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Original scientific paper

Effect of pork to beef meat ratio on the physicochemical properties of frankfurters

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A b s t r a c t: This study was conducted to investigate the effects of raw material, pork and beef meat, ratio on the physicochemical characteristics of emulsion-type sausage. Five different frankfurter formulations were calculated as follows: B100 (40% beef meat); B75 (30% beef and 10% pork meat); B50 (20% beef and 20% pork meat); B25 (10% beef and 30% pork meat) and B0 (40% pork meat). Frankfurters made solely from beef meat (B100) showed significantly better emulsion stability than those made with pork meat (B0). The increase in the fat content also decreased gel strength, leading to lower values of hardness, cohesiveness, gumminess and chewiness. The optimal ratios between pork and beef meat to enhance the textural properties of frankfurters were B50 and B75. The lightness values (L) increased with increasing pork meat content, while the redness values (a*) demonstrated the opposite trend. Protein, fat and total pigments displayed a positive relation, whereas water content exhibited a negative relation with a* values.*

Key words: *Emulsion-type Sausages; Meat Ratio; Composition; Texture; Colour.*

Introduction

Emulsification technology has been used over several hundred years for the preparation of emulsion-type meat products. Emulsified meat products such as frankfurter sausages are generally consumed in many countries. They tend to be more popular than other processed meat products, because they are convenient and are utilized in a variety of foods (*Allais, 2010*). The wide diversity in physicochemical and sensory characteristics of food emulsions is due to the variety of ingredients and processing conditions. Emulsified meat products, also called meat batters, are complex systems in which fat is emulsified into a viscous fluid mainly composed of solubilized myofibrillar proteins previously extracted from meat from different animal species (*Ugalde-Benítez, 2012*).

One of the most important quality characteristics for processed meat products such as emulsified sausages is emulsion stability between fat and water contents. Fat is one of the most variable raw materials in emulsified meat products, as it plays an important role in the formation of meat emulsions with other ingredients, and is related to flavor intensity, juiciness, and tenderness in sausage products (*Hughes et al. 1997*).

Protein is also an important material for binding both the fat and water constituents in the meat emulsion. For example, soluble myofibrillar proteins are extracted by salt surrounding the fat particle, and they subsequently form the emulsion matrix with water and fat (*Youssef and Barbut, 2010*). Meat emulsion formation includes the activation of most of the proteins present in the muscle by disrupting the sarcolemma to release myosin and actin, which are subsequently solubilized by salts and phosphates. Myofibrillar proteins, with fibrous structures, turn into a viscous fluid during protein activation. This fluid is responsible for fat emulsification and immobilization of added water. Changing fibrous proteins into a viscous fluid is relatively easy with pork and chicken meat, but more difficult with beef and lamb (*Feiner, 2006*). This is because different animal species can present a wide variety of protein characteristics, probably due to interaction effects (*Zorba, 2006*). According to Feiner (2006), meat hardness, as a result of fiber thickness variation among meat type and cuts, is also related to protein solubility variation within the same animal species. Another major component of the meat

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emulsion is water. In the emulsion, water performs a number of functions such as: 1) functioning as a curing solution; 2) regulating the temperature of the batter; 3) saving on production costs; and 4) having an impact on the texture and juiciness of the product (*Ockerman and Basu, 2014*).

Numerous studies regarding the processing technology of emulsion-type sausages have been published, including research into additives, substitutes, chopping temperature, pressure, mixing time, and processing procedure (*Bañón et al. 2008 ; Carballo et al.1995; Colmenero et al.1995; Wang et al.2009*). However, although the raw material components have a big impact on emulsion-type sausages, very few studies have been conducted to assess the physicochemical characteristics based on the ratio of raw materials. Therefore, the objective of this study was to investigate the effect of the pork to beef meat ratio on physicochemical characteristics of emulsion-type frankfurter sausages, and to determine the optimized ratios of these raw material components for frankfurter production.

Materials and methods

Frankfurter preparation

As raw material, post-rigor pork and beef meat (mixture of round and shoulder muscles) and fresh back fat were obtained from the slaughterhouse at the Institute for Animal Husbandry (*Belgrade, Serbia*). The meat was trimmed of visible fat and connective tissue. Frankfurters were manufactured in a small meat processing plant at the Institute under commercial processing conditions.

Five different formulations were calculated to yield a 20 kg batch as follows: B100 (40% beef meat); B75 (30% beef and 10% pork meat); B50 (20% beef and 20% pork meat); B25 (10% beef and 30% pork meat) and B0 (40% pork meat). All the formulations also contained: 30% of pork back fat, 30% water (ice), 1.5% nitrite-salt (Prima Commerce, Serbia), 0.3% polyphosphate (Tari K2, BK Giulini GmbH, Germany), 1% soy protein isolate (Supro 548 IP Non-GMO, Solae™) and 0.4% of a ready-to-use frankfurter spice mixture (Prima Commerce, Serbia) (Table 1).

All formulations were produced on the same day and in an identical manner: meat and fat were chopped to 8 mm particle size in a meat grinder (Balint, Serbia) and then mixed with ice, nitrite-salt, soy protein and spices in a meat cutter (Belje, Croatia). The prepared batter was stuffed into 24 mm diameter collagen casings, after which they were hung, smoked and cooked for approximately 2 hours in a smoking/cooking chamber (Belje, Croatia), until the temperature in the central part of the sausages reached 72°C10 min^{-1}. The cooked frankfurters were showered in cold water and stored at 5 ± 1°C for 48h before testing.

Composition analysis of the frankfurters

Ten samples from each formulation of frankfurters were used for the composition examination. The casing was removed and the sausages were ground in a mixer (Ultra Turrax T18, IKA, Germany) before all analysis were carried out, in triplicate. The moisture content was determined by drying at 105°C (*ISO 1442, 1997*); protein content by the Kjeldahl method and a multiplication factor of 6.25 (*ISO 937, 1978*); total fat content by the Soxhlet method (*ISO 1443, 1973*), and ash content by mineralization at 550 ± 25°C (*ISO 936, 1998*). The pH value

Table 1. Experimental design and composition of frankfurters

Ingredients (%)[1]	100B	75B	50BP	75P	100P
Beef	40.0	30.0	20.0	10.0	–
Pork	–	10.0	20.0	30.0	40.0
Pork back fat	30.0	30.0	30.0	30.0	30.0
Water (ice)	30.0	30.0	30.0	30.0	30.0
Total	100.0	100.0	100.0	100.0	100.0
Nitrite-salt	1.5	1.5	1.5	1.5	1.5
Polyphosphate	0.3	0.3	0.3	0.3	0.3
Soy protein	1.0	1.0	1.0	1.0	1.0
Spices	0.4	0.4	0.4	0.4	0.4

Legend: [1] Formulations were calculated to yield a 20 kg batch.

was measured using a pH-meter, Hanna, HI 83141 (Hanna Instruments, USA), equipped with a puncture electrode. The pH meter was calibrated using standard phosphate buffers (*ISO 2917, 1999*).

Textural profile analyses

The frankfurters were cut into 15 mm thick slices and from each slice, the 15 mm diameter core was removed to obtain cylindrical samples for textural profile analysis (TPA). The TPA tests were carried out using TA.XT Plus Texture Analyzer (Stable Micro Systems Ltd., UK) with 50 kg load cell. Frankfurter cores were placed upright on a platform (sample height 15 mm), and compressed with a 25 mm diameter cylindrical aluminum probe (P/25). The texture attributes obtained from TPA were: hardness, springiness, cohesiveness gumminess and chewiness according to Pons and Fiszman (*1996*). Test speed was 60 mm min^{-1}, and strain was 50%. The TPA tests were performed without rupture of the cores, so rupture force, rupture work of energy and rupture deformation of sausages was obtained from a rupture test, also according to Pons and Fiszman (*1996*), in single compression at 65% strain, with the same test speed and with the same probe. Texture attributes from each type of sausage were obtained from at least eight measurements.

Pigment content and instrumental colour measurement

The content of total pigments and nitroso-myoglobin (mg per kg of sausage) were determined on a spectrophotometer (Spekol 1300, Analytic Jena, Germany) at 640 and 540 nm respectively, according to the method described by *Hornsey* (1956). For instrumental colour analyses, each sausage was cut and the colour was measured three times using Chromameter CR-400 (Minolta Co. Ltd, Tokyo, Japan), configured with the following parameters: D65 light source, 0° observer, and 8 mm aperture size and calibrated using a white ceramic tile. Values were given in the colour space CIE, where L* – lightness; a* – redness; b* – yellowness (CIE, 1976). The colour measurements were performed at room temperature (20 ± 2°C). Chroma (C*) and hue angle (h) were calculated using the available software.

Statistical analysis

Data entry and decoding were 100% verified. A one-way ANOVA was conducted to compare the results of the different assays, using SPSS Statistics 17.0 (*Chicago, Illinois, USA*) data analysis software. An alpha level of $p<0.05$ was used to determine significance. For the TPA tests, multivariate analysis of variance (MANOVA) was performed, with pork:beef ratio as fixed factor, and textural attributes as dependent variables. Subsequent univariate analyses were also conducted, and in post-hoc analysis, Duncan's test was performed to obtain homogeneous subsets of samples for each texture attribute.

Results and discussion

Composition of frankfurters

The observed pH and composition values (Table 2) show that frankfurters B0 and B25 had somewhat higher fat content and consequently lower moisture content compared to B50, B75 and B100 frankfurters. Protein contents varied from 12.83% (B100) to 11.49% (B0) and were significantly different between all formulations. The variations in pork to beef meat ratios used in frankfurter formulations in our investigation revealed a clear pattern that connects slightly higher pH values, higher protein levels, higher moisture and reduced fat content with higher beef content frankfurters (Table 2).

Table 2. Composition and pH values of frankfurters (mean ± standard deviation)

Sample	pH	Moisture (%)	Fat (%)	Protein (%)	Ash (%)
B100	$5.97^{a} \pm 0.02$	$56.13^{a} \pm 0.06$	$27.39^{a} \pm 0.91$	12.83 ± 0.03	2.75 ± 0.01
B75	$5.97^{a} \pm 0.02$	$59.63^{a} \pm 0.06$	$24.25^{a} \pm 0.17$	11.72 ± 0.02	$2.59^{a} \pm 0.01$
B50	$5.97^{a} \pm 0.01$	$59.05^{a} \pm 0.17$	$26.41^{a} \pm 0.40$	11.61 ± 0.01	2.48 ± 0.01
B25	5.84 ± 0.01	54.14 ± 0.08	31.13 ± 0.16	11.58 ± 0.04	$2.58^{a,b} \pm 0.02$
B0	5.88 ± 0.01	53.61 ± 0.04	31.73 ± 0.10	11.49 ± 0.07	$2.52^{b} \pm 0.03$

Legend: B100 (40% beef meat); B75 (30% beef and 10% pork meat); B50 (20% beef and 20% pork meat); B25 (10% beef and 30% pork meat); B0 (40% pork meat); Means in the same column that have no superscript in common are significantly different ($p<0.05$)

Table 3. The effect of pork to beef meat ratio on color and pigments of frankfurters

	B100	**B75**	**B50**	**B25**	**B0**
L*	68.8±0.7	69.6±0.3	71.9±0.8	72.8±0.2	75.1±0.6
a*	$9.2^{a,b}$±0.2	9.7±0.3	9.0^{a}±0.4	8.9^{b}±0.2	8.2±0.3
b*	12.3±0.2	11.9±0.2	11.5±0.2	11.2±0.3	10.8±0.3
h	15.4^{a}±0.2	15.3^{a}±0.1	14.6^{b}±0.4	14.3^{b}±0.2	13.6±0.4
C	53.1^{b}±0.7	50.9^{a}±1.2	$51.9^{a,c}$±1.0	51.4^{a}±1.1	$52.9^{b,c}$±0.8
Total pigments (mg/kg)	84.3±1.2	68.9±2.4	54.6±1.1	51.1±0.9	39.6±1.0
Nitroso-myoglobin (mg/kg)	31.6^{a}±1.0	25.8^{b}±1.0	25.5^{b}±1.6	32.2^{a}±1.1	25.4^{b}±2.0
Conversion rate	$39.6^{a,b}$±0.5	35.2^{a}±0.3	43.8^{b}±2.5	60.4^{c}±2.0	60.2^{c}±6.2

Legend: B100 (40% beef meat); B75 (30% beef and 10% pork meat); B50 (20% beef and 20% pork meat); B25 (10% beef and 30% pork meat); B0 (40% pork meat); Means in the same row that have no superscript in common are significantly different (p<0.05)

Textural profile analyses

MANOVA was calculated, examining the effect of pork:beef ratio on textural attributes, and a significant effect was found [Wilks' Lambda (32, 138) = 0.1 and p<0.05]. Subsequent univariate analysis showed that the pork:beef ratio did not have a statistically significant effect only on springiness . Mean values of other texture attributes are presented (Table 3), along with homogeneous subsets for each attribute. The means listed under each subset comprise a set of means that are not significantly different from each other.

Compared to other formulations, the highest hardness values were observed for frankfurters made solely from beef meat (100B) (Table 3). The highest values of cohesiveness, gumminess, and chewiness were each observed for the same frankfurter formulation (100B), which had significantly the greatest protein content. According to Choe et al. (*2013*), emulsion sausages with higher values in cohesiveness, gumminess and chewiness showed significantly greater emulsion stability than those with low values.

Our results also revealed that increasing the fat content also decreased gel strength, leading to lower values of hardness, cohesiveness, gumminess and chewiness. This result was likely due to the lack of emulsifying agents from salt-soluble proteins such as myosin, which would result in poorer quality characteristics in the frankfurters. Similar results were also reported by a number of research groups (*Bañón et al., 2008; Bloukas and Paneras, 1993; Cofrades et al.2000 ; Colmenero et al., 1995*). An excessive fat content causes the emulsion to break down, due to lack of protein content surrounding the fat globules in emulsion formation. *Hughes et al.* (1998) reported that a decrease in fat content significantly reduced cohesiveness and gumminess in Frankfurter sausages. This is in contrast to our result, where we observed that the fat content showed a negative relationship to all textural attributes investigated (Table 3).

Pigments and colour

The instrumental colour data (Table 4) show the pork to beef meat ratio had a significant effect on L*, a* and b* measurements of frankfurters. We observed that frankfurters made exclusively from beef meat (B100) had the lowest L* values compared to all other formulations (p<0.05). The lightness increased with increasing pork meat content, while the redness values (a*) demonstrated the opposite trend, with the lowest value (8.2) observed in frankfurters made solely from pork meat. Protein, fat and total pigments displayed a positive relation, whereas water content exhibited a negative relation with a* values (Tables 2 and 4). Our results are in concurrence with the findings of *Youssef and Barbut* (2011), where the higher levels of protein and lean meat resulted in a significant increase in redness values in the emulsion meat batter. Additionally we have confirmed their assumption that this phenomenon is attributed to a higher myoglobin content. This theory is also supported by the work of *Carballo et al.* (1995), where the dilution of myoglobin through reduced protein content in the formulation led to a lower redness value.

According to *Hughes et al.* (1997), it was previously noted that reducing the fat content resulted in a decrease of lightness and increase of redness of

Table 4. Homogeneous subsets for different textural parameters and the effect of pork to beef meat ratio

a) Hardness	Subset			
	1	2	3	4
B0	2054.8			
B25	2276.	2276.7		
B50		2567.4	2567.4	
B75			2709.6	
B100				3608.2

b) Gumminess	Subset			
	1	2	3	4
B0	1599.6			
B25	1745.3	1745.3		
B50		1992.7	1992.7	
B75			2075.0	
B100				2540.3

c) Chewiness	Subset			
	1	2	3	4
B0	1400.9			
B25	1520.8	1520.8		
B50		1714.9	1714.9	
B75			1833.4	
B100				2180.2

d) Cohesiveness	Subset	
	1	2
B0	,7061	
B25		,7659
B50		,7678
B75		,7783
B100		,7816

Legend: B100 (40% beef meat); B75 (30% beef and 10% pork meat); B50 (20% beef and 20% pork meat); B25 (10% beef and 30% pork meat); B0 (40% pork meat);

frankfurter sausages. In a number of previous studies, it was observed that the colour of emulsion-type products was mostly influenced by fat content (*Bloukas et al.,1997 ; Carballo et al., 1995*). In our research, the fat content increased in the series from B100 to B0, and the lightness of the frankfurters also increased. As the water content in the frankfurters increased in the series from B0 to B100, the yellowness increased (Tables 2 and 4).

Conclusion

We investigated a number of pork:beef meat ratios used in the preparation of emulsion-type frankfurter sausages, and examined their effects on the physicochemical characteristics of the sausages. All of the treatments investigated showed normal pH (5.84–5.97), protein content between 11.49% and 12.83%, fat content between 24.25 % and 31.73%, and moisture in the range of 53.61-59.63%. It was observed that both the fat and protein contents significantly affected the textural profile of the sausages, where the frankfurters containing only beef meat had the highest values for hardness, cohesiveness, gumminess, and chewiness . Frankfurter colour was also influenced by variations in pork:beef meat ratios and fluctuations in protein, fat and total pigment content. Lightness was significantly reduced with increasing water content, while yellowness values were amplified. In conclusion, therefore, increasing the moisture content and reducing the fat and protein contents of the frankfurters resulted in reduced values of a range of physicochemical characteristics. Frankfurters made solely from beef meat showed significantly better emulsion stability than those made with pork meat.

Knowing that consumer studies are crucial for understanding the relation between food properties on the one hand and human preferences and purchasing behaviour on the other, we also conclude that its absence is a thoughtful limitation in our investigation. This exactly why we would suggest an exploratory study of the perceived relationship of price and quality of frankfurters with different pork:beef meat ratios among Serbian consumers should be a subject of future research.

Conflict of Interest. The authors declare that they have no conflicts of interest.

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