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QUALITY ASSESSMENT OF FRANKFURTERS PRODUCED FROM FRESH VS. FROZEN/THAWED GROUND BEEF

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Abstract: In order to evaluate the effect of raw meat's freezing/thawing process on meat products produced from them, frankfurter's quality was monitored. Fresh beef meat was grounded and separated into two lots – the first lot was immediately used in the preparation of frankfurters (G1F), and the other lot was frozen and stored at -18°C for 4 weeks, when it was used in the preparation of the second group of frankfurters (G2F). Physicochemical and technological properties were investigated on fresh (CG-FM) and thawed meat (G-F/TM) samples and the frankfurters made from these samples. Frozen storage significantly affected ($p<0.05$) moisture, TBA value, instrumental color parameters ($L^*a^*b^*$), WHC, total pigment, and total heme pigment in the raw meat samples; some frankfurters characteristics, such as moisture, L*(lightness), a* (redness) and b* (yellowness) were affected ($p<0.05$). However, the differences in the final products' process loss/cooking loss/frying loss and FRP were not significant. The sensory evaluation did not show any significance between the two groups of frankfurters It can be concluded that the frozen storage of minced beef meat for 4 weeks at -18°C and the consequential thawing process (at 4°C for 24h) does not significantly affect the overall acceptability of frankfurters prepared from them. However, effects on the marked changes in instrumental color are apparent.

Key words: frankfurter, ground beef, frozen storage, meat quality

Introduction

In the last 20 years, global meat consumption has increased by almost 60% (*Whitnall and Pitts, 2019*). Rising incomes and economic development in developing countries represent a significant driver of increased meat consumption,

accounting for around 85% of this rise. Although in most countries, beef represents considerably less than half of total meat consumption, beef consumption dynamics are changing rapidly due to the pace of economic development (*Smith et al., 2018; Whitnall and Pitts, 2019*). Growing demand has the global meat export industry blooming, and freezing plays a crucial role in ensuring the safety and quality of the meat products that are being supplied worldwide.

Although freezing and frozen storage represent an important preservation method, quality deterioration cannot be avoided since the freezing process can lead to a change in muscle foods' structural and chemical properties (*Jeong et al., 2011*). After microbiological degradation, the most significant changes that occur include the alterations in muscle fibers and their characteristics and oxidative processes, which affect not only lipids but also pigments and proteins of the meat. During these reactions, a sensory deterioration of the product can occur, which can cause consumers rejection of the meat and the final product produced from this meat (*Miller et al., 1980; Domínguez et al., 2019*).

Despite the fact that the meat color alone is usually a poor guide to choosing quality meat (due to varying in color among different meat cuts), most consumers will make a purchasing decision solely based on this trait and usually gravitate toward bright and red beef meat *(Young et al., 1999; Stanišić et al., 2012)*. However, the occurrence of deterioration of meat color has often been observed in thawed meat compared to fresh meat, and it is proven that prolonged frozen storage time does affect color change in meat *(Jeong et al., 2011; Stanišić et al., 2012*). The change in meat color occurs due to the drying during the freezing stage and denaturation of meat pigments due to the evaporation of water (sublimation) from frozen tissue and oxidation of meat pigments (*Josipović and Stanišić, 2022*). Myoglobin oxidation is a major contributor to color deterioration, as the oxidation of the bright red oxymyoglobin pigment leads to the formation of brown metmyoglobin, which is considered undesirable (*Johns et al.,* 1989). The proneness of beef meat to oxidative processes may result from its relatively high concentrations of unsaturated lipids, heme pigments, metal catalysts, and other oxidizing agents (*Johns et al., 1989; Jeong et al., 2011)*. Also, damage to cell membranes caused by ice crystals formed during freezing and the subsequent release of pro-oxidants, especially the heme-iron, accelerate the further lipid oxidation by a number of heme compounds present in the meat *(Johns et al., 1989; Akhtar et al., 2013*). Lipid oxidation is closely linked to color changes in beef meat (*Akamittath et al., 1990)*. There is also increasing evidence that indicates that lipid oxidation occurs primarily at the cellular membrane level (phospholipids) and then proceeds to spread to the triglyceride fraction. Thus, lipid oxidation is a problem occurring in both lean and fatty types of meat (*Thanonkaew et al., 2006; Akhtar et al., 2013*).

Authors *Gruić et al. (1993)* and *Petrović et al. (1993),* based on their previous research, stated that biochemical reactions still take place in meat stored

in temperatures higher than -70°C (temperatures below the eutectic point) since there is sufficient unfrozen water available remained for a period of time for such reactions to occur. In addition, a slower rate of the freezing process and higher temperatures define the size of the ice crystals formed outside the fibers (*Gruić et al., 1993)*. The growth of ice crystals causes distortion of tissue structure since, once removed, water from the fibers cannot be returned during the process of thawing and rebound to proteins (*Petrović et al., 1993; Jeong et al., 2011)*. The fraction of unfrozen water is also essential in the oxidation process since chemical reactions that occur during frozen storage initiate primary lipid oxidation (peroxidation) in the meat, which can lead to secondary lipid oxidation upon thawing (*Leygonie et al., 2012*), shown through TBA number. Freezing/thawing processes impact the content and moisture distribution in meat samples that could be, evaluated in several different ways, including the determination of total moisture content, water binding capacity, drip/thaw/cooking loss, etc. (*Leygonie et al., 2012*). Generally, there seems to be an agreement in the scientific literature on the notion that frozen storage and freezing/thawing processes all play an important role in a decrease in the water-holding capacity of meat (*Miller et al., 1980; Vieira et al., 2009; Kluth et al., 2021*). It has been reported by *Leygonie et al. (2012)* that the decrease in water-holding capacity is related to the modification and/or denaturation of the proteins, as well as the disruption of the muscle fiber structure.

Meat products are usually produced from frozen meat for various technological reasons, including the prevention of excessive heating during the manufacturing process (*Popp et al., 2013; Kluth et al., 2021*). Since the nutritive and physicochemical quality of frozen food is interlinked with the freezing/thawing processes, in order to provide consumers with a high-quality product prepared from frozen/thawed beef, our goal was to examine some of the possible effects involved in the freezing process concerning the quality of meat after thawing. Although there are numerous publications centered around the effects of the freezing/thawing process on muscle food quality, little has been reported concerning the relationship between the freeze-thaw cycle and the use of meat for processing. *Verma et al. (1985)* found that the use of mixed frozen meat (pork, beef, and mutton) in frankfurters negatively affected their texture, but that was no significant difference found in color or cooking loss. On the other hand, *Miller et al. (1980)* presented that frozen meat in frankfurters had an adverse effect on their texture, cooking loss, and sensory properties.

There are limited publications regarding quality characteristics and the functional changes that occur in the storage of frozen meat and the relation of these properties to changes within a meat product. This study offers the practical relevance of frankfurters prepared using fresh or frozen/thawed meat.

Material and Methods

Fresh beef meat (10 kg of a mixture of beef chuck muscles; 24h, post-mortem; storage temperature: 4°C) was grounded at 8 mm diameter (Laska W 130-H, Austria). Around 200 g of freshly grounded meat was used for proximate analysis, as well as the pH measurements, TBA measurement, water-holding capacity, total pigments, and objective color determination (readings of L*, a*, and b*), and the rest of the batch was separated into two groups. The first group (control group - freshly ground beef, CG-FM) was immediately used in frankfurter preparation (G1F). The second group (group-frozen/thawed meat, G-F/TM) was packed into 1 kg lots in moisture-proof plastic bags and left at -18°C for 4 weeks, after which it was thawed (4°C for 24h) and used for analysis (same as the freshly grounded meat) and preparation of the second group of frankfurters (G2F). The pork backfat used in formulations was obtained fresh (24h post-mortem) each time. Prior to mixing with the meat batter, pork backfat was grounded through an 8 mm plate (in the same manner as beef). Both series of frankfurters were made by the same formulation, as follows: 51.05% of grounded beef, 22.20% ice, 21.64% of pork backfat, 2.22% soy isolate, 1.66% commercially bought salt (99.5% NaCl + 0.5% $NaNO_2$), 0.67% polyphosphates, 0.55% commercially acquired spices. Ground beef, ice, salt, and condiments were blended for 8 minutes in the cutter (Seydelmann K60, Germany), and afterward, ground pork backfat was added and blended until the smooth batter was obtained. Meat emulsion was stuffed into 22 mm diameter collagen casings and manually paired (to approximately 70 g), measured and placed on the smoke sticks from the sausage hanging trolleys. Each group of frankfurters was spread onto six sticks and placed in the chamber for the smoking/cooking process as follows: 10 min drying at 50°C, 30 min smoking at 60°C and lastly, heating at 85°C (until the temperature in the center reached 72°C). Frankfurters were showered with ice-cold water and placed in a cooling chamber at 4°C for 48h before measuring and further analysis. Prior to analysis, frankfurters (four of both groups) were taken, collagen casings were removed, and samples were homogenized in a blender.

Proximate analysis – moisture (SRPS ISO 1442, 1998), ash (SRPS ISO 936:1999), protein (SRPS ISO 937, 1992; Gerhardt Vapodest 50S, Germany), and fat (SRPS ISO 1444, 1998; Gerhardt Multistat, Germany) were performed in meat and the final product. Hydroxyproline content (%) was done in frankfurters according to SRPS ISO 3496:2002 method (SPEKOL 1300, Analytik Jena, Germany), and collagen content (connective tissue content) was calculated by multiplying the hydroxyproline (%) result with factor 8. The relative content of connective tissue proteins to total protein content was then calculated by dividing the calculated collagen (%) value by the total protein (%) content in frankfurters multiplied by 100 (*Operta et al., 2012*). Levels of sodium chloride, nitrites, and

total phosphorus content were performed in frankfurter samples. NaCl content was obtained using the Volhard method (SRPS ISO 1841-1:1999), nitrite content was determined by SRPS ISO 2918:1999, and total phosphorus content by SRPS ISO 13730:1999 method. The pH value was obtained in raw meat as well as the frankfurters using a pH meter (model HI 83141, Hanna Instruments, USA), with a penetration electrode previously calibrated using standard buffer solutions (SRPS ISO 2917:2004). Analyses were performed in triplicate (per parameter) for each sample.

Thiobarbituric acid (TBA) was performed in raw meat samples (nine times total for each sample) following the procedure by *Buege and Aust (1978)* 2 ± 0.001 g of the homogenized sample was weighted into the cuvettes for centrifugation, and 10 mL of solution (0.375 g 2-thiobarbituric acid and 15 g TCA dissolved in 85 g 0.25 mol/dm^3 hydrochloric acid by stirring and heating in a water bath; freshly prepared each time) was added. The centrifuge tubes were sealed and immersed in a boiling water bath for 10 minutes to develop the color. The cuvettes were cooled under cold water and centrifuged for 10 minutes at g = 12. Afterward, the content of the cuvettes was filtered through a low-density filter paper (black strip) into a test tube. The intensity of the resulting red color was measured at 532 nm (SPEKOL 1300, Analytik Jena, Germany). The final value of TBA was calculated by multiplying the extinction (ε_{532}) by 2.77 and expressed as mg malonaldehyde/kg of the sample.

Instrumental color was determined by Chroma Meter CR-400 (Minolta, Japan) as described by *Stajić et al. (2014)*. The instrument was previously calibrated using a standard white surface (illumination D65, observer angle 2°, and aperture size 8 mm). Color values are presented in the CIE L* a* b* system (*CIE, 1976*), where factor L* indicates the lightness, a* corresponds to the relative proportion of red, and b* represents the yellowness of color of the samples. Measurements were performed in triplicate for each sample on non-overlapping areas, and their average value was used for statistical analysis.

The method of *Hornsey (1956)* was used to determine the total heme-iron concentration in raw meat groups (nine times per sample). Total pigments (mg/kg) were determined spectrophotometrically (SPEKOL 1300, Analytik Jena, Germany) by measuring absorbance at 640 nm, multiplying the extinction result with 680. Total heme-iron was calculated as total pigments (mg/kg) x 8.82/100 (*Von Seggern et al., 2005*).

Water holding capacity (WHC) in raw meat samples was conducted by *Grau and Hamm (1953),* and the value of WHC is expressed in cm^2 of the wet surface. Fluid release under pressure (FRP) of frankfurter samples was performed by the method suggested by *Stajić et al. (2020)*. Three frankfurters from each batch were taken, and samples were cut at 10±0.5 mm height, weighed, and compressed between two filter papers previously dried at 103°C for 30 min and cooled in an exicator to room temperature for 5 min using the weight of 200±2 g. The samples

were then removed, and filter papers were measured. Fluid release under pressure (expressed as %) represents the amount of the released fluid relative to the initial sample weight.

Frankfurters were measured after stuffing the collagen casings and after the heat treatment in the smoking/cooking chamber. The process loss was determined as a weight difference between frankfurters before and after heat treatment (%).

Frying loss was determined based on the method described by *Fahimeh et al. (2019)*. Three frankfurters were selected and sliced 1 cm in thickness (in quadruplicate). Samples were then weighted and fried (in 250 mL borosilicate glass filled with 200 mL of oil). The oil temperature was maintained at 172 - 174°C. Frying was performed for 2 min, and samples were left to cool at room temperature (around 30 min) before weighing. The test was done in triplicate for each sample. Frying loss was calculated using the initial and final weights expressed in g/100 g, the initial sample weight.

The cooking loss was performed by the method suggested by *Amini et al. (2015)*. Three frankfurters were sliced at 3 mm thickness (in quadruplicate) and cooked in an oven (160°C for 2 min). The cooking loss was calculated by weighing the samples before and after the cooking process (expressed as g/100 g of the initial sample weight).

Sensory analysis was performed by the taste panel, which consisted of seven semi-trained evaluators on samples of frankfurters cut at approximately 3 cm piece after cooking in boiling water for 10 min. In sensory evaluation, the 5 points system was used: from 1-extremely unacceptable to 5-extremely acceptable to the following attributes: taste, smell, texture, juiciness, color, and general acceptability; rancidity scores were set to be given in reverse order – score of 5 was indicative of high present of rancid taste, while score 1 suggested that no rancid taste was found in the samples.

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

The first part of the experiment included the physicochemical and technological properties of raw ground beef chuck meat, shown in Table 1.

Table 1. Results on physicochemical meat quality parameters and technological properties of raw ground beef chuck meat before (CG-FM) and after freezing/thawing (G-F/TM) process

Parameter	CG-FM	G-F/TM	Significance
Physicochemical analysis			
Moisture (%)	68.94 ± 0.22	67.70 ± 0.30	*
Ash (%)	1.33 ± 0.20	1.45 ± 0.09	ns
Total fat (%)	12.46 ±0.36	12.73 ± 0.24	ns
Protein (%)	16.92 ± 0.21	17.11 ± 0.19	ns
pH	5.57 ± 0.01	5.56 ± 0.02	ns
TBA (mg malonaldehyde/kg meat)	0.21 ± 0.03	0.43 ± 0.03	*
Technological properties			
Instrumental color			
L*	45.68 ± 0.91	43.90 ± 1.66	*
a*	23.32 ± 1.40	19.79 ± 1.28	*
b*	10.30 ± 0.57	8.60 ± 0.60	*
WHC (cm^2)	11.52 ± 0.34	10.38 ± 0.40	*
Total pigment (mg/kg)	391.64 ± 34.85	267.20 ± 43.82	*
Total heme-iron (mg/kg)	34.54 ± 3.87	23.57 ± 3.07	*

TBA – 2-thiobarbituric acid; WHC – water holding capacity;
* p<0.05; ns: differences not significant;

Standard chemical analysis performed on fresh and frozen/thawed meat showed no significant difference except for the total moisture parameter ($p<0.05$). This marked change goes in hand with the fact that freezing and thawing processes are known to mainly influence the water fraction of meat and affect the amount of exudate through thaw loss and/or drip loss (*Akhtar et al., 2013; Met et al., 2013*). Loss of fluid as exudate represents a great quality concern within the meat processing industry (*Leygonie et al., 2012b*), as this occurrence results in the loss of water-holding capacity (WHC). The phenomenon in which ice crystal formation occurs during freezing in intracellular and extracellular space of myofibrillar fibers causes the puncturing of the cell membranes with subsequent leakage of moisture. This increase in solute concentration during the freezing process/prolonged frozen storage leads to protein denaturation, which additionally influences the water-binding property of meat. Both of these instances contribute to the loss in the ability of the meat to absorb fluid during thawing and retain fluid during the time of post-thawing (*Leygonie et al., 2011; Leygonie et al., 2012a; Leygonie et al., 2012b*). This is in agreement with the results obtained in our research. WHC of the frozen/thawed ground beef has decreased significantly ($p<0.05$). Our results also comply with the results obtained by *Miller et al. (1980)* and *Vieira et al. (2009)* who examined, among all, the water-holding capacity of beef meat during the frozen storage period of 30 days at -20°C.

The pH values of the minced beef in the present study do not show any significant differences between the fresh and frozen/thawed samples ($p>0.05$). The

results of the pH values varied throughout the papers. While *Kluth et al. (2021)* presented similar results obtained in fresh and frozen turkey meat, *Leygonie et al. (2011)* stated that the pH of meat that has been frozen and thawed tends to be lower than prior to freezing as a result of the loss of the fluid from the meat tissue due to an increase in the concentration of the solutes, which results in a decrease in the pH values. Contrary to this, *Verma et al. (1985)* found that the pH levels of all the meats examined (pork, beef, mutton) over a storage period of 52 weeks at -18°C increased significantly ($p<0.01$).

Various factors, such as heme concentration and oxidation status, influence the color of meat (*Kluth et al.,2021)*. The color of the muscle foods mainly comes from the intracellular heme protein myoglobin, with some contribution by hemoglobin, the blood pigment, which will account for 20–30% of the total pigment present (*Von Seggern et al., 2005*). Myoglobin has been identified in the exudate of meat that occurs after the freezing/thawing process, accounting in part for the change in color stability due to an increased susceptibility of myoglobin to autoxidation and subsequent loss of optimum color presentation (*Leygonie et al., 2012a*). Total pigment levels were observed, and a significant difference ($p<0.05$) compared to the control sample was found. Generally speaking, heme-iron content varies in different types of meat, with a high range of 26.20 - 75.60 % of its iron content, with red meat, such as beef, containing a higher heme iron content, and poultry meat which is on the lower scale of the spectrum. Since iron has 2 - 3 times higher bioavailability than non-heme iron (usually found in plant sources), it represents a very valuable micronutrient in battling iron deficiency (*Met et al., 2013*). Needless to say, changes in heme-iron levels portray important instances regarding the evaluation of meat quality. Heme-iron represents a water-soluble component that could be lost through thawing (and found in drip loss) (*Met et al., 2013*). Our research results cohere with this statement, with a decreased total heme iron value by a third, as same as a result of total pigment, which is similar to results obtained by *Met et al. (2013)* and *Jeong et al. (2011).* The variation in concentration of myoglobin and its oxidation state can affect color not only in fresh meat (whole muscle) but in processed meat applications, such as frankfurters, as well (*Von Seggern et al., 2005*). Frozen storage impacted the levels of surface color instrumentally determined as well. All of the parameters measured in frozen/thawed meat samples - L*, a*, and b* showed a significant decrease ($p<0.05$) in value compared to the control group. Our results agree with the research by *Jeong et al. (2011)* who noted a decrease in all parameters (L*, a*, and b*) after the freezing/thawing process in beef meat. Additionally, research by *Vieira et al. (2009)* showed the differences in the L* and b* parameters but not in the a* after 30 days of frozen storage. a* value showed a significant decline ($p<0.05$) only after 90 days of frozen storage but had a steady decreasing trend throughout the frozen storage. *Akamittath et al. (1990)* examined only the changes

in a*, since the consumer associate redness with the acceptability of red meat, and reported a decrease in the levels of a* after 30 days of frozen storage on the samples of beef round meat, while the values on L* were not shown. Still, the authors reported that during informal visual observation, the samples appeared darker with storage.

Changes in the color of the meat are closely linked with oxidative processes, as lipid oxidation results in the formation of pro-oxidation capable of reacting with oxymyoglobin, which leads to metmyoglobin formation (*Vieira et al., 2009; Leygonie et al., 2012a)*. In our research, the products of secondary lipid oxidation were measured using thiobarbituric acid (TBA). Results indicated an increase in TBA value ($p<0.05$), which provided evidence of oxidation during storage. *Keller and Kinsella (1973)* reported that TBA values act differently in relation to a different grade of meat – with an insignificant change in ground round and a progressive increase in ground chuck meat. Contrary to our research, *Akamittath et al. (1990)* did not find changes in TBA in beef meat during 30 days of frozen storage, opposing to increased values found in pork and turkey meat, and suggested that the pork and turkey rapid oxidation of pigments that occurred might have provided a pool of biological catalyst that initiated lipid oxidation in the relatively unsaturated fat system compared to beef. *Vieira et al*. (*2009)* stated that the TBA value of fresh meat was significantly lower than meat stored for 30 days at -20 °C with an increasing tendency over a frozen storage time. Obtained results indicate that frozen storage is not by definition sufficient to prevent oxidation from occurring, which adheres to remarks offered by *Petrović et al. (1993)* who stated that biochemical reactions still takes place in meat during frozen storage temperatures higher than -20 °C since sufficient unfrozen water remained available at these temperatures for such reactions to occur.

The second part of this experiment was composed of the physicochemical and technological properties of frankfurters are shown in Table 2.

Since freezing/thawing processes impact the technological and chemical properties of meats, it is fair to assume that, in return, these changes will affect certain quality characteristics of the product manufactured from them. Even though the same amount of water (ice form) was added to the formulation of both frankfurters, the total moisture in the final products differed. This result could potentially be explained by dissimilarity in the moisture of the building blocks themselves (fresh meat vs frozen/thawed meat). However, although *Lowry et al. (1982)* suggested that meat emulsions produced from frozen/thawed meat were less stable than those made from fresh meat, in terms of moisture, our results did not show significant differences in process loss, cooking loss, and/or frying loss. *Kluth et al. (2021)* suggest that the water release during the cooking process is mainly due to chemically bound water and melting fat. Our results are in alignment with the results offered by *Colmenero et al. (1995)* who concluded that the effect of the cooking loss of Bologna sausages was not altered by the freeze-

thawing process endured by the meat. Similarly, *Verma et al. (1985)* found no significant differences in terms of cooking loss in sausages prepared from minced meat stored for 52 weeks at -18°C.

Table 2. Results of physicochemical meat product quality parameters and technological properties of frankfurters prepared from fresh meat (G1F group) and freeze/thawed meat (G2F group)

Parameter	G1F	G2F	Significance
Physicochemical analysis			
Moisture (%)	61.31 ± 0.21	60.48 ± 0.33	*
Ash (%)	2.45 ± 0.03	2.56 ± 0.12	ns
Total fat (%)	20.92 ± 0.22	21.16 ± 0.37	ns
Protein (%)	14.84 ± 0.08	14.99 ± 0.21	ns
NaCl (%)	1.63 ± 0.07	1.69 ± 0.03	ns
Total phosphorus (mg/kg)	4.37 ± 0.04	3.95 ± 0.04	ns
Nitrites (mg/kg)	47.55 ± 0.23	49.11 ± 0.18	*
Hydroxyproline (%)	0.23 ± 0.01	0.30 ± 0.02	*
Collagen content (%)	1.86 ± 0.05	2.38 ± 0.12	*
Collagen-to-protein ratio	12.55	15.85	-
pH	6.14 ± 0.02	6.19 ± 0.03	ns
Technological properties			
Instrumental color			
L*	65.78 ± 0.79	64.41 ± 0.62	*
a*	15.61 ± 0.12	15.95 ± 0.15	*
b*	11.24 ± 0.08	10.80 ± 0.09	*
FRP (%)	4.53 ± 0.67	4.38 ± 0.83	ns
Process loss (%)	11.28 ± 0.51	11.76 ± 0.79	ns
Cooking loss (%)	12.74 ± 0.55	13.22 ± 0.31	ns
Frying loss (%)	13.98 ± 0.55	14.39 ± 0.49	ns

* $p<0.05$; ns: differences not significant;

Contrary to our results, *Miller et al. (1980)* demonstrated that cooking tests showed that frozen storage did affect cooking loss ($p<0.01$), and as frozen storage of meat was prolonged, the frankfurters produced lost their ability to retain moisture and fat, resulting in a higher cooking loss for the sausages made from frozen/thawed meat. *Smith (1987)* expressed that freezing causes protein insolubility and changes the myofibrillar microstructure - from filamentous to spherical, leading to a reduced water-holding capacity. However, our results did not adhere to this statement, as there was no statistical difference ($p>0.05$) found in expressible moisture (FRP %). Even though there was a significant change ($p<0.05$) found in the WHC parameter conducted in raw meat (CG-FM and GF/TM), it could possibly be assumed that different added components, such as soy isolate, which is being used as a water-holding-increasing agent, could affect these results (*Josipović and Stanišić, 2022*). In addition, the collagen content was found significantly higher ($p<0.05$) in the G2F group than in the G1F group, which

could indicate the possible compensation and cause a „false“ increase of the WHC found in the G2F group since the efficiency of collagen in retaining water in frankfurter type sausages is shown through several papers (*Prestes et al.*, *2012*; *Sousa et al.*, *2017)*. Differences ($p<0.05$) in hydroxyproline content and, consequently, collagen content could be explained by the nature of the meat cut selected for the purpose of this experiment. Beef chuck cut is composed of a vast number of muscles (27 of them) whose collagen content varies on a large scale (*Von Seggern et al., 2005*). However, the calculation of the ratio of collagen to total protein confirmed that both types of frankfurters adhere to the *Official Gazette of RS (2019).*

The results on instrumental color parameters (CIE L*a*b*) showed significant differences found in *L** (lightness), as well as the parameters a* (redness) and b* (yellowness) ($p<0.05$). According to *Kluth et al. (2021),* numerous different factors, such as heme concentration in the meats which frankfurters were made from and oxidation status, which increases during the thermic processes that frankfurters go through, influence the color of meat. It is, therefore, not surprising that there is a difference in relation to the way the frozen storage/thawing process influences the L* value. During the production process of frankfurters, salt containing sodium nitrite was added to the mixture for antimicrobial effect as well as for developing the characteristic reddish-brown color of the product. This color change occurs as a consequence of the nitrite reduction to nitric oxide (NO) and, consequently, the formation of nitroso-myoglobin, whose concentration is known to be increasing with the rise in the temperature during thermic treatment of the frankfurters (*Kluth et al., 2021; Bloukas et al., 1999; Josipović and Stanišić, 2022)*. Since there was a significant difference ($p<0.05$) found in physicochemical analysis on nitrites content, it could be assumed that this could potentially be the reason, apart from already discussed differences in raw meat analysis as the building blocks, for the shifts in the parameters indicative of redness (a*) and yellowness (b*). Similar to *Kluth et al. (2021)* results, and their research on turkey sausages produced from fresh and frozen/thawed turkey meat, we found that the close pH and color values of the ground beef meat samples (CG-FM and GF/TM) before processing, as well as the similar pH results of the frankfurters after production, are comparable.

The results of the sensory evaluation are shown in Figure 1. The taste panel could not determine any significant change with respect to the taste, smell, texture, juiciness, color, rancidity, and general acceptability of the frankfurters ($p>0.05$). These results are in agreement with results obtained by *Verma et al. (1985),* who observed a storage period of different meat groups for 52 weeks at -18°C prior to the characterization of sausages prepared from them. However, *Miller et al. (1980)*, noted that meat and fat stored for 7 weeks at -17.8°C resulted in frankfurters being distinguishable ($p<0.01$) from controls, especially for the rancidity parameter, and these differences had that tendency which continued

throughout the course of storage, up until 31 weeks, when contrasts were notable to all of the panelists for all of the parameters observed (rancidity, texture, and flavor). Nonetheless, different results than the ones obtained in our experiment could lie in the formulation of sausages, as well as the experiment setting, as *Miller et al. (1980)* used and evaluated changes that occur in frozen storage not only in beef and pork meat but also, the pork fat. This could indicate that the higher rancidity scores were given in relation to oxidation that took place on a much larger scale than in our experiment (since we used fresh pork backfat in both formulations).

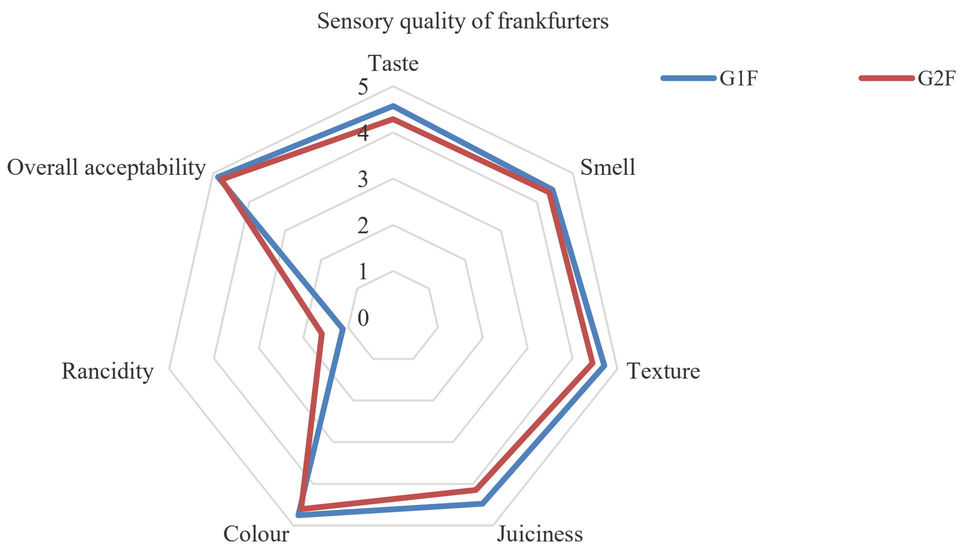

Figure 1. Spider plot for sensory quality of frankfurters

Since the results on technological parameters vary based on the frozen storage period and the freezing/thawing process, it could be assumed that 4 weeks in frozen storage is not a long enough period for severe changes that could greatly impact the final product, to occur. In conclusion, frozen storage of minced beef meat for 4 weeks at -18°C has small effects on the technological properties of frankfurters prepared from them.

Conclusion

Meat production that is of the highest quality and appealing to consumers' eyes is anticipated to translate into a revenue climb for meat producers and further stimulate the entire meat industry. The need to obtain meat freshness increases as global demand increases, and the distance between producer and buyer expands. Beef represents one of the meat products that are produced worldwide, and many studies have been conducted in relation to freezing rate, freezing storage duration, and, consequently, rates of the thawing process. However, not many studies have been conducted on the usage and impact of frozen raw materials on products, such as frankfurters, in terms of quality evaluation. This paper is of practical relevance for industries using frozen meat in the preparation of their products. Frozen storage of ground chuck beef meat for 4 weeks at -18°C has little to no effects on the technological and sensory properties of frankfurters. The thawed meat showed lower WHC and higher TBA values than the control group, and differences in color and total pigment contents were noticeable ($p<0.05$). On the other hand, WHC and process/cooking/frying loss performed on the frankfurters produced from frozen/thawed meat were comparable and showed no significant difference ($p>0.05$). However, even though the difference in color was present ($p<0.05$), based on the sensory evaluation, there were no significant color or any other (taste, smell, texture, juiciness, rancidity, and general acceptability) impairments noted by the panelists.

Procena kvaliteta viršli proizvedenih od svežeg i zamrznutog mlevenog goveđeg mesa

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Rezime

U cilju procene uticaja procesa zamrzavanja/odmrzavanja sirovog mesa na mesne prerađevine proizvedene od njih, vršena je procena kvaliteta viršli. Sveže goveđe meso je samleveno i podeljeno na dve partije – prva partija je odmah korišćena za pripremu viršli (G1F), a druga zamrznuta i čuvana na -18°C u period od 4 nedelje, kada je korišćena za pripremu druge grupe viršli (G2F). Fizičko-hemijska i tehnološka svojstva ispitivana su na uzorcima svežeg (CG-FM) i odmrznutog mesa (G-F/TM) , kao i viršli pripremljenih od ovih uzoraka. Skladištenje smrznutog mesa je značajno uticalo ($p < 0,05$) na vrednos ukupne vlage, kao i TBA vrednost i instrumentalno određene parametre boje (L*a*b*), SVV, ukupne pigmente i ukupne pigmente koji potiču od hema u uzorcima sirovog mesa. Kod određenih

parametara viršli, poput ukupne vlage, L* (svetloća), a* (udeo crvene boje) i b* (udeo žute boje) došlo je do značajne promene ($p < 0,05$). Međutim, razlike u kalu proizvodnje finalnih proizvoda/kalu kuvanja/kalu prženja i FRP-u nisu bile značajne. Senzorna procena nije pokazala nikakavu značajnu između dve grupe viršli ($p > 0,05$). Može se zaključiti da skladištenje smrznutog mesa mlevenog junećeg mesa u trajanju od 4 nedelje na -18°C i posledični proces odmrzavanja (na 4°C tokom 24h) ne utiču značajno na ukupnu prihvatljivost hrenovki pripremljenih od njih. Međutim, efekti promene u instrumentalnoj boji su očigledni.

Ključne reči: viršle, juneće mleveno meso, skladištenje smrznutog mesa, kvalitet mesa

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