Enhancing Sausage Functionality Products: A Study On Sausage With Natural Purslane Powder As An Antioxidant Additive

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Abstract:
The study of meat products from alternative protein sources is a promising direction, as these types of meat possess valuable properties. These meats are rich in protein, low in fat, and have good digestibility, making them attractive for baby food. The purpose of this study was to investigate sausages made from alternative protein sources with the addition of purslane at 1,2% by weight of minced meat. The results showed that experimental samples of sausage with chicken fillet and sausage from alternative meats had a moisture content of 72.7% and 70.6%, fat 8.1% and 6.7%, protein 13.41% and 15.31%, carbohydrates 3.0% and 4.4%, respectively. The results obtained demonstrate that sausages made with chicken fillet and alternative proteins, as well as sausages made from different combinations of alternative proteins with purslane, have a high moisture-binding capacity. The moisture-binding capacity of sausage with chicken fillet and purslane is 78.16%, which is 1.73% higher than the benchmark at 76.43%. The moisture-binding capacity of sausage with other alternative proteins and purslane was 78.65%, which is 2.22% higher than the control. High moisture-binding ability helps preserve the freshness and taste of the sausage for a longer time. During the study, a comparative analysis of the protein digestibility of experimental samples of boiled sausage products was conducted. It was found that sausage with chicken fillet is characterized by a lower concentration of tyrosine due to the action of proteolytic enzymes (pepsin and trypsin) – from 624.6 mcg/ml (during the first three hours of hydrolysis) to 371.3 mcg/ml (after six hours of hydrolysis), compared to sausage made from different alternative proteins, which had a concentration of 674.2 mcg/ml when digested with pepsin and 377.3 mcg/ml when digested with trypsin, indicating a higher degree of protein digestibility. Thus, research on sausages made from alternative proteins for school-age children can contribute to the development of innovative products that meet the health and developmental needs of children, as well as support the sustainable development of rural regions and stimulate economic growth.

Keywords: meat; sausage; purslane; moisture-binding ability

DOI: 10.24297/j.cims.2024.10.1

1. Introduction

The issue of ensuring proper nutrition for children remains relevant and essential for safeguarding their health and well-being. Currently, there is a rise in cases of pathological conditions associated with intolerance to certain food components. In this context, biologically complete products, which can be produced only on an industrial scale, play an important role in meeting the dietary needs of children. With the growing demand for meat products each year, our country still relies on imports. Considering the potential of alternative livestock breeding, the development of industrial production of meat products from alternative protein sources is a new and promising direction in the industry. The global trend toward consuming low-fat and hypoallergenic types of meat, especially in baby food, continues to grow. With this in mind, the development of technologies for producing meat products for children from alternative protein sources, which are rich in nutrients and possess dietary properties, appears highly relevant. Scientific studies confirm that the quality of life is closely tied to general health, which is strongly influenced by nutrition. According to statistics, proper and balanced nutrition can increase life expectancy by 15-20%.

Although less common, alternative protein sources deserve more attention due to their unique nutritional characteristics. Unlike traditional types of red meat, these sources have a rich amino acid and mineral composition, along with high levels of unsaturated fats. They are also easily digestible and hypoallergenic, making them a valuable component for functional food production.

In recent years, a variety of food products based on these alternative meats have entered the market, including smoked, fried, dried, and minced meat products. In particular, minced meat products such as meatballs and sausages are gaining popularity among consumers for their taste and convenience. Over the past five decades, there has been a significant increase in the global population of certain livestock species, with a focus on sustainable production in developing countries. These trends demonstrate the expansion of production, which is expected to continue growing in the coming decades. Alternative protein sources are rich in protein, vitamins, and minerals essential for healthy growth and development in children. However, incorporating these meats into children's diets presents certain technological and taste-related challenges. In this context, natural purslane powder, known for its strong antioxidant properties, helps preserve the freshness of products and extends their shelf life without compromising nutritional value. School-age children require a balanced diet rich in protein, vitamins, and minerals to support growth and development. Meat products for children should be enriched with essential nutrients, which may necessitate careful selection of ingredients and additives. Children's products must meet high

food safety standards, including microbiological cleanliness and the absence of allergens or other harmful factors. The right choice of ingredients and additives can enhance the nutritional value and structure of the product. However, the use of natural ingredients and antioxidants, like purslane powder, presents challenges in ensuring product stability, necessitating research into the effects of plant-based raw materials on sensory qualities and shelf life.

The aim of this study is to improve the nutritional value, technological and organoleptic characteristics and increase the shelf life of sausages through the use purslane powder.

2. Materials and methods

2.1. Materials

The objects of the study are two samples: the first is a boiled sausage made with a combination of chicken fillet and dry (1,2%) purslane powder, and the second is a boiled sausage made with camel meat and dry (1%) purslane powder.

The boiled sausages with purslane were prepared according to the standard technology for boiled sausages. Purslane powder (1% of the mass for 100 kg of minced meat) was added during the meat mincing process. Heat treatment was conducted until the internal temperature of the sausage reached 72°C.

The samples were developed in the pilot production facility at the Kazakh Agrotechnical Research University named after Saken Seifullin.

2.2. Determination of the moisture binding capacity of sausages

The moisture binding capacity of the samples was determined by the Grau-Hamm method based on pressing the test sample. To do this, a sample weight of 0.30 ± 0.01 g was weighed on a laboratory scale on a circle of polyethylene with a diameter of 15-20 cm. Then it was transferred to a decontaminated filter with a diameter of 9-11 cm, placed on a glass or plexiglass plate so that the suspension was under a polyethylene circle. From above, the suspension was covered with a plate of the same size as the lower one, a load weighing 1 kg was placed on it and maintained for 10 minutes. The filter with a hitch was released from the load and the lower plate. With a pencil, the contour of the spot was outlined around the compressed suspension, the contour of the wet spot was drawn by itself when the filter paper dried in the air.

The area of the spot formed by adsorption moisture was calculated from the difference between the total area of the spot and the area of the spot formed by the sample sample. The areas of spots formed by the compressed sample and adsorption moisture were measured with a planimeter. 1 cm^2 of the wet spot area of the filter corresponds to 8.4 mg of water.

2.3. Digestibility of sausage proteins by digestive enzymes

The simulation of digestion for boiled sausage product samples followed the protocol devised by Pokrovsky and Yertanov, as outlined below. To begin, 0.5 g of finely crushed sample was combined with 25 mL of freshly prepared pepsin solution (at a concentration of 1 mg/mL). This mixture was created by blending 25 mL of 0.02 N hydrochloric acid solution (with a pH of 1.2) and 25 mg of crystalline pepsin. It was thoroughly mixed and then heated to 37°C, maintaining this temperature for a duration of 3 hours.

Following the digestion process with pepsin (25 mL), the remaining samples were neutralized by stirring in 0.65 mL of 2 N sodium hydroxide. Subsequently, 25 mL of 0.02 N sodium bicarbonate solution (with a pH of 8.2) and 25 mg of crystalline trypsin (resulting in a final enzyme concentration of 0.5 mg/mL) were added. This mixture was then incubated at 37°C for another 3 hours.

Upon completion of the digestion process, the samples were promptly frozen at -40°C for several hours. To measure the protein concentration, the samples were thawed and subjected to centrifugation for 20 minutes at 14,000 rpm, after which the supernatant was collected [33].

2.4. Determination of Color Characteristics

Color characteristics of the samples were assessed utilizing a Konica Minolta CM-2300d spectrophotometer, which had been calibrated using standard black-and-white calibration plates. The color parameters were represented as follows: L (lightness), a (redness), and b (yellowness).

For the evaluation of color stability under light exposure, the criterion employed was denoted as Y. Color stability was calculated using the following formula:

$$Y = (1 - \left(\frac{L_1 - L_2}{3 * L_1} + \frac{a_1 - a_2}{3 * a_1} + \frac{b_1 - b_2}{3 * b_1}\right) * 100\%, \quad (1)$$

where

L_1 and L_2 are the values of the light index before and after exposure to light;

a_1 and a_2—the values of the redness index before and after exposure to light;

b_1 and b_2—the values of the yellowness index before and after exposure to light.

In the assessment of color stability to light, the sample was positioned beneath an artificial light source, specifically an incandescent fluorescent lamp with a minimum power rating of 40 watts. Color attribute changes were measured instrumentally after 1 hour from the commencement of the experiment.

These investigations were conducted with a five-fold repetition for each sample. Data analysis was performed using Microsoft Excel version 16.76, in conjunction with the XLSTAT program [34].

2.5. Measurement of the Peroxide Number

This method relies on the reaction involving the initial products of fat oxidation, primarily peroxides and hydroperoxides, in the presence of potassium iodide under acidic conditions. Subsequently, titration is carried out using a sodium thiosulfate solution, enabling the quantitative determination of the liberated iodine.

2.6. Determination of the ultimate shear stress

The limiting shear stress of the samples was determined on the Geppler consistometer according to the formula, Pa:

$$\theta_0 = K\alpha^*(M/ h^2), \quad (2)$$

where θ_0 - is the limiting shear stress, Pa;
Kα - is the constant of the cone, depending on the angle α at its vertex;
M - is the mass of the load acting on the cone, kg;
h - is the immersion depth of the cone, m

2.7. Determination of carbonyl content

Carbonyls reacted with 2,4-dinitrophenylhydrazine, and the products were detected by measuring absorption at 370 nm. Protein concentrations were calculated by measuring absorption at 280 nm using bovine whey protein as the standard. The carbonyl content was calculated using an extinction coefficient equal to 22, 000 0 $M^{-1}cm^{-1}$.

2.7. Analysis of Methyl Esters of Fatty Acids

The analysis of methyl esters of fatty acids was conducted using an Agilent 7890 gas chromatograph, manufactured by Agilent Technologies (Santa Clara, CA, USA). The system was

equipped with a flame ionization detector and a capillary column (HP-Innowax, dimensions: 60 m × 0.32 mm × 0.5 μm), operated with a nitrogen flow. The temperature gradient ranged from 100 to 260 °C at a rate of 10 °C/min. A 1 μL injection was made, and gas flow was mixed at a ratio of 1:100. The detector temperature was maintained between 250 and 300 °C, respectively. The analysis utilized a standard mixture of methyl esters of fatty acids (Supelco No. 47885U) for comparison, and data on the content of C6 to C24 fatty acids were automatically calculated. Quantitative determination of fatty acid content was performed using the internal normalization method.

Statistical analysis of the results followed standard methodologies, in accordance with the specified metrological characteristics of the methods. In cases where such characteristics were lacking, principles outlined in paragraph 5.5 of RMG 76-2014 were applied, assuming a critical significance level (p) of 0.05 [35].

3. Results and Discussion

3.1. The results of the study of the chemical composition of sausage products

When assessing the chemical composition of experimental samples of boiled meat products (Table 1).

Table 1. Physico-chemical parameters of the studied samples of boiled sausage products with the addition of purslane.

Name of the Indicators to Be Determined	Unit of Measurement	Test Results	
		Sample 1	Sample 2
Mass fraction of moisture	%	72.7±7.3	70.6±7.1
Mass fraction of fat	%	8.1±1.2	6.7±1.0
Mass fraction of protein	%	13.41±2.01	15.31±2.30
Carbohydrates	%	3.0	4.4

Attention is drawn to the higher protein content and lower fat content. Typically, with the generally accepted technology for producing this type of product, fat content can reach up to 18%, while protein content ranges between 12-14%. The lower fat content in the samples was particularly notable, as certain meat types generally contain more fat than chicken breast.

The investigation into the dynamics of changes in protein fraction composition, based on comparative studies of sarcoplasmic protein ratios, involved the extraction of sarcoplasmic

proteins from muscle tissue using a low ionic strength buffer solution. Subsequently, fractions of water-soluble, salt-soluble, and alkali-soluble proteins were obtained, and their quantities were determined using the Kjeldahl method. The results, presented in Table 1, show that in sample 2, the highest quantity of protein fractions was found in the alkali-soluble fraction, while the salt-soluble fraction had the lowest amount.

Cutoff voltage and limiting shear stress are indicators used to characterize certain properties of the tested materials. Cutoff voltage measures the maximum pressure or force at which the material undergoes a specific change or reaches a certain limit. For sample 1, the cutoff voltage is approximately 31.4 kPa, while for sample 2, it is approximately 37.6 kPa.

Limiting shear stress refers to the maximum amount of shear stress a material can withstand before deformation or failure. For sample 1, the limiting shear stress is around 463 Pa, while for sample 2, it is about 760 Pa. These indicators are essential for assessing the mechanical properties of materials and play a crucial role in food technology, as they help determine how materials respond to loads and pressures during production and quality control.

The data obtained demonstrate excellent strength characteristics in the sausage products. The results highlight the consistency of the sausages, confirming the juiciness and quality of both samples.

3.2. Results of the Study of Fatty Acid Composition, Oxidation of Lipids and Proteins

Table 2 shows the main content of the fatty acid composition of the studied samples.

Table 2. Fatty acid composition of sausages.

Name of the Indicator	Unit of Measurement	Sample 1	Sample 2
Myristic C14:0	%	0.5±0.4	1.8±0.4
Myristolein C14:1	%	less than 0.1	0.1±0.4
Pentadecane C15:0	%	0.1±0.4	0.1±0.4
Palmitic C16:0	%	16.6±2.1	20.4±2.1
Palmitoleic C16:1	%	2.6±0.4	2.9±0.4
Margarine With 17:0	%	0.3±0.4	0.5±0.4
Heptadecene C17:1	%	0.2±0.4	0.1±0.4
Stearic C18:0	%	5.8±2.1	7.2±2.1

Oleic C18:1	%	29.7±2.1	30.1±2.1
Linoleic C18:2ω6	%	41.6±2.1	34.3±2.1
Linolenic C18:3ω3	%	1.7±0.4	1.6±0.4
Arachin C20:0	%	0.1±0.4	0.2±0.4
Eicosadienoic acid C20:2ω6	%	0.3±0.4	0.3±0.4
Tricosan C23:0	%	0.4±0.4	0.3±0.4

After conducting the research, it was found that significant concentrations of only 14 out of 36 fatty acids were identified. To improve sensory evaluation, meat needs to achieve a minimum amount of intramuscular fat (IMF) and ensure a large deposition of oleic acid and conjugated linoleic acid (CLA). As a result of the studies, the content of linoleic acid in samples of boiled sausage products with the addition of poultry meat was determined to be 30% higher than in the alternative product. However, the content of oleic acid was found to be within the margin of error in equal proportions between the two samples.

Therefore, it is not entirely reliable to assume the sensory lability of the consumer based on these findings alone. Additionally, it is worth noting that the W3 (omega-3) fatty acid content in both products remains at the same level.

Phospholipids, which are plastic components of cell membranes, contain a larger proportion of polyunsaturated fatty acids (PUFA) than triacylglycerols in ruminants. Thus, the dilution of phospholipids with triacylglycerols explains why lean meat contains more PUFA. Our results confirm that the fat composition in the muscle tissue corresponds to the general patterns described for other red meats.

Portulaca (Portulaca oleracea L.) is a plant known to contain vitamin C and antioxidants. Adding purslane to meat products can help protect fats from oxidation. Vitamin C and antioxidants slow down the oxidation process, which can extend the product's shelf life. However, it should be noted that adding purslane may alter the taste and aroma of the product, which is why it was used in moderation, at no more than 1% in the products under study.

The objective of this research was to evaluate how purslane extract could protect lipids and proteins from oxidation during a 7-day period of refrigerated storage (Table 3).

Table 3. Dynamics of fat oxidation and protein oxidation (background) in boiled products during storage.

Name of the Indicators to Be Determined	Unit of Measurement	Sample 1	Sample 2
Peroxide number (1 day)	meq/kg	1.8±0.2	1.6±0.2
Peroxide number (2 days)	meq/kg	2.2±0.2	2.1±0.2
Peroxide number (3 days)	meq/kg	2.6±0.3	2.5±0.3
Peroxide number (4 days)	meq/kg	2.8±0.3	2.9±0.3
Peroxide number (5 days)	meq/kg	3.5±0.3	3.6±0.4
Peroxide number (6 days)	meq/kg	4.0±0.4	4.2±0.4
Peroxide number (7 days)	meq/kg	4.6±0.5	5.4±0.5
Carbonyl compounds	nmol/mg of protein	96.5	94.8

Peroxides accumulate in meat during storage, especially under conditions of high temperature and humidity. They form as a result of the oxidation of fats and proteins, leading to changes in taste, smell, color, and an overall decline in meat quality. To prevent the accumulation of peroxides, meat needs to be stabilized using both natural and synthetic stabilizers and antioxidants. Antioxidants that slow down the oxidation process, such as purslane, can be effective due to the plant's ability to neutralize free radicals and oxidation products in both fats and proteins.

Based on the findings, it can be deduced that the peroxide value gradually accumulates over time, with an initial buildup followed by a reduction during the storage period. Once the threshold of 10.0 meq/kg is surpassed, the meat can no longer reestablish its biochemical equilibrium, making it unsuitable for further use in food production.

Purslane (Portulaca oleracea L.) is a plant with several beneficial properties, including antioxidant capabilities. Its antioxidant properties may be related to its ability to protect cells from free radical

damage, which is one of the main causes of aging and numerous diseases. Free radicals can cause cell damage that leads to various conditions such as cancer, cardiovascular diseases, and diabetes. Purslane contains antioxidants like flavonoids, carotenoids, and vitamin C, which help protect cells from free radicals.

Studies have shown that introducing even 1% purslane into a product formulation provides a protective mechanism against fat spoilage during storage. The plant's antioxidant properties effectively contribute to maintaining the quality and extending the shelf life of meat products.

3.3. Results of Color Stability

In the investigation of color stability, both before and after exposure to light, various key color attributes of the cooked sausages were assessed. These attributes include L (lightness), a (redness), and b (yellowness). The corresponding data is detailed in table 4 for reference.

Table 4. Color characteristics of sausages.

Samples	Color Characteristics Before Exposure to Light			Color Characteristics after Exposure to Light			Color Stability, %
	L-lightness	a-redness	b-yellowness	L-lightness	a-redness	b-yellowness	
Sample 1	70,27±0,35	20,01±0,38	10,86±0,32	69,14±0,34	20,07±0,33	12,53±0,35	93,89±1,67
Sample 2	62,89±0,32	17,27±0,40	12,08±0,26	59,57±0,74	17,57±0,44	14,25±0,11	91,69±1,06

Boiled sausages exhibit specific color characteristics that are influenced by the ingredients used and the production technology. The color of boiled sausages can range from pink to red, depending on the type of meat and spices used during preparation. The stability of the color in cooked sausages is affected by various factors, including ingredient quality, production methods, and storage and transportation conditions.

When sausage products are stored under optimal conditions, such as low temperature and controlled humidity, they can maintain their color for extended periods. However, exposure to high temperatures or direct light can cause the sausages to lose color and become faded. This discoloration may occur, for example, during grilling or when stored in direct sunlight. The color stability of cooked sausages is a crucial factor that impacts product quality and consumer appeal.

Therefore, manufacturers must carefully monitor storage and transportation conditions to ensure that the color and overall quality of the products are preserved.

During the assessment of meat product color stability under different temperature conditions, specifically heating to a range of 70-72 °C, an evaluation of the effects of chemical additives (as per standard recipes) and color stability during storage was conducted. The results revealed that the changes in lightness and redness were relatively minor, with decreases of approximately 1.5% and 5%, respectively, in samples containing poultry and other meats with added purslane. Notably, there was almost no change in redness for both sets of samples. However, yellowness increased significantly (by 15% and 18%) after light exposure, compared to initial values, indicating a reasonably stable color formation in the product.

The oxidation of meat pigments is primarily caused by the reaction between oxygen and meat proteins, which occurs during preparation, storage, and transportation. Pigment oxidation can lead to changes in meat color and a decrease in quality. To combat this, purslane was added as an antioxidant to slow down the oxidation process. The stabilization of meat pigments is a critical part of processing, as it helps retain the meat's color after cooking and prevents discoloration during storage. Thus, adding purslane as a natural antioxidant can effectively enhance the color stability of meat products, maintaining their visual appeal and quality throughout their shelf life.

4. Conclusion

In conclusion, the physicochemical parameters of the experimental sausage samples were analyzed, and the effectiveness of using a combination of different meats with the addition of purslane powder was demonstrated. The use of certain types of meat as the main ingredient in sausages showed high nutritional value and excellent moisture-binding capacity, positively influencing the quality of the final product. The addition of 1,2% purslane powder by weight of minced meat had an antioxidant effect, extending the shelf life of the sausages and allowing for a reduction in the amount of sodium nitrite used. The results support recommending these sausages for consumption by all population groups, including school-age children.

5. Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, au-thorship or otherwise, that could affect the research and its results presented in this paper.

6. Financing

This research is funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan (AP14871765).

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