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Reducing the sodium content in meat products: The effect of the formulation in low-sodium ground meat patties

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Abstract

This study investigated the effect of formulation on quality characteristics of low-sodium ground meat patties. The variation in sodium content was achieved by varying the NaCl content. The formulation variables studied were sodium and fat content and the use of phosphate. The patties were made using 50% or 60% meat in the formulations. Formulation affected the perceived saltiness of ground meat patties. Fat and lean meat content affected perceived saltiness, but their effects were opposite. When the fat content was increased the perceived saltiness increased, but when the meat content increased the perceived saltiness decreased. However, the effect of fat content on perceived saltiness was less than the effect of meat content. The use of phosphate effectively decreased cooking loss, particularly of high-fat-low-sodium patties. The same firmness could be reached with lower sodium content when phosphate was used.

Keywords: Meat patty; Salt; Phosphate; Fat content; Meat content; Low-sodium

1. Introduction

Reports linking excessive sodium intake to the incidence of hypertension (Dahl, 1972; Law, Frost, & Wald, 1991a, 1991b) is the main reason for reducing the sodium content of processed meats. A major portion of sodium in the diet derives from processed foods, mostly in the form of sodium chloride (NaCl). Common salt (NaCl) is used in the production of meat products because of its effects on texture, flavour and shelf life. Salt reduction in meat products thus has adverse effects on water and fat binding, impairing overall texture and increasing cooking loss, and also on sensory quality, especially taste.

The perceived saltiness of NaCl is produced by the Na^+ cation in combination with the Cl^- anion (Miller & Bartoshuk, 1991). Salt also acts as a flavour enhancer, increasing the flavour intensity of meat products (Gillette, 1985; Matulis, McKeith, Sutherland, & Brewer, 1995). Thus, salt reduction does not reduce only the perceived saltiness but also weakens the overall flavour in meat products. Fat and salt in tandem contribute to many of the sensory properties that are characteristic of cooked sausage. For example when the salt level rises, the increase in saltiness is more noticeable in fatty products than in lean ones (Matulis, McKeith, & Brewer, 1994). Ruusunen, Simolin, and Puolanne (2001), however, have shown that the fat content of cooked sausages affects the perceived saltiness in different ways, depending on the formulation. By replacing lean pork with pork fat, thus increasing the fat content and

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simultaneously reducing the protein content, the perceived saltiness of sausages is increased, but on replacing water with fat on an equal weight basis, the perceived saltiness of the sausage did not change. Therefore, the increase in meat protein content was thought to reduce perceived saltiness in cooked sausage.

There are several excellent reviews on salt and phosphates in meats giving the theoretical basis and practical aspects for cooked sausage and whole meat products (Hamm, 1972; Offer & Knight, 1988), but not so many for ground meat patties. In meat products, salt contributes to water and fat binding by expanding the filament lattice of myofibrils and by partially solubilizing the myofibrillar proteins. If both salt and phosphates are present in meat products, they act synergistically to improve yield and the binding of meat particles (Hamm, 1972; Knipe, Olson, & Rust, 1985; Puolanne & Ruusunen, 1980b; Huffman, Cross, Campbell, & Cordray, 1981).

The ultimate goal of this research is to reduce sodium intake from muscle foods. The aim of this study was to investigate the effect of the formulation on the quality characteristics (sensory saltiness, flavour intensity, firmness and juiciness as well as cooking loss) of low-sodium ground meat patties using response surface analysis. The variation in the sodium content was achieved by varying the NaCl content. The variables in the formulations were sodium and fat contents and the use of phosphate. The study used 50% or 60% meat in the formulations.

2. Materials and methods

The ground meat patties used in this study were made from beef trimming (18.8% fat), pork trimming (44.8% fat), water, textured soy protein (R311770), breadcrumbs (R321660), potato flakes (R331150), seasonings (P501750) (onion, white pepper, paprika, black pepper and mustard) and wheat protein. The studied variables were sodium content, fat content, the addition of phosphate (±) and the meat content (50% or 60%).

The target sodium contents were 300, 450 and 600 mg Na/100 g. The target sodium content was the total sodium content, including sodium from the other ingredients as well as NaCl. Consequently, the added salt contents were 0.04%, 0.42% and 0.8% for 300, 450 and 600 mg Na/100 g, respectively. These salt amounts were based on earlier studies in which the effect of cooking loss on overall sodium content had been considered.

The target fat content of the formulations was achieved by varying the proportions of beef and pork trimmings, and the target meat content was achieved by increasing the amount of beef and pork trimmings, and reducing the amount of added water. In this study, tetrapotassium phosphate, (43% P_2O_5) was used. In those formulations where salt content was lowered and phosphate was not used, maltodextrin was used as an inert replacer to keep the same weight of each component of the recipe.

Meat was first ground through a plate (5 mm). Water was then mixed with the dry ingredients, and the mixture was allowed to swell for 30 min at room temperature. Salt and phosphate were added to the lean meat. The swollen ingredient mixture, the meat with salt and the rest of the water were then put into a kitchen chopper (*Tecator 1094*, Perstorp Analytical Company). Chopping was continued until the batter reached an endpoint temperature of 12 °C. The homogenized mixture was allowed to rest for 1 h before the patties were formed.

To produce patties 90 mm in diameter and 15 mm in thickness, ≈90–95 g of the ground meat mixture was taken and placed in a gap, flattened between two plates and subsequently punched out as a patty. These patties were cooked in an electric grill (*Bistro Fix,* Turku, Finland) for 2 min 45 s at 150 °C. This was a contact griller, in which patties were cooked between two hot plates. This allowed for cooking without a need for turning the patties. The core temperature of the ground meat patties after cooking was measured with Foodcheck Thermometer (Comark Limited, England). The endpoint core temperatures ranged between 80 and 83 °C.

Two series of 2^3 full factorial designs were done and both series comprised of 10 trials: In Series 1, the meat content was 50% and the studied recipe variables were sodium, fat and phosphate. In Series 2, the meat content was 60% and the recipe variables were the same as in Series 1. Each formulation was made twice, thus resulting in 40 trials. The response properties of meat patties within the combined data of 40 trials were then studied by response surface analysis using the real values of the recipe variables, instead of the original target values.

2.1. Physical and chemical analyses

The pH values of the ground meat mixture and cooked meat patties were measured directly with a Xerolyte electrode (*Ingold Xerolyt LoT406-M6,* Inlab 427, Mettler Toledo GmbH, Germany). Cooking loss was determined by weighing the meat patties before cooking, and 24 h after cooking. Cooking loss was calculated as the weight difference between the heated and unheated weight (%). Fat content was determined by using the Gerber method. The NaCl content of the ground meat patties was determined by analysing their chloride-ion content (Corning 926 Chloride Analyser, Corning Medical and Scientific Corning Limited, England). Sodium content was determined using a sodium specific electrode (*Ross*^{TM} *sodium electrode*, Orion Research Inc.).

2.2. Sensory evaluation

The saltiness, flavour intensity, firmness and juiciness of the warm meat patties (70 °C) were evaluated by a trained sensory panel ($N=10$). The panel consisted of experts who routinely evaluate meat products. The ground meat patties were sectioned (one-half patty per panelist) and served to the panelists. Attribute intensities were rated using 10-unit graphic intensity scales, which were anchored on both ends (0 = weak, 10 = strong) (Lawless & Heymann, 1998). The samples were presented to the panelists with three-digit codes and in a random order, and tap water was provided for rinsing the mouth between samples. The samples were evaluated twice. The mean of all of the evaluations of the 10 panelists was used as the input score for each of the 40 trials, in the computation of the response surface models and the correlations.

2.3. Statistical analyses and modeling

The response surface analysis of the measured response variables of the sensory variables of saltiness, flavour intensity, firmness and juiciness and of cooking loss was performed using the general linear regression based on 40 trials. The response surface models consisted of the linear terms of meat content, sodium, fat and phosphate contents as well as the pairwise interactions of sodium, fat and phosphate contents. The real measured values of sodium and fat contents were used in the calculations.

All of the computational work, including the graphic presentations of the response surface models, was performed using a Statistica for Windows software package (Version 5.5, edition 99, Statsoft, Inc., Tulsa, OK, USA).

3. Results and discussion

3.1. Background data

The target fat contents of the studied meat patties were 10.0%, 15.0% and 20.0%, and the analysed fat contents on average were 10.0%, 15.5% and 19.8%, respectively. The target sodium contents were 300, 450 and 600 mg/100 g, and the analysed sodium contents were 321, 490 and 646 mg/100 g, respectively. The analysed salt contents of cooked meat patties, based on chloride content averaged 0.6%, 1.0% and 1.4%, this includes chloride from other ingredients as well as NaCl. The phosphate used in this study increased the pH value of the product. The mean pH value of the patty mixtures made without phosphate was, pH 6.04 while that of cooked meat patties was, pH 6.19. With added phosphate the pH-values were 6.28 and 6.37, respectively.

Although the formulations had been made using the two meat contents, the results presented in Figs. 1–5 are only for patties made with a meat content of 50%, because of the linear effect of meat content in the response surface models, which implies that the effect of the meat content on the response variables is constant throughout the areas presented in Figs. 1–5. The direct correlations of the meat content with the response variables are, however, not statistically significant, as shown in Table 1. On the other hand, its contribution in the response surface models is significant as far as saltiness, flavour intensity and juiciness are considered. When the meat content increases from 50% to 60%, the changes in the response variable values are as follows:

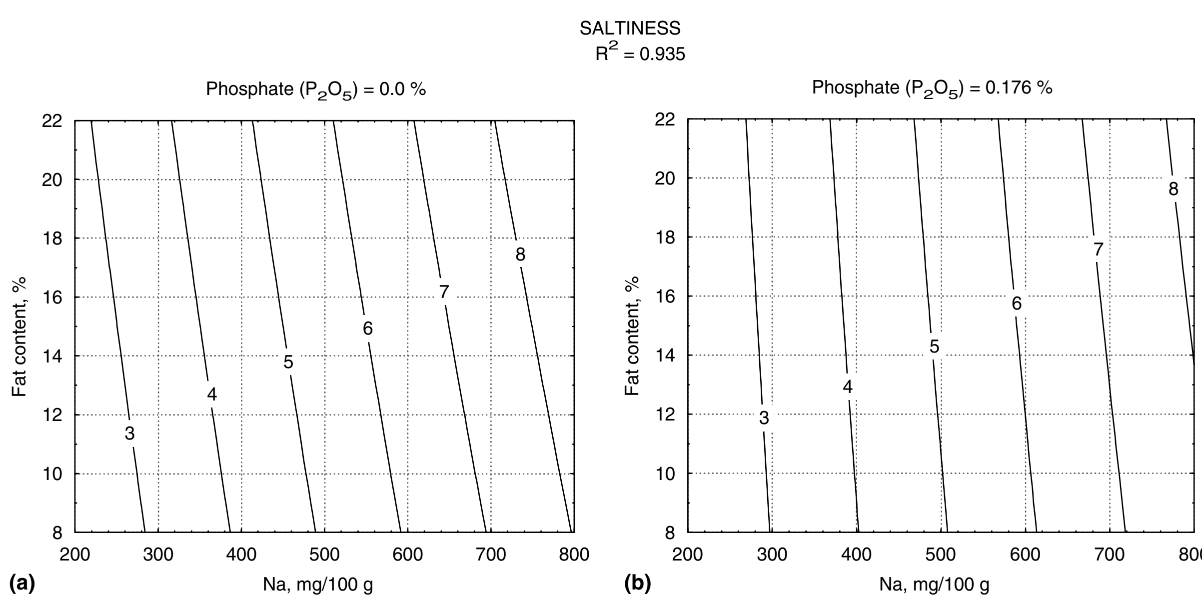

Fig. 1. The effect of sodium and fat content on the perceived saltiness of ground meat patties (scale in perceived saltiness: 0 = weak, 10 = strong): (a) without phosphate; (b) with phosphate.

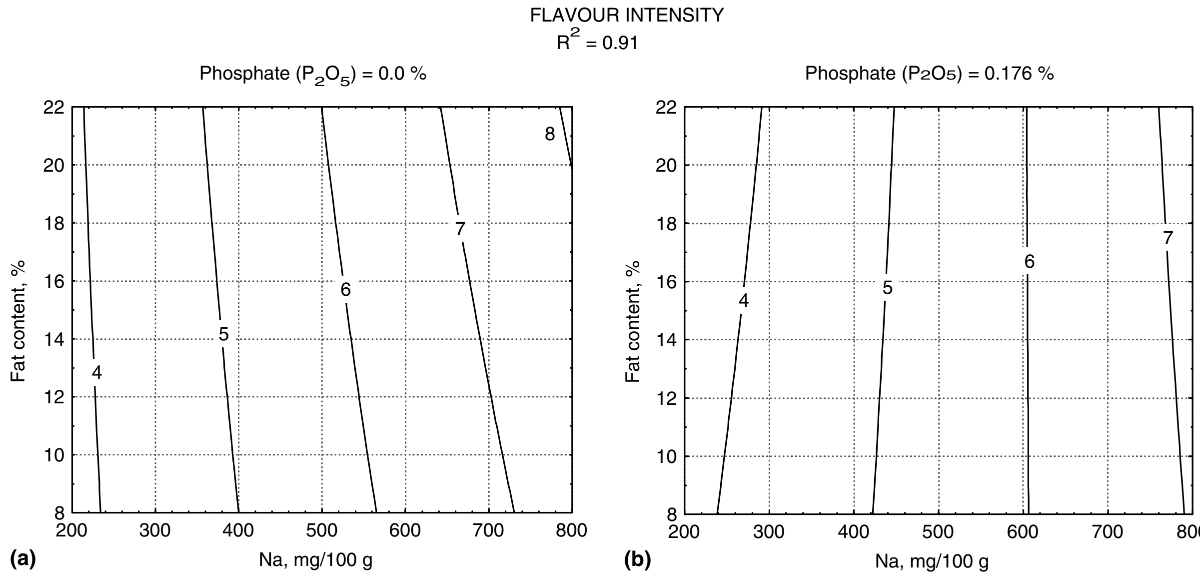

Fig. 2. The effect of sodium and fat content on the flavour intensity of ground meat patties (scale in flavour intensity: 0 = weak, 10 = strong): (a) without phosphate; (b) with phosphate.

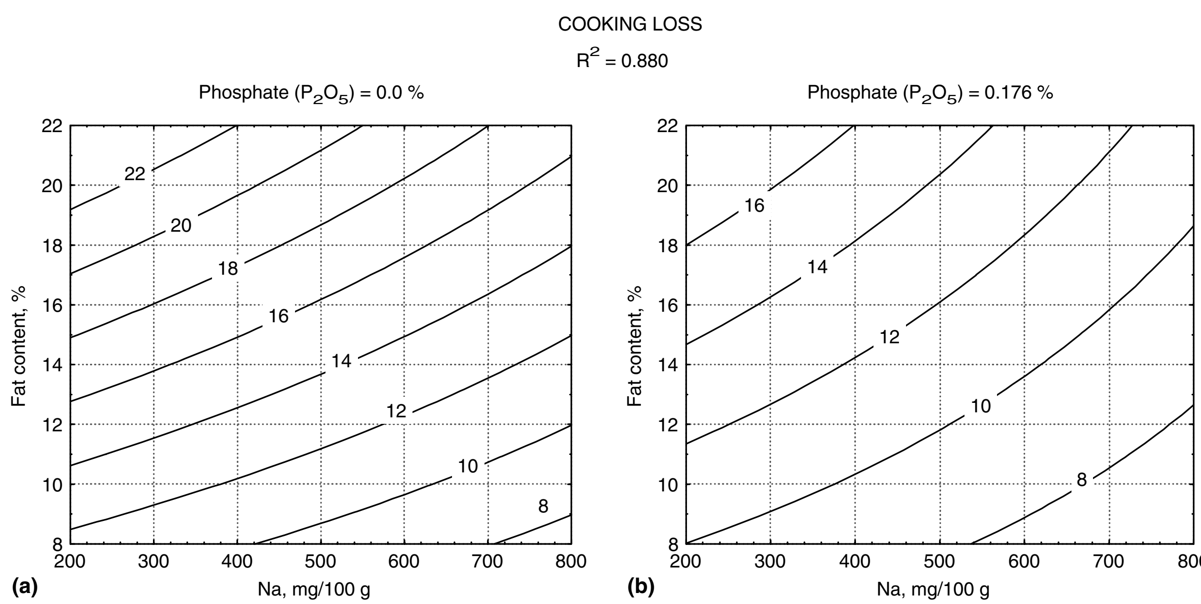

Fig. 3. The effect of sodium and fat content on cooking loss (%) in ground meat patties: (a) without phosphate; (b) with phosphate.

cooking loss (%) (−0.9) and sensory traits in the scale of 0–10: saltiness −1.0, flavour intensity −0.5, firmness +0.1 and juiciness −0.7 units.

3.2. Saltiness and flavour intensity

As expected an increase in sodium content resulted in increased perceived saltiness (Fig. 1(a) and (b)) and flavour intensity (Fig. 2(a) and (b)). When the fat content increased, the saltiness increased at a higher rate in the patties without phosphate than in those with phosphate, but the effect of fat content on the perceived saltiness of meat patties was very weak. For example in Fig. 1(a), at sodium content of 400 mg/100 g the perceived saltiness value of meat patties was 4.2 (scale 0–10) when the fat content was 10%, but was found to be 4.8 when the fat content was 20%. In the patties with phosphate (Fig. 1(b)), the saltiness values were 4.0 and 4.2, respectively, indicating that phosphate had no marked effect on perceived saltiness. The effect of the sodium content and fat content on the flavour intensity (Fig. 2(a)) was similar to the effect of sodium and fat content on the perceived saltiness (Fig. 1(a)) in patties without phosphate. When the patties were made with phosphate,

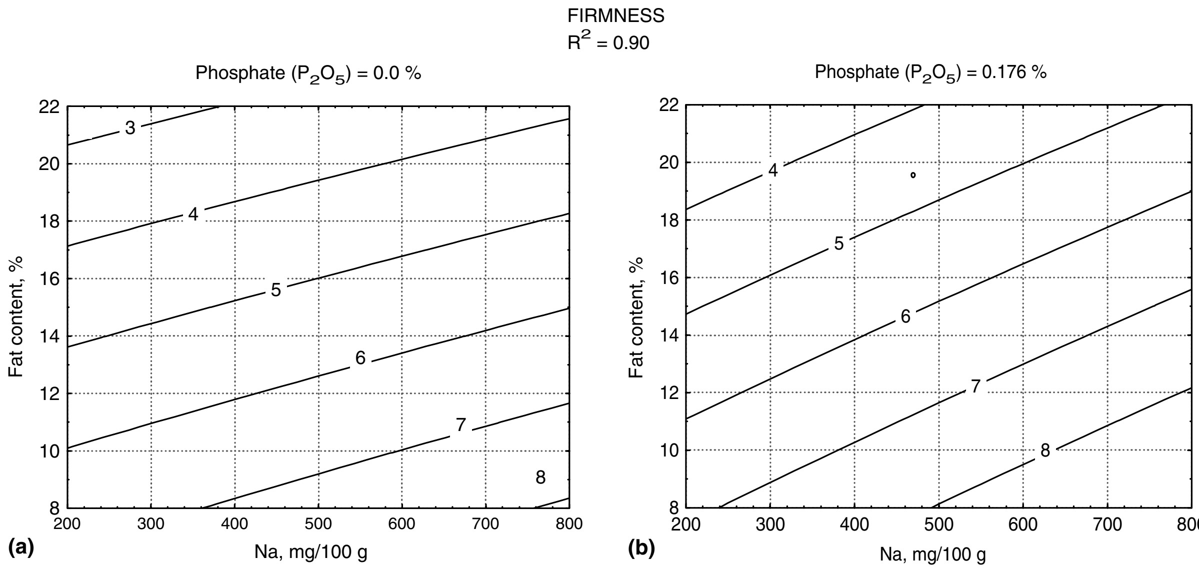

Fig. 4. The effect of sodium and fat content on the sensory firmness of ground meat patties (scale in firmness: 0 = weak, 10 = strong): (a) without phosphate; (b) with phosphate.

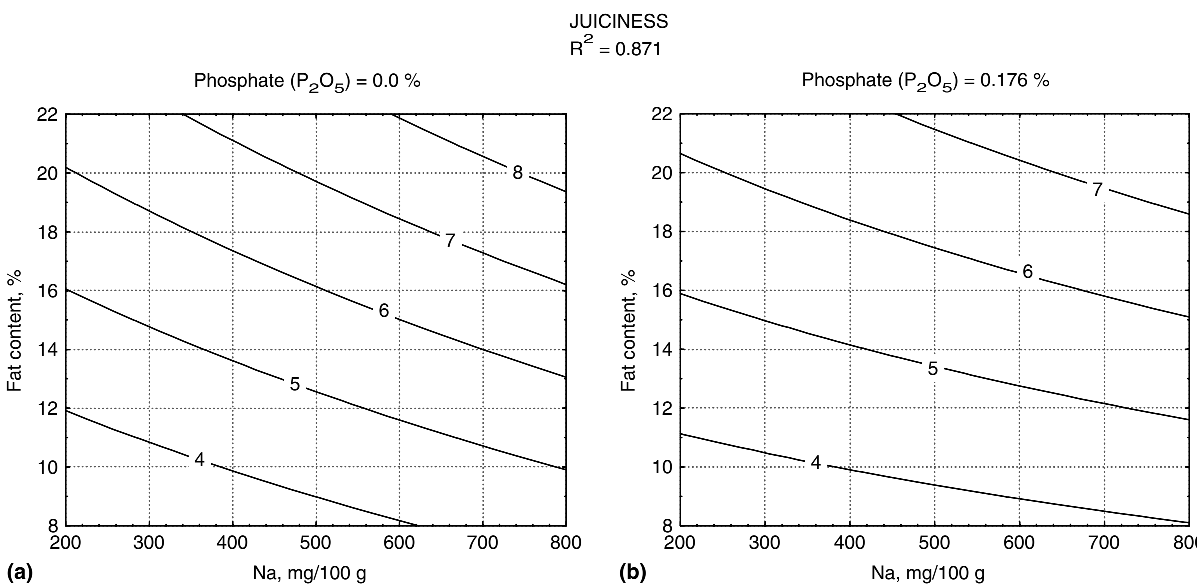

Fig. 5. The effect of sodium and fat content on juiciness of ground meat patties (scale in juiciness: 0 = weak, 10 = strong): (a) without phosphate; (b) with phosphate.

Table 1
Correlation coefficients between the studied variables and the analysed properties of the ground meat patties ($N = 40$)

	Meat content	Phosphate	Na mg/100 g	Fat content
Cooking loss	−0.166; $p = 0.306$	−0.377; $p = 0.017$	−0.295; $p = 0.065$	0.656; $p = 0.000$
Firmness	0.064; $p = 0.695$	0.125; $p = 0.444$	0.200; $p = 0.215$	−0.850; $p = 0.000$
Juiciness	−0.196; $p = 0.227$	0.011; $p = 0.948$	0.350; $p = 0.027$	0.856; $p = 0.000$
Saltiness	−0.231; $p = 0.152$	−0.123; $p = 0.448$	0.900; $p = 0.000$	0.206; $p = 0.202$
Flavour intensity	−0.185; $p = 0.253$	−0.220; $p = 0.173$	0.884; $p = 0.000$	0.122; $p = 0.454$

flavour intensity even slightly decreased at the lowest sodium contents, when the fat content of the patties increased (Fig. 2(b)). Matulis et al. (1994) have also shown that when the salt level rises in meat products, the increase in saltiness is more noticeable in fatty products than in lean ones.

Table 2
Statistical significance of each variable in the response surface models ($N=40$)

	Cooking loss (p)	Firmness (p)	Juiciness (p)	Saltiness (p)	Flavour intensity (p)
Meat content	0.052	0.385	0.001	0.000	0.000
Phosphate	0.670	0.881	0.362	0.797	0.437
Na mg/100 g	0.499	0.129	0.550	0.000	0.000
Fat content	0.000	0.000	0.004	0.516	0.888
Phosphate×Na mg/100 g	0.729	0.203	0.354	0.795	0.432
Phosphate×fat content	0.003	0.797	0.456	0.405	0.174
Na mg/100 g×fat content	0.156	0.778	0.317	0.699	0.366

Meat content affected the perceived saltiness differently to fat content. When the meat content increased from 50% to 60%, both the perceived saltiness and the flavour intensity decreased (Tables 1 and 2) (see also Ruusunen et al., 2003). When the meat content increased from 50% to 60% perceived saltiness of the meat patties decreased on average by 1.0 unit (scale 0–10) and flavour intensity by 0.5 unit over the whole studied sodium area. The effect of meat content on perceived saltiness was stronger than the effect of fat content. The study showed that more salt is needed in ground meat patties of high lean meat content to achieve the same perceived saltiness as in products of low meat content, as has been shown previously in cooked sausages (Ruusunen et al., 2001).

Typically, the salt content in Finnish meat patties ranges from 0.9% to 1.6%. The lowest salt content used in this study (on average 0.6% NaCl) was quite low, and therefore the flavour intensity of such patties was weak. Consumers want, however, a flavour intensity and texture similar to the product they are accustomed to. When producing meat patties with reduced salt content, it is easier to produce meat patties with a texture which resembles that of the normal-salt product than produce meat patties which have the pleasantness of the taste acceptable to consumers. Therefore, the weakness of the flavour intensity is a more restrictive factor than the texture when producing low-salt meat patties.

3.3. Cooking loss

The cooking of the patties inevitably leads to cooking losses. In the present study, the increase of sodium content was due to an increase of salt content in the patties and as expected, increased sodium content gave the largest reduction in cooking loss. At the same sodium content cooking loss was, however, always higher in high-fat rather than low-fat contents (Fig. 3(a) and (b)). Puolanne and Ruusunen (1980b) found that the water-binding capacity of cooked sausage without phosphate increases almost linearly as the salt content rises to ≈2.5%. With phosphate there is a marked increase in water-holding in the range of 1.0–1.5% NaCl and the salt maxima are shifted to lower values with increasing fat content of the batter (Puolanne & Ruusunen, 1980a).

The phosphate used in the present study increased the pH value of the product by about 0.2 pH-units, and decreased the cooking loss of the patties (Fig. 3(a) and (b)) as has previously also been shown in the studies of Matlock, Terrell, Savell, Rhee, and Dutson (1984) and Keeton (1983). The use of alkaline phosphates may be the most practical alternative when reducing salt levels in processed meats (Rust & Olson, 1982; Ruusunen, Niemistö, & Puolanne, 2002). Macfarlane, McKenzie, and Turner (1984) have also described the effect of pH on the binding properties of tetrasodium pyrophosphate in meat patties. The highest binding occurs at a pH value of about 6, and binding increases with an increase in salt content.

In the present study, the increase in fat content increased the cooking loss (Tables 1 and 2) in patties both with and without phosphate. However, the use of phosphate decreased the cooking loss, especially when high fat contents were involved (Fig. 3(a) and (b)). The effect of phosphate on cooking loss was within 1–6% points, depending on fat content. For example at a sodium content of 400 mg/100 g (Fig. 3(a)), the cooking loss in patties made without phosphate increased by about 8%-points (from 12% to 20%) when the fat content increased from 10% to 20%. Under the same conditions, in the patties made with phosphate, the increase in cooking loss was only 5%-points (from 10% to15%) (Fig. 3(b)). It is therefore possible to prepare meat patties with lower sodium contents and higher yields when phosphate is used.

3.4. Firmness and juiciness

The amount of fat in the patty mixture has been found to significantly affect the quality of meat patties. Reduction of fat in ground beef patties causes a loss of palatability, especially when the fat is reduced to the 5–10% level (Troutt et al., 1992). When fat levels are increased in beef patties, tenderness and juiciness also increase (Berry & Leddy, 1984; Cross, Berry, & Wells, 1980). One of the major problems in lowering the fat content in finely chopped meat products is its subsequent effect on texture, i.e., an increase in toughness and a decrease in juiciness, and therefore, an overall decrease in acceptability (Sofos & Allen, 1977).

In this study, fat content also had the largest effect on sensory firmness, as found by Kregel, Prusa, and

Hughes (1986) and Troutt et al. (1992). When the fat content of the ground meat patties increased from 10% to 20%, the firmness decreased by three units, independent of the sodium content. The interactions between phosphate and fat, or between sodium and fat were not pronounced (Table 2). Fig. 4(a) and (b), however, show that phosphate increases the effect of salt on firmness. At a constant fat level, the same firmness was reached with a lower sodium content when phosphate was added. For example, with a fat content of 14%, a firmness value of 6 (scale 0–10) was reached at 680 mg Na/100 g (Fig. 4(a)) in patties without phosphate, but with phosphate at 420 mg Na/100 g (Fig. 4(b)).

In this study, fat content had the largest overall effect on meat patty juiciness, as Kregel et al. (1986), Egbert, Huffman, Chen, and Dylewski (1991) and Berry (1992) also found. For example at a sodium content of 400 mg/100 g the juiciness of meat patties made with or without phosphate (Fig. 5(a) and (b)) increased by two-and-a-half units (scale 0–10) when the fat content of the patties increased from 10% to 20%. The same increase in juiciness in relation to fat content increase was found at all sodium contents.

4. Conclusions

The fat and meat contents in patties both affect the perceived saltiness, but their effects are opposite. When the fat content increases the perceived saltiness also increases, but when the meat content increases the perceived saltiness decreases. The effect of fat content on perceived saltiness is weaker than the effect of meat content. The use of phosphate has no marked effects on perceived saltiness, but it effectively decreases cooking loss, particularly in high fat and low-sodium patties. The same firmness can be reached with a lower sodium content when phosphate is used.

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