A comparative study of fat replacers in cooked sausages

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Abstract. Reduction of fat in meat products is an important task aimed at solving the problem of excessive fat intake. Different substances are used as fat replacers: plant and animal proteins, and polysaccharides. The aim of the research was a comparative study of the effect of different fat replacers (inulin; a mixture of hydrocolloids; soy protein, and; collagen protein) on the quality of low-fat cooked sausage. In the experimental samples, 50% of backfat was replaced with: inulin gel (exp. 1), a mixture of hydrocolloids (carrageenan, xanthan gum and guar gum) with additional incorporation of water (exp. 2), hydrated soy protein (exp. 3), or hydrated collagen protein (exp. 4). Addition of the fat replacers reduced the fat content by more than 40%. The use of hydrocolloids and soy protein in the hydrated form as fat replacers negatively affected sausage taste and consistency. Addition of the hydrated animal protein had no significant effect on taste, color characteristics, or water activity, but led to a decrease in the sausage shear force. The sausage produced with inulin had the organoleptic, color and strength characteristics closest to the control sausage. Inulin gel, therefore, is recommended as a fat replacer in cooked sausages.

1. Introduction
The problem of high fat intake has gained a considerable importance in the world due to the increased incidence of cardiovascular diseases and development of obesity. An important measure aimed at solving this problem is increasing the production of products with reduced fat contents. Substances with a structure different from fat, for example, protein- and carbohydrate-based substances, can be used as fat replacers separately or in different combinations. Moreover, these components should have properties that allow them to imitate several functional characteristics of fat and impart the necessary tenderness consistency and attractive appearance to a product. When choosing fat replacers, the fact that fat determines product consistency and palatability must be taken into consideration.

Various hydrocolloids are used in reduced fat products: carrageenan [1], guar [2], xanthan gum [3] and others [4, 5]. With that, a prerequisite is maintenance of the typical organoleptic properties of a product.

Soy protein is used as a protein component that allows the fat content in meat products to be reduced, while improving consistency of sausages with reduced caloricity [6], increasing stability of meat emulsions [7], making the structure firmer and retarding oxidation in low-fat pork patties [8].

A promising substance for production of meat products with reduced fat content is inulin, which is closest to the fat components by appearance, texture and taste. Inulin is easy to use and improves the structure of the finished product; its application does not require changes in the production process parameters. In certain cases, the use of inulin also leads to an increase in product yield. It is possible to use inulin in different types of meat products such as cooked sausages [9], and minced meat [10].

When choosing an optimal fat replacer, it is necessary to take into consideration the meat product type. In Russia, the prevalent product type is cooked sausages, which account for about 60% of total volume. In this regard, the aim of this research was to study the effect of different fat replacers on the quality of low-fat cooked sausages.
2. Materials and methods of investigation

Cooked sausages were made, with the control containing 56 kg beef, 24 kg backfat, 20 kg water, curing ingredients (common salt, sodium nitrite), spices, food-grade phosphates, and sodium ascorbate.

In the experimental sausages, 50% of the backfat was replaced with: inulin gel with an inulin:water ratio of 1:1.5 (exp. 1), 0.5 kg carrageenan:xanthan:guar (2:1:1) and 14.5 l water (exp. 2), hydrated soy protein with a soy protein:water ratio of 1:5 (exp. 3), or hydrated collagen protein with a collagen protein:water ratio of 1:15 (exp. 4). Cooked sausages were produced by traditional technology. Sausages were cooked to an internal temperature of 72±2 °C to obtain the final products.

The mass fraction of protein in the sausages was determined by mineralization of the Kjeldahl sample using a Foss Tecator Kjeltec 2300 (Foss A/S, Denmark), and nitrogen was determined according to the amount of ammonia formed.

Fat content was determined by extracting the total fat with hexane or petroleum ether with a boiling point of 50 to 60 °C in the Soxhlet extraction apparatus (BUCHI Labortechnik AG, Switzerland).

The mass fraction of carbohydrates was determined by subtracting the values of moisture, fat, protein and ash mass fractions from 100 g of the product.

To determine the caloric value, the conversion coefficients for protein and carbohydrates was 4 kcal/g, while for fat it was 9 kcal/g.

Determination of the meat product color characteristics in the CIELab system was carried out using a spectrocolorimeter (Spectroton, Russia) while simultaneously measuring reflection coefficients of sausage samples at 24 fixed wavelengths in increments of 13 nm in the visible spectral range from 380 to 720 nm, followed by mathematical processing of the measurement results by the microprocessor controller integrated in the measuring unit.

The shear force was determined using an Instron-3342 universal testing machine (Instron, USA), with subsequent recording and export of results to an Excel file.

The pH was measured by a potentiometric method using a Zamer-1 portable pH-meter (Zamer, Russia).

The water activity was determined by the cryoscopy method using a Kriometer AWK-20 (Nagy-instruments, Germany).

Each experiment was carried out in three replications. Statistical data processing was performed using Microsoft Excel. The statistical significance of differences between indicators was assessed using the Student’s t-test.

3. Results of the investigation

The organoleptic assessment of cooked sausages showed that all sausages had good marketable appearance and elastic consistency. The results of the organoleptic assessment are given in Figure 1.
Addition of hydrated soy protein instead of backfat led to deterioration of cooked sausage taste, which significantly affected the overall score of product acceptability. According Goldman and Brown, the scores for texture and pork flavor of meat patties decreased significantly as soy hulls were added from 0 % to 4 % or 6 %. Off-flavor scores were significantly higher for patties containing 6% soy hulls than for patties with no soy hulls [11]. Yeung and Huang reported soy protein had negative effects on sensory acceptance of emulsified pork meatballs [12]. In our study, the use of hydrocolloids instead of backfat negatively influenced sausage taste and consistency (p<0.05). The cooked sausages in which part of the backfat was replaced with inulin and collagen protein were the closest to the control by color, taste and odor. Some analogous results have been published by Vasilev et al., who stated that up to 8 % inulin gel can be added to sausage without significant effect on sensory properties [13]. Cho et al. indicated no significant differences in color, flavor, tenderness, juiciness, warm-off flavor, and overall acceptability between control sausage and sausage containing 20% pig skin and wheat fiber mixture [14]. However, the sausage with collagen protein in the current study was significantly inferior to the control (p<0.05) in terms of consistency.

Table 1 presents the results of the determination of the cooked sausage chemical composition. The use of fat replacers instead of backfat did not affect the protein content in the cooked sausages (p>0.05).

| Table 1. Chemical composition of cooked sausages |
|------------------------------------------------|
| **Mass fraction in the product, g/100 g sausage** | **Caloricty, kcal** |
| Protein | Fat | Carbohydrates | |
| Control | 11.9±0.3 | 25.1±1.4 | - | 273.5 |
| Exp. 1 | 11.3±0.2 | 14.8±0.3 | 4.8±0.2 | 197.6 |
| Exp. 2 | 11.0±0.2 | 14.1±1.1 | 0.4±0.0 | 172.5 |
| Exp. 3 | 12.5±0.3 | 14.6±0.5 | - | 181.4 |
| Exp. 4 | 11.7±0.3 | 13.9±0.4 | - | 171.9 |

* p<0.05 compared to control

The fat mass fraction in the experimental sausages was 41.0-44.6 % lower (p<0.05) compared to the control. Incorporation of the fat replacers resulted in products with the fat content reduced by more than 40 % and caloricty reduced by 27-37 % compared to the control. Vasilev et al. noticed that the addition of inulin reduced the fat content in functional cooked sausages compared to traditional ones [13]. According to Choe et al., fat content decreased by 40 % with addition of 15% pig skin and wheat fiber mixture compared to the control, and the calorict content was 19.0–31.9 % lower in sausage samples containing pig skin and wheat fiber than that of the control [14].

The use of the fat replacers did not significantly affect water activity, pH or color characteristics of cooked sausages (p>0.05) (Table 2). Similar data were obtained by Alvarez and Barbut, who found no differences in color of sausages with up to 6% inulin gel [15]. Modi et al. reported the different levels of carrageenan used in low-fat meat kofta had no effect on a* and b* values [16]. Silva-Vazquez et al. indicated no differences between a* values of traditional sausages and treatment with 30 % inulin [17]. Choe et al. noticed the color values of cooked frankfurter-type sausages containing pig skin and wheat fiber were not affected by the fat content [14]. In contrast, according to Rather et al., high-fat goshtaba had a significantly higher L* value, but a lower a* value than its low-fat counterparts [18].

| Table 2. Physico-chemical properties of cooked sausages |
|------------------------------------------------|
| **Indicators** | **Water activity, units** | **pH** | **Color characteristics** |
| | | | lightness L* | redness a* | yellowness b* |
| Control | 0.9778±0.0009 | 6.81±0.04 | 59.3±1.2 | 15.2±0.6 | 9.9±0.2 |
| Exp. 1 | 0.9790±0.0011 | 6.89±0.01 | 57.9±0.7 | 15.6±0.2 | 10.0±0.1 |
Decreases in the back fat content of the cooked sausages affected product texture. The results of structural-mechanical investigations are presented in Figure 2.

**Figure 2.** Shear force of cooked sausages

The use of the fat replacers facilitated decreases in the shear force compared to the control, which was apparently linked with the additional incorporation of moisture into the product composition. The shear force value closest to the control was in sausage produced with the inulin gel (exp. 1; \( p > 0.05 \)). Some analogous results have been published by Modi et al., who indicated the hardness of cooked and fried low-fat meat kofta decreased with the increase of carrageenan levels [16]. Alvarez and Barbut reported that the addition of inulin resulted in a creamy and softer product [15]. In contrast, according to Keenan et al., the hardness increased with increasing inulin concentration [19]. Goldman and Brown found as soy hulls were added to ground pork, peak force values decreased [11]. Ulu noticed when fat level was decreased, hardness decreased in both raw and cooked meatballs [1]. Similar data were obtained by Rather et al., who indicated the hardness was significantly greater in high fat restructured meat product in comparison with low-fat ones [20].

4. Conclusions

The use of fat substitutes instead of backfat in cooked sausages led to a decrease in fat by more than 40%, without significantly affecting the physico-chemical properties of pH, water activity, and color characteristics. The decrease in fat in cooked sausages was accompanied by a decrease in hardness. Organoleptic indicators and shear stress depended significantly on the type of fat substitute used. Addition of soy protein and hydrocolloids instead of backfat in the cooked sausage resulted in product with reduced fat content and lower caloricity, but it negatively affected the organoleptic properties of product taste and consistency. The use of the inulin gel and collagen protein as fat replacers resulted in production of cooked sausages with low fat content and high overall acceptability. However, sausages with collagen protein were significantly inferior to the control in terms of consistency, while those with inulin had organoleptic and
physico-chemical properties closest to the control. Therefore, this comparative investigation of the stabilizers, polysaccharide and natural protein, shows inulin to be an optimal fat replacer in these cooked sausages.

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