Combined effects of high hydrostatic pressure and sodium nitrite on color, water holding capacity and texture of frankfurter

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Combined effects of high hydrostatic pressure and sodium nitrite on color, water holding capacity and texture of frankfurter

G Jonas, B Csehi, P Palotas, A Toth, Gy Kenesei, K Pasztor-Huszar and L Friedrich

Department of Refrigeration and Livestock Products Technology, Faculty of Food Science, Szent István University, 1118 Budapest, Ménési str. 43-45, Hungary

E-mail: Jonas.Gabor@etk.szie.hu

Abstract. The aim of this study was to investigate the effect of sodium nitrite and high hydrostatic pressure on the color, water holding capacity (WHC) and texture characteristics of frankfurter. Three hundred, 450 and 600 MPa (5 minutes; 20 °C) and 50, 75, 100 and 125 ppm (calculated on weight of meat) sodium nitrite were applied. Parameters were measured right after the pressure treatment. Data were evaluated with two-way analysis of variance (p 0.05) with pressure levels and sodium nitrite amounts as factors. Nitrite reduction significantly increased lightness (L*) and resulted in decreased redness (a*) value. The pressure treatments decreased the lightness at all nitrite concentrations and did not significantly affect the red color of frankfurters. Fifty and 75 ppm nitrite and pressurization at 300 or 450 MPa improved the water holding property of frankfurter. The pressure treatment did not significantly affect the WHC but changing the nitrite amount had significant effect on it. Interactive effect occurred between pressure levels and nitrite concentrations for hardness. The pressure treatment increased and the nitrite reduction decreased hardness. Significant changes were found in cohesiveness at 450 and 600 MPa in frankfurters containing 50 and 75 ppm nitrite: pressure treatment at higher levels and nitrite reduction decreased the value of cohesiveness.

1. Introduction

Frankfurters belong to the group of classical raw-cooked meat products, originated more than 100 years ago and now enjoy worldwide popularity [1]. Sodium nitrite (NaNO₂) mixed in salt (NaCl) are important additives of meat products (e.g. frankfurter) to provide color, flavor, antioxidant and antimicrobial activity and texture properties [2]. However, nitrite in meat products have been identified as a potential health risk that can generate methemoglobin, which is a recognizable sign of nitrite toxicity in humans and may react with certain amines in foods to produce carcinogenic N-nitrosocompounds such as nitrosamines [3,4]. In view of the potential health risks and the increasing demand for healthier products, the use of nitrite in meat products faces a challenge to reduce the content of nitrite [5].

High hydrostatic pressure (HHP) treatment is a non-thermal technology to preserve foods and food products. The high hydrostatic pressure treatment is also known as ‘minimal processing technology’ because it retains more original properties of foods than the conventionally used technologies (e.g. heat treatment) [6]. Based on earlier findings the industrial application of HHP began in the 1990’s...
At present more than 300 HHP equipment are in use worldwide [8]. In the last two decades, a lot of studies have shown the efficacy of this technology in inactivation of pathogenic microorganisms and increasing the shelf-life of meat products [9]. High pressure has an effect on proteins in meat products and can modify their functional properties by protein denaturation, aggregation or gelation [10]. Due to changes in protein structure HHP suggests a process to tenderize meat or produce innovative and additive-free meat products [11, 12].

HHP has proved an alternative to reduce the salt level in frankfurter and sausage [13, 14]. Macfarlane et al. [15] and Mandava et al. [16] found that high pressure below 200 MPa increases the water holding and binding properties of meat batters at reduced salt concentration. High pressure treatment results in changes in fresh meat color. The lightness (L* value) increases right after the pressure treatment (above 250 MPa), whereas the redness (a* value) decreased at 400 to 500 MPa resulting in gray-brown color [17]. In case of meat products the color changes are acceptable and depending on the water content and a_w-value [18]. However, these changes are not too relevant if the products are further processed for example cooked before eating. Sikes et al. [14] investigated the effects of HHP on texture of low-salt beef sausage batters and found that at all salt concentrations (0% to 2%), the hardness and gumminess of pressure-treated (up to 400 MPa, 10 °C, 2 min) samples were higher compared to the non-pressurized ones. There was greater acceptability in terms of both appearance and texture of pressure treated low-salt sausages in comparison with the non-pressurized samples.

In this sense the high pressure treatment could be used to improve the functional properties and safety of meat products with reduced additive (e.g. nitrite) content. Impact of sodium chloride and phosphates under high pressure was investigated by Crehan et al. [13], Tintchev et al. [19] and Villamonte et al. [20]. However, there is no clear relationship between the applied sodium nitrite amount and high hydrostatic pressure treatment. Therefore the aim of this study was to investigate the effect of sodium nitrite and high hydrostatic pressure on color, WHC and texture characteristics of frankfurter.

2. Materials and methods
2.1. Preparation of frankfurter
Frankfurter samples were prepared from pork muscle (pork shoulder) and back-fat that were obtained from a local producer. The muscle was ground (diameter 4 mm) and mixed with salt (sodium chloride, NaCl; 2.0% weight of meat), polyphosphate (tetrasodium pyrophosphate, Na_4P_2O_7; 0.4% of meat), ascorbate (sodium L ascorbate; 0.5% weight of meat), ice (70% weight of meat) and pork back-fat (40% weight of meat). The amount of added nitrite (sodium nitrite, NaNO_2) was 0.005% (50 ppm), 0.0075% (75 ppm), 0.01% (100 ppm), 0.0125% (125 ppm) weight of meat. The raw meat batters were relaxed between 4-6 °C for 30 minutes then filled into polyethylene casing (diameter 100 mm). The frankfurters were hand-linked and cooked in a Kerres CS 305 smoker cabin to core temperature of 72 °C. The cooked frankfurters were showered by cold water then stored overnight at 4-6 °C. Before pressure treatment the frankfurters were vacuum packed without removing the casing. Three frankfurter samples from each nitrite concentration were pressure treated in independent cycles.

2.2. Pressure treatment
After heat treatment the frankfurters were pressurized at 300, 450 and 600 MPa for 5 minutes in RESATO FPU-100-2000 (Resato International B.V, Netherland) high pressure equipment. Pressure gradient was 100 MPa/min. Pressure treatment was carried out at room temperature (approx. 20 °C) and sample temperature variations due to adiabatic heat were considered as intrinsically included inside pressure factor (reproducible sample thermal history linked to pressure level). Zero (0) MPa means unpressurized frankfurters.
2.3. WHC determination
The WHC was characterized as released water from frankfurter samples and was measured according to Grau [21]. An amount of sample between 200 and 300 mg was exactly weighed and put on a known weight 2500 mm² (50x50 mm) area filter paper. The filter paper and the sample were placed between two glass plates and pressurized with 0.5 kg weight for 5 min then the filter paper was dried. The appeared spot (moisture from sample) was cut out from the filter paper and the paper without spot was weighted. The released water from sample was calculated as the proportion of area and weight of spot and sample and was expressed in [mm²/mg] dimension. Three replicates were analyzed from each pressure treatment-nitrite content combinations.

2.4. Color measurement
Objective color was measured using a Minolta ChromaMeter CR-400 (Konica Minolta Inc., Japan) on the cut internal surface of frankfurter. The measured values were expressed in CIE Lab as L* (lightness), a* (redness) and b* (yellowness). Appearance of frankfurter is basically determined by its lightness and redness. Therefore lightness (L*) and redness (a*) parameters were evaluated. Nine replicates were analyzed from each combination.

2.5. Texture profile analysis (TPA)
Texture of pressure treated frankfurters were measured using SMS TA. XT Plus (Stable Micro Systems Ltd., United Kingdom) texture analyzer. Three cylinders (diameter=18 mm; height=20 mm) were cut from each frankfurter and axially compressed to 70% of their original height in two cycles. Load cell was 500 N and crosshead speed was 2 mm/s. Evaluated texture parameters were the hardness (N) and cohesiveness (dimensionless). Three replicates were analyzed from each pressure treatment-nitrite content combinations.

2.6. Statistical analysis
The data were analyzed using IBM SPSS 22.0 software. Statistical analysis was performed by analysis of variance (ANOVA) with pressure levels and nitrite concentrations as factors. Difference was considered to be statistically significant at p<0.05.

3. Results and discussion
3.1. Water holding capacity
According to Macfarlane et al. [15] pressure treatment at 150 MPa improved the water holding property of heat treated beef patty and decreasing WHC was found between 300 and 600 MPa. These results are in part consistent with ours. Figure 1 shows the released water of heat treated then pressurized frankfurters prepared with varying nitrite concentrations. Changing the nitrite concentration had an effect on amount of released water of pressurized samples. Fifty and 75 ppm nitrite and pressurization at 300 or 450 MPa decreased the amount of released water. However, pressure treatments slightly increased the amount of released water in case of frankfurter prepared with 125 ppm nitrite. Based on statistical results pressure treatment had no significant effect on released water (p=0.302). However, changing the nitrite concentration had significant effect on the released water (p=0.020) of frankfurters in case of all pressure treatments. Interaction between pressure level and nitrite concentration was not observed (p=0.208).
3.2. Instrumental color

Appearance of frankfurter is basically determined by its lightness and redness. Therefore the lightness (L*) and redness (a*) parameters were evaluated. Figure 2 and figure 3 show the objective lightness (L*) and redness (a*) of heat-treated and pressurized frankfurters prepared with various nitrite concentrations. Nitrite reduction increased the lightness value (L*) of frankfurter at each pressure level. Application of 50 and 75 ppm nitrite resulted in ‘paler’ appearance than 100 or 125 ppm. Difference of lightness values between 100 and 125 ppm frankfurters was negligible. The pressure treatments decreased the lightness of frankfurters in case of each nitrite concentration. Based on statistical results pressure treatment at 450 and 600 MPa significantly decreased the lightness of frankfurters (p<0.05) and the nitrite reduction significantly increased the lightness (p<0.05). Nitrite reduction resulted in decrease of redness (a*) independently of the pressure treatment. This, taking into account the role of nitrite in promoting red color development was in line with our expectations. Nitrite reduction in frankfurter samples resulted in significantly lower red color values (p<0.05). High pressure treatment of meat pigment (myoglobin) caused partial denaturation and discoloration [22]. In our study the pressure treatments did not significantly affect the red color of frankfurters (p=0.365). It is explicable since the effect of high pressure treatment on myoglobin depends on the temperature at which the pressure treatment occurs [23]. Interactive effect on lightness (p=0.320) and red color (p=0.912) was not observed between nitrite amount and pressure treatment.

Figure 1. Effect of 50, 75, 100, 125 ppm nitrite and 0, 300, 450 and 600 MPa pressure treatment on released water of frankfurter

Figure 2. Effect of 50, 75, 100, 125 ppm nitrite and 0, 300, 450 and 600 MPa pressure treatment on lightness (L*) of frankfurter’s internal surface

Figure 3. Effect of 50, 75, 100, 125 ppm nitrite and 0, 300, 450 and 600 MPa pressure treatment on redness (a*) of frankfurter’s internal surface
3.3. Texture profile analysis

Changing the nitrite amount and pressure treatment had effect on hardness of frankfurter (figure 4). The effect was statistically verifiable in case of both parameters. Crehan et al. [13] found that pressure treatment at 300 MPa resulted in improved hardness compared to non-pressurized frankfurter. Hardness of frankfurters prepared with 100 and 125 ppm nitrite gave similar results. However, hardness of 50 and 75 ppm nitrite frankfurters did not change. At 450 MPa pressure level a decrease in hardness was seen at 100 and 125 ppm levels while in case of lower nitrite concentrations an increase in hardness was observed. Based on statistical results interactive effect occurred between pressure treatment and nitrite concentrations for hardness (p=0.009). Pressure treatment can improve the cohesiveness in meat products [15]. However, our results presented that pressure treatment at higher levels and nitrite reduction decreased the cohesiveness (figure 5). Significant decrease was found in cohesiveness at 450 and 600 MPa in frankfurters containing 50 and 75 ppm nitrite. At these pressure levels a tendency was seen: reducing the amount of nitrite resulted a product with less cohesive texture. Effects of pressure treatment and nitrite concentrations were significant (p<0.05) on cohesiveness but between the factors no statistically verified interactions (p=0.053) were shown.

Figure 4. Effect of 50, 75, 100, 125 ppm nitrite and 0, 300, 450 and 600 MPa pressure treatment on hardness of frankfurter

Figure 5. Effect of 50, 75, 100, 125 ppm nitrite and 0, 300, 450 and 600 MPa pressure treatment on cohesiveness of frankfurter

4. Conclusion

Our experiment showed that nitrite reduction combined with high pressure to 450 MPa decreased the amount of released water and improved the hardness of frankfurter. However, pressure treatment at higher level and nitrite reduction resulted in a decrease of cohesiveness. In terms of lightness antagonist effect was seen. Pressure treatment decreased the lightness while nitrite reduction increased it. Changing in redness was caused by the nitrite alone. The high pressure treatment did not affect the red color. Combination of 75 ppm nitrite and 450 MPa resulted in acceptable product in the viewpoint of investigated functional properties right after the pressure treatment. The high pressure treatment showed promising results that could allow the production of frankfurter with less sodium nitrite. However, further experiments need to be carried out to investigate the microbial effects and changes of functional properties and shelf-life.

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