INULIN AS A FAT-REDUCTION INGREDIENT IN CHICKEN FRANKFURTERS WITH A REDUCED LEVEL OF SODIUM - TECHNOLOGICAL PROPERTIES AND CONSUMER ACCEPTANCE*

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Summary

Cooked sausages (frankfurters) are one of the most popular meat products in Serbia and the world. However, high contents of saturated fatty acids and sodium, along with the lack of complex carbohydrates, such as dietary fibers, contribute to the unfavorable health perception of these products. In today's market, a wide variety of additives and substitutes are being used as a replacement for animal fat and sodium in meat products that have little to no impact on processing loss and/or the sensory quality of the final product. Research in this field usually goes toward partial or complete fat replacement with different hydrocolloids or vegetable oils, while KCl is generally recommended for partial replacement of NaCl. However, there is limited data regarding frankfurters that have reduced contents of fats and sodium, along with reduced caloric value with additional prebiotics function. The results of this paper suggest that half of the pork backfat and a third of the NaCl could be replaced in chicken frankfurters with inulin gel and potassium salt to improve their nutritive characteristics and to obtain a product that would have characteristics of functional food. The experimental formulation (INK^+) analysis showed characteristical traits for this group of meat products in terms of technological quality and chemical composition and received high sensory evaluation scores for taste, odor, texture, and juiciness. The improved chicken frankfurter group has also shown exceptional nutritional value, considering that it contains a significantly reduced fat content (the main contributor to the caloric value of the final product) and prebiotic function (originating from inulin).

Key words: *inulin, sodium, fat substitution, chicken frankfurters*

INTRODUCTION

In recent years, the meat industry, as well as other branches of the food industry, following consumer demands and modern scientific knowledge, has begun to produce products with functional food properties. Functional food refers to foods that, in addition to essential nutritional components (proteins, fats, carbohydrates, vitamins, and

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minerals), also contain ingredients that positively affect human health. These ingredients include probiotics, prebiotics, antioxidants, omega-3 fatty acids, dietary fiber, additional micronutrients, and vitamins (Jiménez-Colmenero *et al.*, 2001; Arihara, 2006). Also, functional foods are considered foods in which ingredients considered harmful and traditionally found in those products have been reduced/replaced. The most common ingredients in meat products considered harmful to health and whose excessive intake is linked to various diseases are saturated fat, cholesterol, and sodium from table salt (Horita *et al.*, 2014).

Cooked sausages are one of the most popular meat products (Lu *et al.*, 2021). In Serbia, they are classified and marketed as hot dogs, frankfurters or boloney sausage (Official Gazette of RS, 50/2019). Frankfurters usually contain 20 to 30% of added pork backfat as a typical representative of this product category. This high content of animal fat affects the high caloric value and, as a rule, the high level of saturated fatty acids and cholesterol. Consequently, this affects the negative health perception of these products on the market (Kang *et al.*, 2016).

However, since fat plays a vital role in the technological process of production and obtaining the characteristic sensory properties of this group of sausages, such as texture, taste, and juiciness, its reduction would cause lower quality of the finished product (Colmenero, 2000; Choi *et al.*, 2009; Wu *et al.*, 2009). Complex carbohydrates, such as dietary fiber, are known to have many health effects (Kaur and Sharma, 2019), and their incorporation into products with high energy potential, such as meat products, significantly improves the nutritional characteristics of the finished product. In addition to having positive health effects, dietary fibers also serve numerous technological functions in meat products, such as binding and retaining water, emulsifying fats, improving the texture of finished products, etc. Present research follows the direction of using different vegetable fibers as ingredients used in the production of frankfurters. The fibers form a "gel-like" network when hydrated with water. This functionality shows promising results, as they contribute to water retention and the characteristic texture of sausages (Lundberg *et al.*, 2014). Several studies have been carried out on the approach of improving the quality of cooked sausages by using vegetable fibers as additives in production, most often to reduce the fat content (Cofrades *et al.*, 2000; Cengiz and Gokoglu, 2005; Ayo *et al.*, 2007; Kim *et al.*, 2015). Research has established that inulin has good potential as a substitute for fat tissue since it forms stable gels with water and has a neutral smell and taste. At the same time, inulin fibers have prebiotic properties, so with the addition of inulin suspension, the sausage becomes enriched with prebiotics.

In addition to the high-fat content, hot dogs on the Serbian market usually contain a relatively high sodium chloride content, between 1.28 and 2.03% (Vranić *et al.*, 2009), as the primary source of sodium in meat products. In addition to the sensory and antimicrobial function, sodium chloride in meat products has many technological effects. One of the most critical effects is on the solubilization of functional proteins of myofibrils, which results in an increase in hydration and the capacity of binding and retaining water of activated proteins and, consequently, in improving the product's

texture (Ruusunen and Puolanne, 2005). Also, since adding NaCl enhances the taste, its reduction would negatively impact the final product's sensory acceptability (Stamenić *et al.*, 2021). However, as excessive sodium intake is one of the leading causes of hypertension and cardiovascular diseases (WHO, 2007), its reduction in meat products would positively affect human health. Recent studies have reported that meat products are accountable for approximately 20-30% of daily sodium intake, justifying the meat industry's attempt to reduce sodium chloride as the primary source of sodium (Horita *et al.*, 2014). There are various strategies to reduce NaCl content in meat products, one of the most common ways is replacement with KCl, which is widely used due to similar ionic strength and chemical properties with NaCl (Geleijnse *et al.*, 2003). However, substitution with a KCl concentration higher than 30–40% (depending on the formulation) results in an unpleasant bitter and metallic taste in the final product. Partial replacement of NaCl with $CaCl_2$ may be a healthier alternative, as it may provide additional calcium in the diet (Cáceres *et al.*, 2006). However, many studies have shown that divalent salts such as $CaCl_2$ can reduce the functionality of meat proteins, leading to unstable emulsions (Piggot *et al.*, 2000; Ma *et al.*, 2013).

In order to be able to use the health claim "reduced sodium content" for a product, it is necessary that, compared to the traditionally sold product, the sodium content is reduced by at least 25% (Regulation EC No 1924/2006). In this regard, the World Health Organization recommends an increased intake of potassium in order to prevent cardiovascular diseases. For a product to be able to use the nutritional statement "good source of potassium", that product must contain at least 30% of the recommended daily amount, which is 2000 mg (Official Gazette of RS, 19/2017).

Based on everything mentioned above, it can be concluded that reducing the fat and sodium content without lowering the finished product quality is currently a big challenge for the meat industry. Fat and NaCl improve cooked sausage's sensory and technological properties, and their reduction is not easily achievable. The problem that this paper tackle is the production of cooked sausages of satisfactory sensory quality, with the characteristics of a multifunctional product: reduced content of saturated fat, caloric value, and sodium, with increased content of potassium and with the addition of prebiotic fibers, which have been found to have positive effects on human health.

MATERIAL AND METHODS

Preparation of chicken frankfurters

The frankfurters were manufactured in the meat processing plant of the Institute of Animal Husbandry (Belgrade, Serbia) in adherence to industrial processing protocol. Fresh chicken breast meat (Piljan komerc, Belgrade, Serbia) and pork backfat (Institute for animal husbandry, Belgrade, Serbia) were used as raw materials in production. Two different batches of frankfurters were made, each of 5 kg. Batch 1 was used as a control (CF) with a traditional formula (percentages in formulation add up to 100%): chicken breast (53%), pork backfat (22%), 22.3% water (ice form), 1.5% sodium chloride

(commercially bought combined 99,5% NaCl + 0,5% $NaNO_2$), 0,5% polyphosphates ("Tari K2"), 0.2% soy isolate ("Supro 548"), 0.48% commercially bought spices and 0.02% vitamin C. The second batch (InK^+) was formulated by replacing 50% pork backfat using inulin gel and replacing a third of sodium chloride with potassium chloride. Inulin suspension (inulin gel) was prepared by mixing inulin (Cosucra, Belgium) and distilled water in a 1:2 ratio in the blender (CombiMax 600, Braun, Germany) and placed at 4°C until added to the meat batter. The experimental group (InK^+) was prepared as follows: chicken breast (53%), 22.3% water (ice form), pork backfat (11%), inulin gel suspension (11%), 1.0% sodium chloride (99,5% NaCl + 0,5% $NaNO_2$), 0.5% potassium chloride, 0,5% polyphosphates ("Tari K2"), 0.2% soy isolate ("Supro 548"), 0.48% commercially bought spices and 0.02% vitamin C. Inulin content in the InK+ group was calculated at 3.67% (to 100% of formulation).

Both batches were prepared on the same day, identically: chilled chicken breast meat and pork backfat were grounded at 8 mm diameter in a meat grinder (Laska W 130-H, Austria) and then mixed with water (ice) and previously prepared inulin suspension (InK^+ group), salt and condiments in cutter (Seydelmann K60, Germany) until the smooth batter was obtained. Meat batter was then stuffed into 22 mm diameter collagen casings and manually linked (to approximately 80 g) and placed on the sticks, which were then hung in the chamber for smoking/cooking and underwent the following regime: 10 min drying at 50°C, 30 min smoking at 60°C and heating at 85°C until the temperature in the central part of the product has reached 72°C
After heat treatment, all frankfurters were showered with cold water and stored in a cooling chamber at 4°C. After 24 hours of storage, frankfurters were sampled from each group for analysis. The proximate chemical analysis and technological quality were determined on ten samples of frankfurters from each group. Sensory analysis was performed on eight frankfurters from each group. The rest of the frankfurters were vacuum-packed in plastic bags and stored at 4°C for 21 days.

Proximate composition and technological properties of frankfurters

The mass of the frankfurters was determined prior to and after heat treatment and after the 21. days of storage in a cooling chamber at 4°C (± 0.001 g) to calculate the process and purge loss (expressed in %). The stability of the emulsion was determined by the method described by Bolger *et al.* (2018). After 2 days of storage in the refrigerator, plastic cuvettes containing approximately 25 ml of the meat batter were heated in a water bath at 98º C for 45 min. Then they were cooled in ice water for 10 min to room temperature, opened, and turned into pre-measured glaas containers for 1 h to drain the liquid (fat and water) released during the heat treatment (HT). The separated liquid, expressed as a percentage of the mass of the filling before HT, represents the total loss of HT. The cooking loss was determined from the difference in the weight before and after cooking in distilled water (at 80°C for 10 min) and expressed as a percentage of the weight of the sample before cooking.

Prior to chemical analyses, the casings were removed from all samples, and the frankfurters were homogenized in a blender (CombiMax 600, Braun, Germany). The proximate chemical composition was determined as follows: water content by drying the samples to a constant mass at 102 ± 2°C (SRPS ISO 1442, 1998); protein content by the Kjeldahl method (SRPS ISO 937, 1992) on the Kjeltec system 1026 apparatus (Foss Tecator, Denmark); fat content, by the Soxhlet method with petroleum ether as a solvent (SRPS ISO 1444, 1998) on a Soxtherm Multistat (Gerhardt, Germany); ash content, by mineralization of samples at 550 ± 25°C (SRPS ISO 936:1999); the portion of carbohydrates was calculated from the difference to 100%. The content of sodium and potassium was determined by atomic spectrophotometry (PinAAcle 500, Perkin Elmer) after microwave digestion, according to the AOAC method (Rachida *et al.*, 2010).

The pH value was measured with a pH-meter Hanna, HI 83141 (Hanna Instruments, USA), with a penetration electrode previously calibrated using standard buffer solutions (SRPS ISO 2917:2004).

The caloric value was calculated based on the proximate chemical composition of frankfurters, where the amount of protein, carbohydrates, and fat has a caloric value of 4 kcal, 4 kcal, and 9 kcal per gram of product, respectively (Garcia-Santos *et al.*, 2019).

Sensory analysis was performed on samples stored for seven days in vacuum bags at 4°C by a panel of 12 assessors. Prior to sensory evaluation, samples were prepared by heating in water at 80°C/10 min. After heat treatment, the samples were identically presented to the evaluators: cut into pieces on white marked plastic plates. For each evaluated parameter, a quantitative-descriptive scale of 5 points was used (from 1 - extremely unacceptable to 5 - extremely acceptable). The following parameters were assessed: taste, smell, texture, and juiciness.

Statistical analysis

The obtained data were processed by analysis of variance in the one-way ANOVA program SPSS Statistics 22, and all results are displayed as the mean value ± standard deviation. The statistical significance of the difference between mean values was determined by a t-test.

RESULTS AND DISCUSSION

Technological quality of frankfurters

The ability to bind and retain water is an important factor in determining the technological quality of frankfurters (Lu *et al.*, 2021). In this experiment, the InK+ group of frankfurters had a significantly higher mass loss after heat treatment (process loss) and after cooking of the finished product. This was probably the result of a higher amount of water in the meat batter due to the replacement of fatty tissue with an aqueous

suspension of inulin (table 2). On the other hand, no change in purge loss (after the 21st day of vacuum storage at 4°C) was found between the tested groups. Also, no significant difference was found in the final pH value of the product. The commercial group of frankfurters had better emulsion stability (expressed as % liquid released) than the InK+ group. Similar results were obtained by Horita *et al.* (2014), as they determined that the partial replacement of NaCl with KCl led to an increase of released fluid (water and fat) and a decrease in the emulsion stability of frankfurter sausages. Despite slightly increased water loss during production and storage, it can be concluded from the obtained data that frankfurters with partially replaced fat (with inulin suspension) reduced-sodium content had satisfactory technological characteristics, very similar to the commercial group of products.

Table 2. Technological characteristics of chicken frankfurters

Parameter	CF n=10	InK^+ n=10	Statistical Significance
Process loss (%)	7,08 ± 0,67	7,45 ± 0,54	*
Purge loss (%)	1,59 ± 0,63	1,46 ± 0,50	ns
pH	6,34 ± 0,05	6,31 ± 0,05	ns
Cooking loss (%)	4,17 ± 0,77	5,20 ± 0,63	*
Emulsion stability (%)	6,71 ± 0,72	9,26 ± 0,86	*

ns–not significant; * significant at the level of $p<0.05$

Chemical composition and caloric value of frankfurters

The proximate chemical composition, the content of sodium, potassium, and the nutritional quality of the frankfurters are shown in Table 3. As expected, the frankfurters in which a part of the pork backfat was replaced by an inulin suspension (InK+ group) had a significantly higher water content and a significantly lower content of extracted fat (by about 7%). As a result, the caloric value of InK+ frankfurters is reduced considerably compared to the commercial group - by about 22%. The protein and mineral matter (ash) content was similar between the groups.

Similar results were achieved by Šojić *et al.* (2011). Their research states that replacing fat tissue with 5% inulin affected a significantly higher water content and a significantly lower fat content. In contrast, the protein content was not statistically significantly different compared to the control group. Also, they state that the content of carbohydrates was statistically significantly higher in sausages with 5% added inulin and that the caloric value was reduced by 30% compared to the control group. There were no significant differences in moisture, protein, and ash content when adding inulin in amounts of 2.5, 5.0, and 7.5% in powder or gel form in the research of Selgas *et al.* (2005). On the other hand, this replacement contributed to a decrease in fat content and caloric value. Similar results were obtained by Mendoza *et al.* (2001) in fermented sausages. The results of the research by Vasilev *et al.* (2011) showed that cooked sausages with inulin suspension contained 2.6 to 3.7% less fat than conventional ones,

corresponding to the amount of fat replaced by the inulin suspension. The same authors report that cooked sausages with inulin suspension contained about 3% more moisture than traditional sausages.

According to the results obtained by Alaei *et al.* (2018), decreasing the level of fat with inulin (the treatment of 25%, 50%, 75 %, and 100% substitution of inulin) increased the content of moisture, protein, and ash, salt, carbohydrates, and lowered the content of fat. However, the research conducted by Huang *et al.* (2011) confirmed that an increase in the level of inulin (from 3.5% to 7%) significantly reduced the fat content in the sausage. In contrast, the moisture content in the sausage samples was reduced, which conflicted with our research results. This difference probably results from the different formulations of the sausages, as well as the type of inulin. Menegas *et al.* (2013) also confirmed that inulin supplementation reduced fat content, which is in line with the results of our study.

Replacing 1/3 sodium salt with potassium salt in the InK+ group resulted in a significant decrease in total sodium level (by about 28%) and an increase in potassium level in the product (nearly 225%). Additionally, the InK+ group of frankfurters was enriched with inulin (about 3.67 g in 100 g of product), which has been shown to have many positive health effects (Yousefi *et al.*, 2018).

Based on the data obtained, the InK+ group of frankfurters can be declared as a product with "reduced sodium content" and "good source of potassium" with reduced caloric value and enriched with prebiotics (Regulation EC No 1924/2006; Official Gazette of RS, 19/2017). The InK^+ frankfurter formulation also complies with the FDA-approved health claim: “Foods that are a good source of potassium and that are low in sodium may reduce the risk of high blood pressure and stroke” (FDA, 2016). The notion states that foods qualifying for the proposed claim must contain 10% or more of the Daily Value for potassium to be considered a "good source of potassium" and be "low in sodium." Therefore, the new frankfurter must contain at least 350 mg of potassium per reference portion customarily consumed, which is a request that InK^+ frankfurter meets (884,4 mg/ 100 g).

For a product to be able to use the nutritional statement "good source of potassium", that product must contain at least 30% of the recommended daily amount, which is 2000 mg (Official Gazette of RS, 19/2017).

Table 3. Chemical composition and caloric value of chicken frankfurters

Parameter	CF n=10	InK^+ n=10	Statistical Significance	Difference (%)[3]
Water (%)	58,86 ± 1,03	63,50 ± 0,85	*	7,88
Fat (%)	20,11 ± 0,74	12,63 ± 0,88	*	-37,20
Protein (%)	17,05 ± 1,94	17,73 ± 1,62	ns	3,99
Carbohydrates (%)	0,97 ± 0,21	3,36 ± 0,39	ns	246,39
Ash (%)	2,52 ± 0,11	2,46 ± 0,14	ns	-2,38
Na (mg/100g)	774,7 ± 14,09	553,1 ± 8,06	*	-28,60

K (mg/100g)	271,7 ± 54,8	884,4 ± 37,2	*	225,51
Caloric value (Kcal/100g)[1]	252,51 ± 12,46	197,23 ± 15,11	*	-21,89

[1] Caloric value – fat (9 Kcal), protein (4 Kcal), carbohydrates (4 Kcal);
[2] ns – not significant; * significant at the level of $p < 0.05$;
[3] Difference (%) = (InK^+ – KF) / KF · 100

Sensory evaluation of frankfurters

Sensory evaluations of taste, smell, texture, and juiciness are shown in Table 4. The 5-point system was used in the evaluation. The taste of commercial chicken frankfurters was rated as highly acceptable (>4.5), with a significantly higher rating than the InK+ group. This difference is probably due to the reduced fat and sodium salt content, which have been proven to correlate positively with the finished product's taste. On the other hand, the InK+ group of frankfurters' texture was rated higher than the commercial group. Juiciness is positively correlated with the product's water content (Aaslyng *et al.*, 2003), which is probably the reason for the higher-rated texture of the InK+ group of frankfurter sausages.

Table 4. Sensory quality of chicken frankfurters

Sensory properties	CF n=8	InK^+ n=8	Statistical Significance
Taste	4,57 ± 0,68	4,09 ± 0,51	*
Smell	4,00 ± 0,64	4,11 ± 0,77	ns
Texture	3,52 ± 0,50	4,23 ± 0,53	*
Juiciness	3,86 ± 0,79	4,03 ± 0,61	ns

[1] 1 – extremely unacceptable to 5 – extremely acceptable;
[2] ns – not significant; * significant at the level of $p < 0.05$;

Research data on sensory evaluation are inconclusive. Some of the literature data reveal that the texture of sausages with the addition of inulin was sensorial assessed as optimal and that the addition of inulin suspension can be done without adversely affecting the product's sensory properties (Šojić *et al.*, 2011; Nitsch, 2006; Zamora *et al.*, 2015). In contrast, Makala (2003) results on the sensory properties of functional cooked sausages containing inulin have lower general acceptability scores than control samples and that products with higher inulin content had lower general desirability. Further, obtained results on taste disability evaluation agree with Makala (2003) research.

CONCLUSION

The results of this work suggest that half of pork backfat and a third of NaCl in frankfurters made from chicken meat could be replaced by a suspension of inulin and potassium salt to improve their nutritional characteristics and obtain a product with functional food characteristics. The analysis of INK^+ frankfurters showed that they have characteristic features for this group of products in terms of technological quality and chemical composition, as well as high sensory scores for taste, smell, texture, and juiciness. This product also has an exceptional nutritional value, considering that it contains significantly reduced fat content, as the primary source of calories, with the addition of prebiotic fibers (inulin). Additionally, these sausages can be declared as a product "reduced in sodium" and a "good source of potassium."

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INULIN KAO ZAMENA ZA MAST U PILEĆIM VIRŠLAMA SA SMANJENIM SADRŽAJEM NATRIJUMA – TEHNOLOŠKE KARAKTERISTIKE I PRIHVATLJIVOST POTROŠAČA

Rezime

Fino usitnjene barene kobasice jedan su od najpopularnijih proizvoda od mesa, kako u Srbiji tako i u svetu. Međutim, visok sadržaj zasićenih masti i natrijuma, uz nedostatak složenih ugljenih hidrata, poput biljnih vlakana, doprinosi negativnoj zdravstvenoj percepciji ovih proizvoda. Danas na tržištu postoje različiti aditivi i dodaci koji se koriste kao zamena životinjskih masti i natrijuma u proizvodima od mesa, a koji nemaju veliki uticaj na gubitak mase tokom proizvodnje i/ili na promene senzornog kvaliteta finalnog proizvoda. Većina istraživanja u ovoj oblasti ide u pravcu delimične ili potpune zamene masti različitim hidrokoloidima ili biljnim uljima, dok se za delimičnu zamenu NaCl uglavnom preporučuje KCl. Međutim, postoji malo proizvoda na tržištu, iz grupe fino usitnjenih barenih kobasica, kod kojih je zamenjena mast i natrijum, a koji imaju i smanjenu kalorijsku vrednost uz dodatne prebiotike.

Rezultati ovog rada sugerišu da bi se 1/2 svinjskog masnog tkiva i 1/3 NaCl u viršlama proizvedenih od pilećeg mesa, mogla zameniti dodatkom suspenzije inulina i kalijumove soli, kako bi se poboljšale njihove nutritivne karakteristike i dobio proizvod sa karakteristikama funkcionalne hrane. Analizom INK+ viršli utvrđeno je imaju

karakteristične osobine za ovu grupu proizvoda, u pogledu tehnološkog kvaliteta i hemijskog sastava, a takođe i visoke senzorne ocene za ukus, miris, teksturu i sočnost. Ovaj proizvod takođe ima i posebnu nutritivnu vrednost, s obzirom da sadrži značajno smanjen sadržaj masti, kao glavnog izvora kalorija, uz dodatak prebiotskih vlakana (inulina).

Ključne reči: *inulin, natrijum, zamena masti, pileće viršle*