FATTY ACID PROFILE, CHOLESTEROL CONTENT, ATHEROGENIC (IA) AND THROMBOGENIC (IT) HEALTH LIPID INDICES OF DIFFERENT FERMENTED DRY SAUSAGES

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Abstract - In this paper, results of the comparative investigation of fatty acid profile, cholesterol content, atherogenic (IA) and thrombogenic (IT) health lipid indices of four different fermented dry sausages made of Mangalitsa and Swedish Landrace pork meat are presented. The highest cholesterol content (64.92 mg/100g) was found in Sremska sausage made from the meat of Landras pigs. The levels of PUFA in sausages made of Landras pork meat were significantly higher than levels in other types. These differences were mainly produced by higher total *n*-6 PUFA content. However, the MUFA and USFA levels were highest in sausages made from the Mangalitsa pork meat. The highest SFA content was noted in sausages made from the meat of Landrace pigs. On the other hand, the IA, IT and PUFA/SFA ratio are more favourable in fermented sausages made of Mangalitsa pork meat.

Key Words – Mangalitsa, Autochthonous pork meat products, Chemical composition

I. INTRODUCTION

Mangalitsa is a typical fat breed of pig, i.e. carcass sides are 65-70% fat and approximately 30–35% meat [1]. The meat of the Mangalitsa pig had a darker colour, its fat was whiter and the intramuscular fat content of meat and thickness of back fat was considerably greater than meat of other pig breeds. The lower saturated fatty acid (SFA) content and higher proportion of unsaturated fatty acid (USFA) compared with that in meat from other fat pig breeds is advantageous from a human-nutrition point of view [2, 3].

Cholesterol levels in blood depend not only on dietary cholesterol, but also on the amount of fat and the fatty acid composition of the diet [4]. The impact of fat on cholesterol content can also be observed through the index of atherogenicity (IA) and throbogenicity (IT), which includes those fatty acids that affect the change of cholesterol. Nutritionists recommend a reduction in total fat intake, particularly of SFA and trans fatty acids, which are associated with an increased risk of cardiovascular disease and some cancers. Besides advocating that they reduce their fat intake, nutritionists urge consumers to increase their intake of polyunsaturated fatty acids (PUFA), particularly *n*-3 PUFA, at the expense of *n*-6 PUFA. The PUFA/SFA and *n*-6/*n*-3 PUFA ratios have, therefore, become some of the most important parameters in evaluating the nutritional value and healthfulness of foods [5, 6, 7].

However, in line with modern trends aimed at reviving and advancing traditional food production processes, autochthonous meat products, made from local breeds, are gaining importances [8].

The aim of this study was to investigate the fatty acid profile, cholesterol content, determine IA and IT health lipid indices of different fermented dry sausages made of Mangalitsa and Swedish Landrace pork meat. Mangalitsa was selected as autochthonous Serbian pig breed, while Swedish Landrace was chosen as the most common commercial meat/fattening pig breed in Serbia.

II. MATERIALS AND METHODS

All animals were bred at the test farm of the Institute for Animal Husbandry (Belgrade, Serbia). All pigs had access to green forages (pasture, clover) ad libitum, with the addition of a feed concentrate based on corn and wheat. Animals were stunned, slaughtered and exsanguinated at a local slaughterhouse. Meat was processed 24 h after slaughter and cooling.

The examined variants of Kulen and Sremska sausages were manufactured in a processing plant of the Institute for Animal Husbandry. Three

sausages were taken from each variant for all analyses and each analysis was done in duplicate. Meat used in the production of Kulen sausage contained little fat or connective tissue, being primarily meat from the leg, shoulder and some parts of neck and a firm backfat tissue, was also used. Muscle and adipose tissue (75:25) was chopped in a cutter (Seydelman K60, Germany) to achieve 10 mm granulation. After chopping, the chopped meat was transferred to a mixer and the other ingredients of the filling were added: 2.3% table salt, 0.4% saccharose, 0.3% garlic (powder), 0.3% pepper and 0.8% ground sweet and hot red paprika. The filling was then firmly stuffed into the natural pig colon casings. Smoking and maturation of sausages was carried out in the winter period. The smokehouse temperature ranged from 10 to 15º C, and humidity from 75 to 90%. Kulen sausages were smoked during the first 4 weeks. Subsequently, sausages were transferred to the ripening room at a temperature of 10 to 12º C. The ripening was carried out in a drying chamber under controlled conditions (Maurer, Germany).

The examined variants of Sremska sausage were produced on the same day and in an identical manner. Meat and fat (85:15) were ground in a cutter (Seydelman K60, Germany) to 8 mm. The same amounts of ingredients were added to sausage variants: 2.3% salt, 0.011% NaNO2, 0.3% dextrose, 0.20% garlic and 0.5% sweet red paprika. The mixture was filled in pig small intestines of around 32 mm diameter. After stuffing, the sausages were hung on sticks and the ripening was carried out in a drying chamber under controlled conditions (Maurer, Germany).

To determine the concentration of fatty acids, total lipids were extracted by the accelerated solvent extraction method on the Dionex ASE 200. Fatty acids, as methyl esters, were determined by capillary gas chromatography with a flame ionization detector [9]. Cholesterol content was measured with a HPLC/PDA on the Waters 2695 Separations Module, with a Waters 2996 Photo Diode Array Detector, as reported by Maraschiello *et al.* [10].

From the data on the fatty acid composition, the following were calculated:

1) Index of atherogenicity (IA): indicating the relationship between the sum of the main saturated fatty acids and that of the main classes of unsaturated [11, 12].

The following equation was applied: IA =

$$[(4 \times C14{:}0) + C16{:}0 + C18{:}0]/[\Sigma MUFA + \Sigma PUFA\text{-}n6 + \Sigma PUFA\text{-}n3]$$

2) Index of thrombogenicity (IT): showing the tendency to form clots in the blood vessels. This is defined as the relationship between the pro-thrombogenetic (saturated) and the anti-thrombogenetic fatty acids (MUFAs, PUFAs-*n*6 and PUFAs-*n*3), [11, 12].

The following equation was applied: IT =

$$\frac{C14{:}0 + C16{:}0 + C18{:}0}{0.5 \times MUFA + 0.5 \times PUFA\text{-}n6 + 3 \times PUFA\text{-}n3 + PUFA\text{-}n3/PUFA\text{-}n6}$$

Two samples were analyzed from each type of dry fermented sausage. Each parameter was determined six times in each sample. Descriptive statistics (means and standard error) were calculated. The results were processed by single factor analysis of variance (ANOVA). The differences between the different types of sausage were tested using Tukey's method. Calculations were conducted using the software Statistica 7.0 (Statsoft Inc.).

III. RESULTS AND DISCUSSION

Palmitic acid (C16:0) was the most abundant SFA, oleic acid (C18:1 *n*-9) the most abundant of the MUFA and linoleic acid (C18:2 *n*-6) the most abundant of the PUFA for the all types of fermented sausages (Table 1). The levels of PUFA in Kulen and Sremska sausages made of Landras pork meat were significantly higher ($P<0.001$) than levels in other types. These differences were mainly caused by higher total *n*-6 PUFA content ($P<0.001$). The lower *n*-6/*n*-3 ratios were established in sausages type KM and SM. In spite of that though, the *n*-6/*n*-3 ratio of unsaturated fatty acids in KM and SM types was between 14 and 17, and above the recommended level of 1:1-5:1 [6]. In separate trials, Hoz [13] and Valencia [14], both found, in their control groups of fermented dry sausages, lower ratios of *n*-6/*n*-3 fatty acids (12.05 and 13.86, respectively), compared to our findings. The content of essential PUFA, linoleic acid, ranged from 6.37% in sausage type KM, to 14.40% in sausage type SL ($P<0.001$).

The levels of MUFA in sausages made of Mangalitsa pork meat were higher (P<0.001) than levels in other types. These differences were mainly caused by higher oleic acid, cis-vaccenic acid, (C18:1 *cis*-11) and palmitic acid (C16:1) levels in these sausages. In relation to the SFA fraction, significant differences were observed for individual fatty acids, giving rise to similar amounts for the total fraction. The total content of SFA was highest in sausage type KL and the lowest in sausage type SM. The sausage types contained significantly differing levels of stearic acid (C18:0), one of the major SFA (P<0.001). In our study, the PUFA/SFA ratio was determined to be the lowest in fermented sausages made of Mangalitsa pork meat (0.22 and 0.23 respectively). The cholesterol content in fermented sausages ranged from 50.16 mg/100g (KM) to 64.92 mg/100g (SL), with significant differences between the samples (P<0.001). Baggio and Bragagnolo [15], for an Italian type salami, found the cholesterol content ranged from 48 to 57 mg/100g. In their study of fermented sausages in Croatia, Pleadin *et al.* [16] established that the average cholesterol content of industrially fermented sausages was 58.48 to 105.24 mg/100g, while that of home-made fermented sausages was up to 75.07 mg/100g. The level of cholesterol in blood does not only depend on cholesterol intake through food, but also on the ratio between unsaturated and saturated fatty acids. Fatty acid composition of lipids is important from the nutritional viewpoint, especially the ratio between PUFA and SFA, the ratio between 'bad' and 'good' fatty acids (IA and IT) and the ratio *n-6/n-3*.

If the IA and IT of certain foods is lower, its atherogenic and thrombogenic potential is also lower. The IA and IT were the highest in sausage type KL and significantly differs from other samples. The IA and IT were lower in sausages made from the Mangalitsa pork meat. IA of beef is 0.72, poultry 0.50 and pork 0.60 [17].

IV. CONCLUSION

There are differences in cholesterol content between sausages made from the Mangalitsa and Landras pork meat. The highest cholesterol content was found in Sremska sausage made from the meat of Landras pigs. The levels of PUFA in sausages made of Landras pork meat were significantly higher than levels in other types.

Table 1. Fatty acid composition (%), cholesterol content (mg/100g), Index of atherogenicity (IA) and Index of thrombogenicity (IT) (means ± standard error) of different fermented dry sausages

Traits	Fermented dry sausages				
	KM[1]	KL	SM	SL	P[2]
C14:0	1.21±0.04	1.18±0.05	1.18±0.04	1.02±0.07	NS
C16:0	26.28±0.07^{a}	24.77±0.06^{b}	25.88±0.13^{a}	23.99±0.14^{c}	***
C16:1	3.87±0.08^{a}	1.86±0.05^{b}	3.87±0.08^{a}	1.76±0.11^{b}	***
C17:0	0.31±0.02	0.35±0.04	0.29±0.01	0.30±0.02	NS
C18:0	11.25±0.10^{a}	14.12±0.08^{b}	10.88±0.21^{a}	14.19±0.08^{b}	***
C18:1c9	42.73±0.26^{a}	39.47±0.11^{b}	43.41±0.12^{c}	37.74±0.12^{d}	***
C18:1c11	4.38±0.10^{a}	3.26±0.05^{b}	4.55±0.07^{a}	2.91±0.11^{c}	***
C18:2n6	6.37±0.12^{a}	11.66±0.12^{b}	6.58±0.09^{a}	14.40±0.13^{c}	***
C18:3n6	ND	ND	ND	ND	
C18:3n3	0.39±0.03^{ab}	0.35±0.04^{a}	0.46±0.01^{b}	0.44±0.02^{ab}	*
C20:0	0.17±0.01	0.18±0.02	0.17±0.01	0.21±0.02	NS
C20:1	0.85±0.21	0.79±0.06	0.84±0.02	0.72±0.03	NS
C20:2	0.63±0.13^{ab}	0.70±0.04^{ab}	0.54±0.07^{a}	0.91±0.04^{b}	*
C20:3n6	1.33±0.11^{a}	0.67±0.02^{b}	1.11±0.06^{ac}	1.03±0.03^{c}	***
C20:3n3	0.08±0.05^{ab}	0.15±0.02^{a}	0.09±0.04^{ab}	ND^{b}	*
C22:1	0.14±0.03^{a}	0.48±0.03^{b}	0.13±0.02^{a}	0.37±0.02^{c}	***
SFA	39.22±0.14^{a}	40.60±0.21^{b}	38.40±0.22^{c}	39.70±0.15^{a}	***
MUFA	51.97±0.29^{a}	45.86±0.24^{b}	52.80±0.20^{a}	43.50±0.15^{c}	***
PUFA	8.80±0.31^{a}	13.53±0.15^{b}	8.78±0.12^{a}	16.78±0.09^{c}	***
USFA	60.78±0.50^{a}	59.39±0.38^{b}	61.58±0.22^{ac}	60.27±0.20^{abc}	**
MU/PU	5.94±0.19^{a}	3.39±0.02^{b}	6.02±0.09^{a}	2.59±0.01^{c}	***
MU/SF	1.33±0.01^{a}	1.13±0.00^{b}	1.38±0.01^{c}	1.10±0.01^{d}	***
PU/SF	0.22±0.01^{a}	0.33±0.00^{a}	0.23±0.00^{a}	0.42±0.00^{c}	***
n-3	0.47±0.04	0.50±0.03	0.55±0.04	0.44±0.02	NS
n-6	7.70±0.20^{a}	12.33±0.11^{b}	7.69±0.12^{a}	15.43±0.11^{c}	***
n-6/n-3	16.96±1.42^{a}	25.21±1.70^{b}	14.38±1.14^{a}	35.86±1.59^{c}	***
Cholest.	50.16±0.11^{a}	61.48±0.26^{b}	59.65±0.26^{c}	64.92±0.12^{d}	***
IA	0.70±0.01^{a}	0.74±0.00^{b}	0.68±0.00^{c}	0.71±0.01^{a}	***
IT	1.24±0.01^{a}	1.31±0.01^{b}	1.19±0.01^{c}	1.27±0.01^{ab}	***

[1]Sausage samples depending of certain meat pig breeds (Kulen sausage - KM; Sremska sausage - SM / Mangalitsa pork meat, Kulen sausage - KL; Sremska sausage - SL / Swedish Landrace pork meat)

[2]NS-not significant ($P \geq 0.05$); *:Statistical significance at the level of $P<0.05$; **:Statistical significance at the level of $P<0.01$; ***:Statistical significance at the level of $P<0.001$; $^{a-e}$Means in the same row with different letters are significantly different (P<0.05).

These differences were mainly produced by higher total *n*-6 PUFA content. However, the MUFA and USFA levels were highest in sausages made from the Mangalitsa pork meat. The highest SFA content was noted in sausages made from the meat of Landrace pigs. On the other hand, the IA, IT and PUFA/SFA ratio are more favorable in

Mangalitsa pork meat. It has been observed that the lower IA and IT implies a lower PUFA/SFA ratio, that is, sausages made from the meat of Mangalitsa breed have less 'bed' and more 'good' fatty acids.

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