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Reducing salt content in beef frankfurter by edible coating to achieve inhomogeneous salt distribution

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Abstract

High dietary salt (NaCl) intake is a global health concern which leads to various chronic diseases, hence the reduction of salt content in foods has been a high demand in the food industry. Inhomogeneous salt distribution is a promising strategy for salt reduction. This study investigated the effect of inhomogeneous salt distribution using salt edible coating on the physiochemical and sensory attributes of beef frankfurter sausages. Results demonstrated that this method significantly reduced the salt content in frankfurter sausages by 60-81% without affecting the consumers' perception of saltiness intensity. Among the coated samples, 7.5% and 10% salt coating samples showed the best performance on the product quality. However, the problems associated with high cooking loss and hard texture of the salt-coated sausages need to be further addressed. This research has potentially developed a new method for manufacture of salt-reduced food.

Keywords: salt reduction; sausage; inhomogeneous salt distribution; edible coating; texture.

1 Introduction

Salt (NaCl) has been used in food preparation by humans for thousands of years, but excessive salt consumption can increase blood pressure, leading to cardiovascular disease, kidney problem and a series of chronic diseases (He & MacGregor, 2009). According to the World Health Organization, the recommended maximum daily salt intake is 5 grams (WHO, 2016). However, the global average daily salt intake is about 10 grams, which far exceeds the recommended level (Mozaffarian et al., 2014). Processed meat is a major source of salt intake in the diet in Australia. Although the salt content of processed meat in Australia has been reduced by about 12% over the past decade due to government promotion, with a median salt content of 775 mg/100 g by 2017, which is still considerably high, so there is a need to further reduce the salt content of processed meat products (Sparks et al., 2018).

Salt reduction is a challenge for processed meat because salt has many important functions in meat processing, including: 1) providing saltiness taste and improving meat flavour; 2) reducing water activity and inhibiting microbial growth to improve meat safety and shelf-life; 3) solubilising salt-soluble proteins to improve the protein binding property and water holding capacity (Desmond, 2006; Inguglia, Zhang, Tiwari, Kerry, & Burgess, 2017). Therefore, any substantial reduction in the salt content of processed meat products can lead to defects in food quality and safety. Many strategies have been developed for salt reduction. For example, salt replacers such as KCl, $MgCl_2$ and $CaCl_2$ are widely used in the meat industry. However, applying these salts may cause unpleasant meat flavour and texture, including "metallic" and "bitter" (Desmond, 2006). Addition of salt enhancers such as yeast extracts and mono-sodium glutamate is another approach to reduce the salt content, but it may also cause off-flavours in the meat products (Inguglia, Zhang, Tiwari, Kerry, & Burgess, 2017). In addition, changing the particle size and shape of the salt has also been used to reduce the salt content, but this method is mainly applied in the food seasoning industry and only suitable for dry and solid food (Rama et al., 2013).

Recently, studies have found that by manipulating the salt distribution in foods to be unevenly distributed, i.e. inhomogeneous salt distribution, the perceived saltiness intensity can be significantly enhanced in pizza (Guilloux, Prost, Courcoux, Le Bail, & Lethuaut, 2015) and bread (Noort, Bult, Stieger, & Hamer, 2010). This can be explained by the fact that the inhomogeneous salt distribution creates partial salt contrast, which can prevent the adaptation and gradual reduction in taste response caused by continuous exposure of the taste buds to high doses of salt (Nakao, Ishihara, Nakauma, & Funami, 2013). However, since meat is a high-moisture food, the inhomogeneous salt distribution strategy has never been studied or applied to meat products for salt reduction.

Edible coating could be an effective method to solve the problem of how to apply inhomogeneous salt distribution to meat products. Edible coating has been widely applied in fruit and meat protection and preservation. It has also been used as a matrix to encapsulate various ingredients such as antioxidants, antimicrobials and flavours to improve food safety and quality (Falguera, Quintero, Jiménez, Muñoz, & Ibarz, 2011). Therefore, salt can be incorporated into the edible coating, to form a concentrated salt coating and then be applied on a meat surface to create a partial salt contrast environment. The aim of this study was to develop a salt reduction strategy by combing inhomogeneous salt distribution and salt edible coating technologies, using beef frankfurter sausage as a food model. The effect on the sausage physiochemical and sensory attributes will be investigated. This study could provide a new method for salt reduction in processed meat.

2 Materials and Methods

2.1 Materials

Normal beef mince (82% lean meat and 18% fat) and lean beef mince (90% lean meat and 10% fat) were purchased from Woolworths supermarket (Parkville, VIC, Australia). Other ingredients including sodium chloride, dextrose, soy protein isolate, white pepper, potato starch, sodium hexametaphosphate, coriander, spice, ascorbic acid, nutmeg, paprika, and sodium nitrite were all food grade and purchased from Woolworths supermarket (Parkville, VIC, Australia). Collagen casing (26 mm diameter) was supplied by Nippi Incorporated (Tokyo, Japan). Food grade gelatine and sorbitol powder were purchased from Solarbio Science & Technology Co., Ltd. (Beijing, China). Quantab chloride test strips (0.05-1.0% NaCl) was obtained from Hach Company (Dandenong South, VIC, Australia).

2.2 Beef frankfurter sausage preparation

The experimental design and analysis are illustrated in Figure 1. The beef frankfurter sausage was prepared using a common frankfurter sausage recipe in a local store of Queen Victoria Market (Melbourne, VIC, Australia) (Table 1). Briefly, all ingredients were weighted and 4 kg beef mince (1.25 kg lean beef mince and 2.75 kg normal beef mince) was used for the preparation of each batch. Sodium chloride, sodium nitrite, and sodium hexametaphosphate were dissolved into 250 ml water to prepare the curing brine. For salted sausage making, the beef mince and curing brine were mixed and chopped in a Mado Garant MTK661 bowl chopper (MADO GmbH, Dornhan, Germany) for 2 min at low speed, and then 500 ml of cool water and the remaining ingredients were added in the bowl chopper and further mixed for 2 min at high speed. The resulting meat batter was transferred into a Reber sausage stuffer (Constante Imports, Preston, VIC, Australia), filled into a 26 mm collagen casing, and tied into 4 cm length sausages with a cotton string. Sausages were then kept at 4 ℃ for 24 h for equilibration. After that, the salted sausages were ready for baking and were used as the control. The unsalted sausages were made with the same process, including collagen casing, but no sodium chloride was added (formulation in Table 1), and then these were subjected to the following salt coating process.

2.3 Preparation of sausage salt coating and cooking

Five different gelatine salt coating solutions were prepared according to Table 2. The unsalted sausages were immersed into the salt coating solutions, stirred thoroughly and then kept at 4°C for 30 min, and then removed, using tongs, and air dried for 5 min. After that, both coated and control sausages were placed in baking pans, covered with aluminium foil and baked in a WFE946SB electric oven (Westinghouse Electric Corporation, Cranberry Township, Pennsylvania, USA) at 210 ℃ for 30 min, flipping once after 15 min. The physicochemical analysis and sensory evaluation of all sausage samples were carried out within 2 h after the sausages were cooked.

2.4 Weight increase after coating and cooking loss

For all sausage samples, the weight of sausages before (W_1) and after (W_2) baking were recorded. For the coated samples, the weight increase after coating (W_C) was also recorded. The wet coated sausages were air dried on a rack for 5 min until there was no moisture dripping from the samples, before weighing; the baked sausages were cooled to room temperature and then gently blotted with a paper towel to remove excess surface moisture before weighing.

The weight increase after the coating (WI_C) was determined as:

Equation 1: $WI_C\ (\%) = \frac{W_C - W_1}{W_1}$

The cooking loss (CL) was determined as:

Equation 2: $CL\ (\%) = \frac{W_1 - W_2}{W_1}$

2.5 pH value

The pH of cooked sausage samples was measured using the method of Gharibzahedi & Mohammadnabi (2017). Sausage samples (20.0 g) and water (40.0 g) were accurately weighed, mixed in a beaker and placed in an ice water bath, and then homogenised using a polytron homogeniser (Kinematica GmbH, Lucern, Switzerland) at 13,500 rpm for 2 min. Afterwards, a HI5221 pH meter (Hanna Instruments, Rhode Island, USA) was used to record the pH value of the homogenate. The pH meter was calibrated in pH 4 and 7 buffers before use.

2.6 Salt content

The salt content of the coated sausages was estimated based on the coating volume, by considering the sausage as a cylinder, so the volume of the sausages was calculated according to $V = h\pi r^2$, where h was the sausage length which was about 4 cm, π was the constant, and r was the casing radius which is 1.30 cm for uncoated sausages. According to literature (Embuscado & Huber, 2009; Guilbert, Gontard, & Cuq, 1995), the thickness of gelatine edible coating/film is generally about 0.03 cm, so 1.33 cm was used as the radius of the coated sausages. Therefore, the gelatine salt coating volume for a sausage was calculated by the volume difference of uncoated and coated sausages which was as about 1 ml, and the predicted salt content of the coated sausages was estimated as:

Equation 3: $Estimated\ salt\ content\ 1\ (\%) = \frac{coating\ volume \times coating\ salt\ conc.}{sausage\ weight} \times 100$

The salt content of the coated sausages was also determined based on the weight increase after coating and was calculated as:

Equation 4: $Estimated\ salt\ content\ 2\ (\%) = \frac{weight\ increase\ after\ coating \times coating\ salt\ conc.}{sausage\ weight} \times 100$

The salt content of both control and coated samples was also determined after cooking, using QuanTab chloride test strips. After pH analysis, the homogenate was immediately used to determine the salt content. A salt test strip was inserted into the homogenate in a beaker and the beaker was sealed with parafilm. The value of the test strip was read and converted to salt content as NaCl percentage when the indicator turned from yellow to black.

2.7 Colour determination

Cooked sausages were cut in half in a transverse direction, and the colour of each cut surface was measured using a Nix Pro colour sensor (Nix Sensor Ltd., Hamilton, Ontario, Canada) according to the method of Holman, Collins, Kilgannon, & Hopkins (2018). The sensor has a 14.0 mm aperture and 45/0° measuring geometry and was set to with D50 illumination and 2° observer. The CIE Lab colour parameters: lightness (L*), redness (a*) and yellowness (b*) were recorded. For each treatment group, three sausages were halved and measured, and each piece was measured in triplicate.

2.8 Texture profile analysis (TPA)

The texture profile of cooked sausages was determined by the double-bite compression test using a Lloyd LS5 single column testing machine (Ametek Inc., Berwyn, Pennsylvania, USA) according to the method of Fang, Lin, Ha, & Warner (2019). Sausages were cut into cylinders of 1.5 cm height. Each sample was compressed twice (5 s interval) by a cylindrical probe (20 mm diameter, 500 N load force) into 75 % of its original height at room temperature, with the probe speed of 2 mm/s. For each treatment group, three pieces of sausage cuts were measured, and each piece was measured in triplicates. The values for hardness, gumminess, chewiness, cohesiveness, springiness and resilience were calculated by the NEXYGENPlus software (Ametek Inc., Berwyn, Pennsylvania, USA).

2.9 Sensory evaluation

The sensory evaluation was approved by the Human Research Ethics Committee of The University of Melbourne (Ethical ID: 1750301). A total of 35 Food Science major postgraduate students from the University of Melbourne volunteered to evaluate the beef frankfurter sausages. The six sausages of different salt treatments were coded with random 3 digital numbers and were provided to the panellists. Sausages were evaluated for the toughness, juiciness, intensity of saltiness and overall acceptability on a 15 cm continuous line scale (with word "nothing" anchored at 0 cm and "very strong" at 15 cm). The purchase intention of the sausages as a beef snack and as a salt-reduced product was assessed by "yes" or "no" only, the question being "would you purchase this product?". The panellists were asked to refresh the palate with warm water and plain crackers between sausage samples.

2.10 Statistical analysis

Except where otherwise specified, three replicates (beef frankfurter sausage samples) were used for each salt treatment, and each sample was measured in duplicate. Results were expressed as mean ± standard deviation, and the statistical analysis was performed using Minitab Statistical Software 18.1 (Minitab Inc., State College, Pennsylvania, USA). The significant difference of means between samples was determined using one-way ANOVA with Fisher's least significant difference test at 95% confidence level.

3 Results and Discussion

3.1 Salt content, weight increase and cooking loss

To estimate how much salt could be reduced by the edible salt coating and inhomogeneous salt distribution, the salt content of coated sausages was calculated before the experiment. The estimation was based on the coating thickness, and the general gelatine edible coating/film thickness of 0.03 cm, according to literature (Embuscado & Huber, 2009; Guilbert, Gontard, & Cuq, 1995), which was assumed as the thickness of the gelatine salt coating built up on the sausage. The estimated salt content of the coated sausages was 0.10%, 0.30%, 0.50%, 0.70% and 1.00% for 1.5%, 4.5%, 7.5%, 10.5% and 15% salt solution coated samples respectively, which was in each case much less than 2.00% salt content of the control sausage (Table 3).

After coating, the weight of the coated sausage was increased (WI_C) by about 6.30-6.90 %, and based on the weight increase, the salt content of coated sausages was also determined by Equation 4. As shown in Table 3, the determined salt contents were generally lower but close to the estimated salt contents, suggesting that the thickness of the salt coating was close to 0.03 cm.

After baking, the salt content of all coated sausages was similar to that before baking, but the salt content of the control sample was much lower than that before baking (Table 3). This is because during cooking, fluid is lost due to dripping and evaporation. Since the salt of the control sample was distributed homogenously within the sausage, a considerable amount of salt was lost with the fluid. However, in the coated samples, the salt was located on the surface coating and the fluid loss had much less effect on the salt content. Because the salt content was generally concentrated on the coating layer after baking as moisture evaporates, presenting greater salt contrast, this could further enhance the perceived saltiness intensity (Noort, Bult, Stieger, & Hamer, 2010).

The cooking loss (CL) of the sausages was 25.5-37.8%, and the CL of the coated sausages was much higher ($P < 0.05$) compared to the control (Table 3). This may be due to the fact that, in the control samples, the salt distributed evenly through the meat batter can extract myofibrillar proteins and increase the water binding capacity, which enables the formation of gel matrix when heated, thereby entrapping fat and water and reducing the cooking loss (Desmond, 2006; Foegeding & Lanier, 1988). Higher cooking loss was also observed in beef frankfurter and pork breakfast sausages when the salt level in the meat batter was reduced (Mathulis, Mckeith, Sutherland, & Brewer, 1995; Tobin, O'Sullivan, Hamill, & Kerry, 2013).

3.2 pH and colour analysis

pH is an important quality indicator of meat and is closely related to its texture and sensory properties. The pH of the sausages was about 6.0 (Table 4), which is in the pH range of 5.8-6.3 where minimum salt addition for frankfurter sausages can be used to achieve sensory acceptance (Matulis, Mckeith, & Brewer, 1994). For example, Mathulis, Mckeith, Sutherland, & Brewer (1995) reported that a minimum of 1.3% salt was required for frankfurter sausages to be acceptable to consumers, at pH 6. In addition, the salt addition had an effect ($P < 0.05$) on the pH; as the salt content was increased, the pH tended to decrease (Table 4). This may be due to the binding of salt ions (Cl^-) to positively charged protein side chains in the muscle matrix, which leads to a shift of the isoelectric point of the proteins to a lower pH (Hamm, 1986). Nevertheless, the salt treatments had little effect on the pH values.

The internal meat colour values of lightness (L*), redness (a*) and yellowness (b*) are presented in Table 4. The results showed that there were no differences ($P > 0.05$) between the coated and control samples, indicating that the salt coating treatment had no effect on the sausage colour, which is very important since the colour of meat has a direct influence on consumer acceptability. Maintaining the colour of meat could be a challenge in salt-reduced samples. Although many salt reduction strategies have significantly reduced salt content on processed meat, they may have negative effects on the meat colour. For example, the colour of cooked sausages tended to become darker and less intense when the salt level was reduced (Tobin, O'Sullivan, Hamill, & Kerry, 2012, 2013; Ventanas, Puolanne, & Tuorila, 2010). High levels of substitution of NaCl with K-lactate (salt replacer) delayed the pH drop and the development of red colour from the nitrite in fermented sausages, and thus affected the meat colour intensity and uniformity (Gou, Guerrero, Gelabert, & Arnau, 1996). In another study of sausages treated with high pressure processing (at 150 MPa) to assist in salt reduction, the salt level below 1.5% was reported to have negative effects on meat lightness and redness (O'Flynn, Cruz-Romero, Troy, Mullen, & Kerry, 2014). The colour change of meat products is a complex phenomenon, which is influenced by many factors such as protein denaturation, fat content, water content and texture of the meat (O'Flynn, Cruz-Romero, Troy, Mullen, & Kerry, 2014). The present study suggested that this gelatine salt coating strategy in reducing salt content in sausage would be acceptable by consumers in terms of minimal changes to the product colour.

3.3 Texture profile analysis (TPA)

Texture is a key determinant of the organoleptic quality of meat products. The double-bite compression test was applied to mimic the chewing process in the mouth to assess the meat texture. For the TPA parameters, hardness is the peak force of the first compression; gumminess and chewiness signify the resistance to compression and is related to the hardness; cohesiveness denotes how well the meat retains its structure after compression; springiness and resilience are how well the meat springs back and fights to regain its original shape after the deformation, respectively, which provides information on the meat elasticity (Texture Technologies, 2019).

As shown in Table 5, the hardness, gumminess, chewiness and springiness of coated sausage samples were significantly higher ($P < 0.05$) than that of the control, but there was no difference ($P > 0.05$) in the cohesiveness and resilience. The results suggested that coated sausages had a harder texture compared to the control. However, the results are inconsistent with those of previous studies. Tobin, O'Sullivan, Hamill, & Kerry (2012) found that salt reduction (from 3.0% to 1.0%) resulted in lower hardness, chewiness, springiness, cohesiveness, and resilience in frankfurter sausages. Also, Mathulis, Mckeith, Sutherland, & Brewer (1995) reported that salt reduction (from 3.0% to 0.5%) decreased the hardness of frankfurter sausages. A possible explanation could be that, compared to the control sausages, the coated sausages had much larger cooking loss as discussed above, and significant amounts of fluids were lost during cooking causing the sausages to dry out, which lead to a harder texture, as it is well-known that dehydrated muscle protein is harder in texture. It is also well known that salt is critical to the formation of the gel matrix to entrap fat and water (Desmond, 2006; Foegeding & Lanier, 1988). The meat patty prepared for the coated sausages in this study was unsalted and therefore the formation of the matrix to entrap fat and water was much weaker. The water content also has an important role in the meat texture. According to Li, Carpenter, & Cheney (1998), the hardness, springiness, cohesiveness increase as the water content decreases. Notwithstanding, the water holding capacity of processed meat products can be improved by adding gelling ingredients such as carrageenan and cellulose gum (Barbut & Mittal, 1996; Candogan & Kolsarici, 2003), which will be investigated in our future meat salt reduction studies.

3.4 Sensory evaluation

Sensory evaluation indicates that there was no difference ($P > 0.05$) in toughness between sausage samples (Table 6). The results are inconsistent with the instrumental hardness as shown in Section 3.3, suggesting the changes in sausage hardness or texture were not sufficient to be detected by the panellists in this study. However, juiciness was different ($P < 0.05$) between samples, and the juiciness tended to increase as the salt content was increased, likely due to increased water retention (Table 6). The results are in line with those of previous studies that increasing the salt content can increase the perceived juiciness (Mathulis, Mckeith, Sutherland, & Brewer, 1995; Ruusunen et al., 2003; Tobin, O'Sullivan, Hamill, & Kerry, 2012). The juiciness of meat is dependent on the water and fat content (Aaslyng, Bejerholm, Ertbjerg, Bertram, & Andersen, 2003), and salt can bind with myofibrillar proteins to increase the water holding capacity and thus juiciness (Puolanne, Ruusunen, & Vainionpää, 2001). The salt gelatine coated sausages (unsalted meat patties) had a high cooking loss with a significant loss of both the water and fat, hence explaining the reduced juiciness score.

Regarding the saltiness of the salt coating samples, the intensity of the perceived saltiness was increased with increasing salt content of the coating ($P < 0.05$) (Table 6). The 15% salt coating formulation sausage had the highest saltiness among all samples and was much higher ($P < 0.05$) than the control, although it contained only 52% of the control group's salt content (based on the salt content determined by the test strip method in Table 3). In addition, the 10.5% salt coating sample, which contained only 40% salt of the control group, was not different ($P > 0.05$) in saltiness compared with the control. The results demonstrated that the inhomogeneous salt distribution by salt coating could substantially increase the perceived saltiness. Furthermore, the moisture evaporation during cooking could increase the concentration of salt on the coating, resulting in greater sensory contrast, which further enhanced the saltiness perception (Mosca, van de Velde, Bult, van Boekel, & Stieger, 2010; Noort, Bult, Stieger, & Hamer, 2010).

In terms of the overall product acceptability, the 4.5%, 7.5% and 10.5% salt coating samples were not different ($P > 0.05$) to the control (Table 6). However, considering the salt reduction rate, the 4.5% salt coating sausage contained only 19% salt of the control, i.e. 81% salt reduction. The purchase intention results showed that, as a beef snack, people still preferred the traditional sausage (control), but the 7.5% and 10.5% salt coating samples were also favoured. However, when the purchase intention was re-phrased as a salt-reduced product, all salt coated samples were preferred over the traditional sausage, except the 15% salt coating sample. The 1.5% salt coating sample may have unacceptably low saltiness and juiciness and the 15% salt coating group may be unacceptably salty in taste, as these two groups were least favoured. Overall, the 7.5% and 10.5% salt coating sausage samples have been demonstrated to significantly reduce the salt content while maintaining high consumer sensory acceptability and purchase intention, and hence could be developed as a new salt-reduced sausage.

3.5 Conclusion

High dietary sodium intake is a global health concern, and processed meat is a major source of sodium intake. This study developed an edible salt coating (NaCl in gelatine solution) and successfully applied on sausages to create an inhomogeneous salt distribution system to enhance the saltiness intensity. This inhomogeneous salt distribution strategy, by coating the salt (NaCl) on the sausage surface, was demonstrated to reduce the salt content by more than 50% without losing the saltiness intensity. The best salt coating formulation was using 7.5% and 10.5% salt coating solutions, with the salt reduction rate of 81% and 60% respectively. These salt coated samples showed no significant difference in pH and colour and had high consumer acceptability and purchase intention compared to the traditional salt added sausage. However, the meat patty prepared for coating was unsalted and unable to form a strong gel matrix to entrap water and fat, which resulted in a greater cooking loss and negatively affected the meat texture and juiciness. Research is underway to investigate the effect of incorporation of different gelling ingredients, combined with this salt reduction strategy, to improve the water and fat holding capacity and possibly meat texture and juiciness.

4 Conflict of interest

None.

5 Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

6 Reference

Aaslyng, M. D., Bejerholm, C., Ertbjerg, P., Bertram, H. C., & Andersen, H. J. (2003). Cooking loss and juiciness of pork in relation to raw meat quality and cooking procedure. *Food quality and preference, 14*(4), 277-288.

This article provides information on how the cooking procedure and raw meat quality affect the cooking loss and juiciness, and the water and fat content are the determinant factors in terms of raw meat quality, which provides important background information.

Barbut, S., & Mittal, G. S. (1996). Effects of three cellulose gums on the texture profile and sensory properties of low fat frankfurters. *International Journal of Food Science & Technology, 31*(3), 241-247.

This study demonstrates that incorporating gelling agents, i.e. cellulose gums, in frankfurters can significantly improve the water holding capacity, which is important for future research.

Candogan, K., & Kolsarici, N. (2003). The effects of carrageenan and pectin on some quality characteristics of low-fat beef frankfurters. *Meat Science, 64*(2), 199-206.

This study provides another evidence of how incorporating gelling agents, i.e. carrageenan, in frankfurters can improve the water holding capacity, which has important reference value for future research.

Desmond, E. (2006). Reducing salt: A challenge for the meat industry. *Meat Science, 74*(1), 188-196.

This article provides a composesheive review of the problems and challenges faced for salt reduction in the meat industry, as well as the strategies to conquer these problems. This article has been cited several times in our manuscript, providing important background information and evidence for this research.

Embuscado, M. E., & Huber, K. C. (2009). *Edible films and coatings for food applications* (M. Embuscado & K. C. Huber Eds. Vol. 9): Springer.

Falguera, V., Quintero, J. P., Jiménez, A., Muñoz, J. A., & Ibarz, A. (2011). Edible films and coatings: Structures, active functions and trends in their use. *Trends in food science & technology, 22*(6), 292-303.

This article is a comporesheive review of food edible coating, which provides us the concept for NaCl coating to reduce the salt content in sausage.

Fang, Z., Lin, P., Ha, M., & Warner, R. D. (2019). Effects of incorporation of sugarcane fibre on the physicochemical and sensory properties of chicken sausage. *International Journal of Food Science & Technology, 54*(4), 1036-1044.

Foegeding, E. A., & Lanier, T. C. (1988). The contribution of nonmuscle proteins to texture of gelled muscle protein foods. *Agricultural Information Management Standards, 32*(2), 202-205.

Gharibzahedi, S. M. T., & Mohammadnabi, S. (2017). Effect of novel bioactive edible coatings based on jujube gum and nettle oil-loaded nanoemulsions on the shelf-life of Beluga sturgeon fillets. *International journal of biological macromolecules, 95*, 769-777.

Gou, P., Guerrero, L., Gelabert, J., & Arnau, J. (1996). Potassium chloride, potassium lactate and glycine as sodium chloride substitutes in fermented sausages and in dry-cured pork loin. *Meat Science, 42*(1), 37-48.

Guilbert, S., Gontard, N., & Cuq, B. (1995). Technology and applications of edible protective films. *Packaging Technology and Science, 8*(6), 339-346.

Guilloux, M., Prost, C., Courcoux, P., Le Bail, A., & Lethuaut, L. (2015). How Inhomogeneous Salt Distribution Can affect the Sensory Properties of Salt‐Reduced Multi‐Component Food: Contribution of A Mixture Experimental Design Approach Applied to Pizza. *Journal of sensory studies, 30*(6), 484-498.

Hamm, R. (1986). *Functional properties of the myofibrillar system and their measurements*. Retrieved from

He, F. J., & MacGregor, G. A. (2009). A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. *Journal of human hypertension, 23*(6), 363.

Holman, B. W. B., Collins, D., Kilgannon, A. K., & Hopkins, D. L. (2018). The effect of technical replicate (repeats) on Nix Pro Color Sensor™ measurement precision for meat: A case-study on aged beef colour stability. *Meat Science, 135*, 42-45.

Inguglia, E. S., Zhang, Z., Tiwari, B. K., Kerry, J. P., & Burgess, C. M. (2017). Salt reduction strategies in processed meat products–A review. *Trends in food science & technology, 59*, 70-78.

Li, R., Carpenter, J. A., & Cheney, R. (1998). Sensory and instrumental properties of smoked sausage made with mechanically separated poultry (MSP) meat and wheat protein. *Journal of Food Science, 63*(5), 923-929.

Mathulis, R. J., Mckeith, F. K., Sutherland, J. W., & Brewer, M. S. (1995). Sensory characteristics of frankfurters as affected by fat, salt, and pH. *Journal of Food Science, 60*(1), 42-47.

Matulis, R. J., Mckeith, F. K., & Brewer, M. S. (1994). Physical and sensory characteristics of commercially available frankfurters. *Journal of Food Quality, 17*(4), 263-271.

Mosca, A. C., van de Velde, F., Bult, J. H. F., van Boekel, M. A. J. S., & Stieger, M. (2010). Enhancement of sweetness intensity in gels by inhomogeneous distribution of sucrose. *Food quality and preference, 21*(7), 837-842.

Mozaffarian, D., Fahimi, S., Singh, G. M., Micha, R., Khatibzadeh, S., Engell, R. E., Lim, S., Danaei, G., Ezzati, M., & Powles, J. (2014). Global sodium consumption and death from cardiovascular causes. *New England Journal of Medicine, 371*(7), 624-634.

Nakao, S., Ishihara, S., Nakauma, M., & Funami, T. (2013). Inhomogeneous spatial distribution of aroma compounds in food gels for enhancement of perceived aroma intensity and muscle activity during oral processing. *Journal of Texture Studies, 44*(4), 289-300.

Noort, M. W. J., Bult, J. H. F., Stieger, M., & Hamer, R. J. (2010). Saltiness enhancement in bread by inhomogeneous spatial distribution of sodium chloride. *Journal of Cereal Science, 52*(3), 378-386.

O'Flynn, C. C., Cruz-Romero, M. C., Troy, D., Mullen, A. M., & Kerry, J. P. (2014). The application of high-pressure treatment in the reduction of salt levels in reduced-phosphate breakfast sausages. *Meat Science, 96*(3), 1266-1274.

Puolanne, E. J., Ruusunen, M. H., & Vainionpää, J. I. (2001). Combined effects of NaCl and raw meat pH on water-holding in cooked sausage with and without added phosphate. *Meat Science, 58*(1), 1-7.

Rama, R., Chiu, N., Carvalho Da Silva, M., Hewson, L., Hort, J., & Fisk, I. D. (2013). Impact of Salt Crystal Size on in-Mouth Delivery of Sodium and Saltiness Perception from Snack Foods. *Journal of Texture Studies, 44*(5), 338-345.

Ruusunen, M., Vainionpää, J., Puolanne, E., Lyly, M., Lähteenmäki, L., Niemistö, M., & Ahvenainen, R. (2003). Physical and sensory properties of low-salt phosphate-free frankfurters composed with various ingredients. *Meat Science, 63*(1), 9-16.

Sparks, E., Farrand, C., Santos, J., McKenzie, B., Trieu, K., Reimers, J., Davidson, C., Johnson, C., & Webster, J. (2018). Sodium Levels of Processed Meat in Australia: Supermarket Survey Data from 2010 to 2017. *Nutrients, 10*(11), 1686.

Texture Technologies. (2019). Overview of Texture Profile Analysis. Retrieved 09 Sep, 2019, from https://texturetechnologies.com/resources/texture-profile-analysis

Tobin, B. D., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2012). Effect of varying salt and fat levels on the sensory and physiochemical quality of frankfurters. *Meat Science, 92*(4), 659-666.

Tobin, B. D., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2013). The impact of salt and fat level variation on the physiochemical properties and sensory quality of pork breakfast sausages. *Meat Science, 93*(2), 145-152.

Ventanas, S., Puolanne, E., & Tuorila, H. (2010). Temporal changes of flavour and texture in cooked bologna type sausages as affected by fat and salt content. *Meat Science, 85*(3), 410-419.

WHO. (2016). Salt reduction. Retrieved 18 Sep, 2019, from https://www.who.int/news-room/fact-sheets/detail/salt-reduction

Table captions

Table 1: Beef frankfurter sausage recipe per batch.

Table 2: Edible salt coating solution formulations.

Table 3: Salt content, weight increase and cooking loss of the six sausage formulations.

Table 4: pH and colour attributes (L*, a* and b*) of the six sausage formulations.

Table 5: Texture profile of the six sausage formulations.

Table 6: Sensory evaluation of the six sausage formulations

Table 1: Beef frankfurter sausage recipe per batch (4 kg of meat).

Ingredients	**Control (salted) (g)**	**Unsalted (g)**
Normal beef mince	2750	2750
Lean beef mince	1250	1250
Water	750	750
Sodium chloride	100	0
Dextrose	75	75
Soy protein isolate powder	15	15
White pepper	15	15
Potato starch	15	15
Sodium hexametaphosphate	10	10
Coriander	5	5
All spice	5	5
Ascorbic acid	4	4
Nutmeg	3	3
Paprika	2.5	2.5
Sodium nitrite	0.5	0.5

Table 2: Edible salt coating solution formulations.

Coating solution salt conc. (%)	NaCl (g)	Gelatine (g)	Sorbitol (g)	Water (g)
1.5	7.5	15.0	3.75	500
4.5	22.5	15.0	3.75	500
7.5	37.5	15.0	3.75	500
10.5	52.5	15.0	3.75	500
15.0	75.0	15.0	3.75	500

Table 3: Salt content, weight increase and cooking loss of the six sausage formulations.

	Control	1.5% salt coating	4.5% salt coating	7.5% salt coating	10.5% salt coating	15% salt coating
Salt content estimation[1] (%)	2.00 (formulation)	0.10	0.30	0.50	0.70	1.00
Salt content (by coating weight increase)[2] (%)	nm[3]	0.10±0.00[e]	0.29±0.02[d]	0.46±0.03[c]	0.67±0.05[b]	0.88±0.06[a]
Test strip salt content after baking (%)	1.66±0.07[a]	0.09±0.04[f]	0.32±0.01[e]	0.46±0.03[d]	0.68±0.05[c]	0.86±0.04[b]
Weight Increase (%)	nm	6.90±0.56[a]	6.90±0.53[a]	6.48±0.51[a]	6.81±0.65[a]	6.30±0.61[a]
Cooking loss (%)	25.53±1.89[b]	36.84±2.05[a]	37.77±2.35[a]	37.40±2.41[a]	37.21±2.31[a]	37.68±2.02[a]

Results are expressed as mean ± standard deviation, except the salt content estimation which is the estimated value.

Values with different lowercase letter superscripts in the same row are significantly different ($P < 0.05$).

[1] Salt content (by estimation) = salt content of the coated sausages was estimated based on the coating volume; salt content of the control sausage was the formulated concentration.

[2] Salt content (by coating weight increase) = salt content of the coated sausages determined based on the weight increase after coating.

[3] nm = not measured

Table 4: pH and colour attributes (L*, a* and b*) of the six sausage formulations.

	Control	1.5% salt coating	4.5% salt coating	7.5% salt coating	10.5% salt coating	15% salt coating
pH	5.98±0.01[de]	6.08±0.02[a]	6.02±0.01[b]	6.00±0.01[c]	5.99±0.01[cd]	5.96±0.01[e]
L*	54.98±1.07[a]	55.09±1.45[a]	55.22±1.47[a]	55.25±1.62[a]	54.17±1.70[a]	54.62±1.29[a]
a*	15.15±0.62[a]	14.77±0.66[a]	14.64±0.68[a]	15.19±0.79[a]	15.20±0.63[a]	14.79±0.72[a]
b*	13.99±0.81[a]	14.20±0.67[a]	14.59±0.79[a]	14.09±0.69[a]	14.04±0.61[a]	14.32±0.73[a]

Results are expressed as mean ± standard deviation.

Values with different lowercase letter superscripts in the same row are significantly different ($P < 0.05$).

Table 5: Texture profile of the six sausage formulations. Are these calculated averages.

	Control	1.5% salt coating	4.5% salt coating	7.5% salt coating	10.5% salt coating	15% salt coating
Hardness (N)	11.57±1.06[b]	14.93±1.01[a]	14.61±1.39[a]	15.03±1.43[a]	14.92±0.94[a]	15.59±1.26[a]
Gumminess (N)	2.36±0.33[b]	3.17±0.71[a]	3.07±0.51[a]	3.32±0.58[a]	3.18±0.44[a]	3.10±0.67[a]
Chewiness (N)	0.99±0.44[b]	1.61±0.47[a]	1.84±0.56[a]	1.69±0.75[a]	1.75±0.61[a]	1.77±1.09[a]
Cohesiveness	0.204±0.028[a]	0.212±0.023[a]	0.210±0.021[a]	0.211±0.021[a]	0.213±0.012[a]	0.199±0.027[a]
Springiness (mm)	0.421±0.341[b]	0.511±0.292[a]	0.602±0.371[a]	0.512±0.263[a]	0.551±0.312[a]	0.572±0.311[a]
Resilience	0.572±0.272[a]	0.541±0.171[a]	0.662±0.342[a]	0.551±0.172[a]	0.622±0.351[a]	0.691±0.321[a]

Results are expressed as mean ± standard deviation.

Values with different lowercase letter superscripts in the same row are significantly different ($P < 0.05$).

Table 6: Sensory evaluation of the six sausage formulations.

	Control	1.5% salt coating	4.5% salt coating	7.5% salt coating	10.5% salt coating	15% salt coating
Toughness	6.90±2.26[a]	6.37±3.12[a]	6.82±3.00[a]	6.38±2.57[a]	6.83±2.32[a]	7.00±2.90[a]
Juiciness	6.11±2.17[a]	2.85±2.02[c]	3.76±2.37[bc]	4.18±2.02[b]	4.41±1.86[b]	4.54±2.54[b]
Saltiness	8.51±2.00[b]	1.88±1.28[e]	5.00±2.35[d]	6.23±2.10[cd]	7.61±2.51[bc]	11.19±1.87[a]
Overall	8.50±2.16[a]	5.92±1.89[c]	7.75±2.15[ab]	8.83±2.08[a]	8.25±1.59[a]	6.52±1.43[bc]
Purchase intention as a beef snack (%)	51	14	26	40	46	11
Purchase intention as a salt-reduced product (%)	31	40	54	40	44	14

Results are expressed as mean ± standard deviation, except the purchase intention which is the percentage of panellists willing to purchase the product. Values with different lowercase letter superscripts in the same row are significantly different ($P < 0.05$).

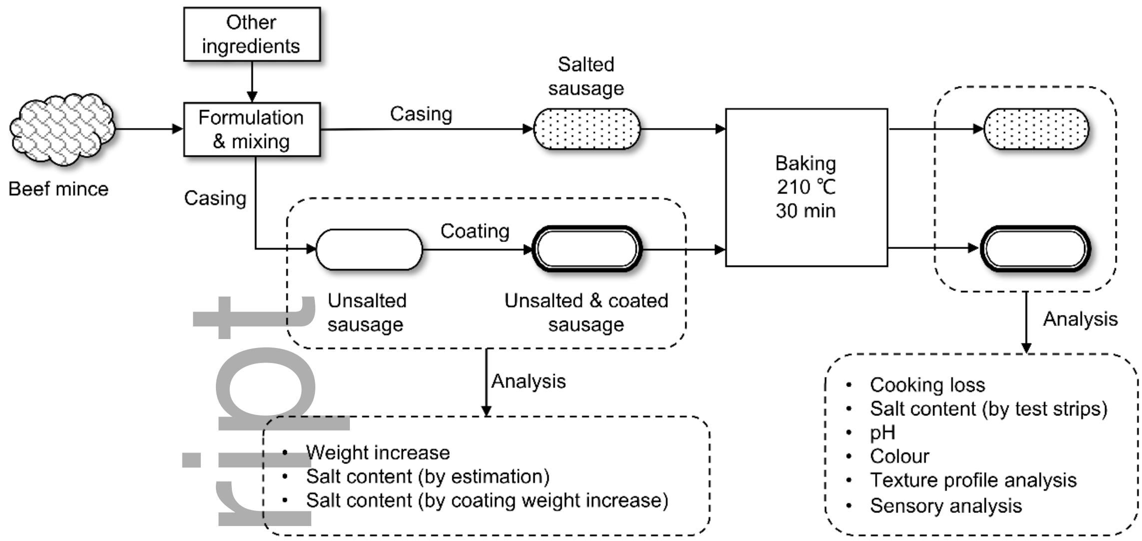

Figure 1: Flow diagram of frankfurter sausage preparation and analysis.