction without statistical significance. However it is necessary to determine the microbiological quality of the home hydric methods.

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