THE INFLUENCE OF ORGANIC ACID WHEY FROM VARIOUS REGIONS IN POLAND ON THE LIPID COMPOSITION AND OXIDATIVE STABILITY OF COOKED SAUSAGE

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I. INTRODUCTION

The research conducted at IBPRS-PIB has demonstrated that the incorporation of organic acid whey into the production process positively influences the colour, quality, and storage stability of uncured meat products [1; 2]. Acid whey also has antioxidant and antibacterial properties. It has been shown that acid whey can affect the profile of fatty acids and demonstrate lipolytic activity, which may explain the increased PUFA ratio in the product [2]. Whey's composition and functional properties may vary depending on the region of production due to the diverse composition of milk. The research aimed to assess the influence of acid whey obtained from various regions in Poland on changes in the fatty acid profile, oxidative stability, physico-chemical parameters, and microbiological quality of cooked sausage.

II. MATERIALS AND METHODS

In this experiment 4 meat batter treatments were prepared for sausage production: (C) treatment with 2.0% of salt, 0.5% glucose, 5% water; (S1) treatment with 2.0% of salt, 0.5% glucose, 5% organic acid whey (Dukla, Poland); (S2) treatment with a 2.0% of salt, 0.5% glucose, 5% organic acid whey (Bydgoszcz, Poland); (S3) treatment with 2.0% of salt, 0.5% glucose and 5% of organic acid whey (Częstochowa, Poland). The pork trimmings meat were minced (8 mm), mixed with ingredients and left for 48 h at 4-6 °C. Next, the meat batter was stuffed into casings and the sausages were smoked (55–65 °C, 1 h) and cooked up to 70 °C in the centre. The products were chilled, vacuum-packed and cold stored at 4–6 °C. In the samples the following values were defined: pH and redox potential, thiobarbituric acid-reactive substance (TBARS), microbiological (*Salmonella spp.* ISO 6579-1:2017, *Listeria monocytogenes* ISO 11290-2:2017 and *Enterobacteriaceae* ISO 21528-2:2005), fatty acid profile, lipid quality indices (AI, TI) and sensory quality (QDP, ISO 13299:2016-05). The experiment was performed at 3 replications (n=3) in industrial conditions. The two-way ANOVA included the main effects (treatments), and the storage period (0, 14 days) as well as their interactions were used. The Fisher's LSD test was used to determine the significance of the mean values for a multiple comparison at $P < 0.05$. The Statistica program version 13 was used.

III. RESULTS AND DISCUSSION

After production, sausage S3 exhibited a lower pH compared to the other samples ($P < 0.001$). This variance is likely attributed to the fermentation initiated by lactic acid bacteria found in acid whey, resulting in the accumulation of lactic acid. However, after 14 days, the pH of sausage S3 increased, possibly due to the production of alkaline substances caused by proteolysis. The analysis of TBARS values revealed that sausage S3 had a significantly lower MDA content initially, but after 14 days, the C sausage showed the lowest TBARS index. The decrease in MDA content during storage is because secondary lipid oxidation products may be further degraded to other, more stable compounds [3]. Moreover, during storage, the permitted amount did not exceed the MDA content in meat products, which is approx. 2-2.5 mg/kg of product. Analysis of the ORP indicated that initially, the S2 sausages exhibited to be the most favourable (the lowest value). However, after 14 days, the S3 sausages presented the lowest ORP index, likely due to the accumulation of protein proteolysis products ($P < 0.001$). After production, all sausage treatments were generally characterized by good sensory quality. Nevertheless, it was shown that the S3 sausage was rated as juicier, of the highest overall quality and more aromatic. This observation may be related to the acidity and TBARS values of the products. Our

study also found that the addition of acid whey positively changed the fatty acid profile during storage, with an increase in the percentage of MUFA and PUFA. Lipid analysis showed that the sausage samples had low atherogenicity (AI) and thrombogenicity (TI) indices, potentially suggesting better nutritional quality of the product (Table 1). Additionally, the sausage samples exhibited good microbiological quality throughout the storage period, with no detection of *Listeria monocytogenes*, *Enterobacteriaceae* and *Staphylococcus aureus*.

Table 1 - The pH, ORP, TBARS and fatty acid of the cooked sausages (means ± SD).

Parameter	Sampling time (days)	Treatment (n=3)				Treatment x time
		C	S1	S2	S3	P
pH	0	6.01±0.13^{bB}	5.99±0.05^{bA}	5.98±0.03^{bA}	5.89±0.06^{aA}	***
	14	5.89±0.13^{aA}	5.91±0.07^{abA}	5.98±0.05^{bcA}	6.02±0.06^{cB}	
ORP [mv]	0	421.00±10.34^{bA}	406.78±6.53^{aA}	398.56±3.59^{aA}	451.67±14.43^{cB}	***
	14	424.22±7.21^{cA}	405.67±3.80^{bA}	406.22±10.64^{bA}	395.11±9.70^{aA}	
TBARS [mg MDA/kg]	0	0.95±0.06^{cdA}	0.90±0.06^{bA}	0.99±0.04^{dA}	0.76±0.05^{aA}	***
	14	0.88±0.07^{aA}	0.91±0.05^{abB}	1.12±0.05^{dB}	0.96±0.04^{cB}	
Σ UFA [%]	0	59.07±0.26^{abA}	59.03±0.12^{abA}	59.13±0.25^{abA}	58.73±0.17^{aA}	*
	14	58.83±0.12^{abA}	58.97±0.17^{abA}	59.67±0.09^{dB}	59.20±0.24^{cB}	
n-3 [%]	0	0,90±0.00^{bA}	0,83±0.05^{aA}	0,90±0.00^{bA}	0,80±0.00^{aA}	NS
	14	0,90±0.00^{aA}	0,93±0.05^{aB}	0,93±0.05^{aA}	0,90±0.00^{aB}	
n-6 [%]	0	10,63±0.61^{abA}	10,37±0.25^{abA}	10,43±0.05a^{bA}	10,07±0.26^{aA}	NS
	14	10,27±0.09^{abA}	10,43±0.34^{abA}	10,80±0.24^{bA}	10,33±0.12^{abA}	
AI	0	0,439±0.005^{aA}	0,441±0.002^{bA}	0,437±0.003^{aA}	0,447±0.004^{bB}	*
	14	0,444±0.002^{bB}	0,442±0.003^{bA}	0,433±0.002^{aA}	0,439±0.003^{aA}	
TI	0	1,263±0.012^{aA}	1,273±0.009^{abA}	1,257±0.011^{aB}	1,292±0.013^{bB}	*
	14	1,272±0.008^{bcA}	1,264±0.008^{bA}	1,233±0.007^{aA}	1,256±0.010^{bA}	

a-c: Means in the same row with different superscript small letters differ significantly ($P < 0.05$); A-B: Means in the same column with different superscript capital letters differ significantly ($P < 0.05$); UFA – the sum of monounsaturated and polyunsaturated fatty acids; n-3 – the sum of the n-3 fatty acids; n-6 – the sum of the n-6 fatty acids; The values are expressed as means ± SD. *P*: significance of effects; treatment; time; treatment-time interaction; NS – not significant; *$P < 0.05$; ** $P < 0.01$; ***$P < 0.001$. AI – Index of Atherogenicity; IT – Index of Thrombogenicity.

IV. CONCLUSION

The research indicates that the suggested technology could potentially offer a promising solution for reducing oxidative changes and enhancing the fatty acid profile of meat products. However, it should be noted that the properties of whey may vary depending on place of origin. Therefore, additional research is required to investigate this issue further.

ACKNOWLEDGEMENTS

The study was performed as part of research project No.: DRE.prz.070.2.2024 financed by the Minister of Agriculture and Rural Development.

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