Abstract

Influence of freeze-dried acid whey on physicochemical characteristics and bioactive compounds in raw fermented ruminant sausages

Based on the analysis of literature data the following research hypothesis was made: The use of freeze-dried acid whey for the production of raw fermented sausages without the addition of nitrates from ruminant meat has a positive effect on the changes occurring during the fermentation process, product safety, physicochemical characteristics and the content of bioactive compounds in the final products. The aim of this dissertation was to determine the effect of freeze-dried acid whey on the physicochemical parameters during the maturation process of raw fermented sausages from ruminant meat, which shape their safety and nutritional value.

The research assumptions formulated in this way were verified through the following specific objectives: to determine the possibility of using acid whey for production of raw fermented sausages without the addition of nitrates from ruminant meat; to determine the influence of the amount of applied freeze-dried whey on the course of changes occurring during the maturing process; to determine the safety of nitrate-free raw fermented sausages; to assess the influence of the amount of applied acid whey and meat species (beef and fallow deer meat) on the nutritional value and content of bioactive compounds in raw fermented sausages.

The approach presented in the attached works consists in determining the potential of using acid whey (liquid and freeze-dried) as an alternative to the use of nitrates. During the design of the research hypothesis, it was assumed that the addition of acid whey to the production of nitrate-free raw fermented sausages will have a positive effect on biological and physicochemical changes occurring during the production of raw fermented products, which will make it possible to obtain safe products with similar or more favorable nutritional and health values than in the case of cured products. Besides, the use of acid whey in the form of freeze-dried whey makes it possible to introduce larger quantities into products, which may increase its potential in meat processing.

The first stage of verifying the hypothesis was to determine the possibility of using acid whey to produce nitrate-free raw fermented beef sausages as conventionally used meat from animals classified as ruminants. A detailed analysis of physicochemical and microbiological changes occurring during the production of raw fermented beef sausages with the addition of

curing salt (variant C), sea salt (variant S) and sea salt with liquid acid whey (SAW) was presented in work **I** entitled: "Addition of acid whey improves organic dry-fermented sausage without nitrite production and its nutritional value". The results presented in the study confirmed that the addition of acid whey favorably affects the pH changes and lactic acid bacteria content during the production process. Moreover, the results of the fatty acids profile and the content of heme iron indicate the antioxidant effect of this additive limiting the oxidation of polyunsaturated fatty acids (PUFA) and the conversion of heme iron into nonheme iron.

In the next stage of research, the acid whey was subjected to a freeze-drying process to preserve it and allow to introduce larger amounts of this product into sausages. Moreover, an attempt was made to assess the influence of various forms of acid whey application (fresh liquid whey, whey reconstituted from freeze-drying and whey reconstituted from double freeze-drying) on microbiological changes and biogenic amine content in raw fermented sausages made from fallow deer and beef. The results presented in work **II** confirmed that the freeze-drying process allowed to obtain higher lactic acid bacteria content while maintaining unchanged pH of whey reconstituted from the freeze-dried powder as compared to fresh, liquid acid whey. Products with the addition of whey reconstituted from the freeze-dried powder did not differ significantly from the variant with liquid acid whey in terms of tested parameters, which made it possible to decide to use only acid whey reconstituted from the freeze-dried powder in further stages of the study.

The influence of different amounts of freeze-dried acid whey on physicochemical changes occurring during the production process, safety, and nutritional value of raw ripened sausages from ruminant animals was evaluated at further stages. The results obtained are presented in publications **III-V**.

The use of increased quantities of acid whey does not affect the physicochemical changes occurring during the production process of raw fermented (**III**) sausages. Nevertheless, some differences were observed between equal types of meat used for their production. In the case of beef sausages, the use of acid whey limited the loss of heme iron, while in fallow deer sausages an increase in the proportion of yellow in the total color tone was observed.

The evaluation of the safety of raw fermented sausages with the addition of freeze-dried acid whey is presented in study **IV**. The results obtained indicate that the use of acid whey as an alternative to the use of nitrates does not adversely affect the parameters related to the safety of the examined sausages both in the case of beef sausages and fallow deer meat sausages.

Products with the addition of acid whey were characterized by the same safety class of pH and water activity and microbiological quality as cured products. The use of freeze-dried acid whey (especially increased amounts) significantly reduced the formation of biogenic amines. The greatest differences in the content of biogenic amines between the sample with curing mixture (C) and the sample with sea salt and four-fold freeze-dried whey (SAW4) were observed in the case of fallow deer meat sausages.

The last stage of verification of the research hypothesis was to assess the effect of freeze-dried acid whey on the nutritional value of fallow deer and beef sausages. The results presented in the **V** study indicate significant differences in the nutritional value and the content of bioactive compounds in the examined sausages, depending on the type of meat used. Sausages from fallow deer meat are characterized by lower protein and fat content and higher water content. Moreover, they are a richer source of peptides (with higher antioxidant activity (ABTS and RP)), L-carnitine or taurine. On the other hand, beef sausages contain more glutathione, CLA and hem iron in relation to fallow deer sausages. The use of freeze-dried acid whey increased the L-carnitine content and decreased the peptide content in both types of sausages. In the case of beef sausages, the effect of whey on the reduction of heme iron loss was also observed. On the other hand, in the case of fallow deer meat sausages, the samples with acid whey were characterized by higher CLA content.

CONCLUSIONS

1. Freeze-dried acid whey has an unchanged pH and a comparable content of lactic acid bacteria in relation to the raw material in a liquid form, which makes it possible to use it in an increased amount in the production of raw maturing meat products without increasing the water content.
2. The use of acid whey prevents the loss of heme iron during the production of raw-ripened beef sausages, which indicates the antioxidant effect of this additive. As a result, limiting the damage to the myoglobin molecule prevents the release of iron in a non-heme form.
3. The addition of acid whey reduces the content of tyramine and cadaverine and the total amount of biogenic amines. Increasing the addition of freeze-dried whey causes an increased reduction in the production of biogenic amines.
4. Fallow deer sausages were characterized by a lower content of biogenic amines compared to beef products, which is probably due to species-specific factors, such as the diversity of endogenous meat microflora characterized by different ability to decarboxylate amino acids or to produce detoxifying enzymes BA.

5. The nutritional value and the content of bioactive compounds in raw fermented sausages made from ruminant meat mainly depend on the raw meat used.
6. The use of acid whey in the production of raw fermented sausages increases the L-carnitine content in beef and fallow deer meat products. In the case of fallow deer sausages, the use of acid whey also has a positive effect on the content of CLA and the antioxidant activity of peptides.
7. Freeze-dried acid whey can be an alternative to nitrogen compounds in meat products. Its use in the production of raw fermented sausages made from fallow and beef meat without the addition of nitrates allows for the same microbiological quality and safety class (pH and a_w) as in the case of products with the addition of nitrates.
8. In raw-ripening sausages, it is recommended to use freeze-dried acid whey as a substitute for nitrogen compounds in an amount corresponding to 10% addition of liquid whey in order to obtain the qualitative characteristics most similar to the product with the addition of nitrates.

Reference to publications

I. Karwowska, M., Kononiuk, A. (2018). Addition of acid whey improves organic dry-fermented sausage without nitrite production and its nutritional value. *International Journal of Food Science & Technology*, *53*(1), 246-253.

II. Kononiuk, A. D., Karwowska, M. (2020). Comparison of the effect of freeze-dried acid whey on physicochemical properties of organic fermented sausages made from beef and fallow deer meat. *Journal of Food Science and Technology*, 57, 5, 1753-1762.

III. Kononiuk, A. D., Karwowska, M. (2020). Comparison of selected parameters related to food safety of fallow deer and beef uncured fermented sausages with freeze-dried acid whey addition. *Meat Science*, *161*, 108015.

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