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DISSERTATION

DEVELOPMENT OF THE PRODUCTION TECHNOLOGY OF COOKED SAUSAGES WITH THE USE OF PLANT RAW MATERIALS

Specialty 181– Food Technology
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Submitted for a scientific degree of Doctor of Philosophy

The dissertation contains the results of own research. The use of ideas, results, and texts of other authors have references to the relevant source

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ANNOTATION

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The dissertation substantiates the methodology and scientific basis of the production of various meat cooked sausages enriched with vegetable raw materials.

Boiled sausages have a rich taste, high protein content and are convenient for daily use. The main raw materials for sausage are pork and beef. They contain a significant amount of refractory fats, cholesterol and saturated fatty acids (mainly stearic). Excessive consumption of traditional raw materials and products from them can negatively affect the health of consumers. Available data indicate that a plant-based diet reduces the risk factors of atherosclerotic cardiovascular diseases and prevents the development of coronary heart disease. Therefore, the use of vegetable ingredients enriched with fiber, protein, natural pigments and easily digestible fats is relevant, as it will allow to rationally reduce the amount of animal fats and improve the quality of sausage products. The use of plant ingredients in the required amount improves the physico-chemical, structural-mechanical, biological, microbiological, technological and organoleptic properties of products.

According to WHO recommendations, to meet physiological needs for nutrients, the human body needs to consume more than 20,000 compounds of plant, animal and microbiological origin. Such products include meat products that make up the diet of a modern person. Therefore, the use of natural plant additives in combination with various meat raw materials can be considered a promising direction of research.

The purpose of the research is the scientific substantiation and development of the technology for the production of cooked sausages from various types of meat enriched with vegetable raw materials.

The object of the research is the production technology of cooked sausages with a reduced content of animal fats, using functional natural plant raw materials. The subjects

of the study were pork (lean pork, pork fat), poultry (ducks and chickens), taro paste, wheat bran, beetroot powder, ginger and onion juice, rice wine, fermented rice, starch, phosphates, sodium isoscorbinate and model samples of cooked sausages are enriched with vegetable ingredients.

The research methodology is based on scientific evidence and experimental studies aimed at the analysis and study of the chemical composition of meat and vegetable raw materials. The formed and substantiated scientific hypothesis, in the theoretical part of the study, was confirmed in the process of experimental research.

The following research methods were used in the work: physico-chemical (moisture, protein, fat, minerals, product yield, pH), structural-mechanical (shear stress, hardness, elasticity, chewing ability, elasticity, shear force), color (redness a*, brightness L*, saturation b*), biochemical (determination of acid number, malondialdehyde, DPPH), sensory (color, consistency, taste, aroma, appearance, comprehensive evaluation), mass spectrometric (determination of aroma) microstructure and microbiological. Based on the results of the research and the obtained data, the innovative technology for the production of cooked sausage products with vegetable raw materials (taro paste, wheat bran, beetroot powder, fermented rice, ginger and onion juice, oil-gelatin emulsion) is substantiated.

The work was carried out in several stages. The first chapter is devoted to the analysis and generalization of the scientific and technical literature on the characteristics, functions and use of poultry meat as a raw material for sausage products. Natural plant raw materials are characterized as sources of: protein, dietary fibers, dyes, antioxidants, as well as functional ingredients (phosphates, gelatin) and the influence of other additives on the quality and safety of sausage products. Traditional and modern technologies for the production of boiled sausages are analyzed.

The second chapter "Organization, methodology and methods of research" provides the object, a list of research materials and methods, and a structural diagram that reflects the sequence of conducting the main stages of research. The experimental part of the work was carried out in the laboratory conditions of the School of Food Sciences of the Henan Institute of Science and Technology (China). The technology was tested in production conditions and implemented at the FOP "Klymenko L.O." and FOP "Filon A.M." (city of Sumy), Guangxi Zhifu Agricultural Development Co., Ltd and Guilin PLANT Biotechnology Co., Ltd (Guangxi Province, China).

In the third chapter, technological regimes are determined and the production process of taro paste from root crops "Areca taro" is analyzed according to food composition, organoleptic evaluation, physico-mechanical indicators, infrared imaging, aroma, and a study of the influence of different amounts of taro paste on the quality characteristics of cooked pork sausages is carried out. It was determined that the optimal amount of taro paste is 8%. The indicated amount ensures minimal weight and moisture loss of sausages during cooking, increases the protein content by 1.34 times, and reduces the amount of animal fat by 1.6 times, compared to the analogue. There were proposals for the development of technology for boiled sausages yes, replace part of the pork meat with duck meat in the amount: 40%. The set amount of duck meat gives the sausage product better elasticity and reduces the cutting effort by 1.26 times and contributes to color saturation.

Wheat bran in the amount of 1.2 кg was used to enrich cooked sausages with dietary fiber and protein, which ensured the structural stability of the protein framework due to its gel-forming properties in combination with the framework of protein tissues.

The temperature and time parameters of the heat treatment of cooked sausages with vegetable raw materials are substantiated and determined: cooking temperature - 75-85˚C, duration - 60-80 minutes.

In the fourth chapter, on the basis of the obtained instrumental results, the optimal formula of prescription indicators (taro paste - 16 kg, wheat bran - 1.5 kg, phosphate complex - 0.3 kg) was derived using the method of orthogonal modeling. The effect of the dosage efficiency of dyes (fermented rice - 0.3%, red beet powder - 0.2%), antioxidants (ginger-onion juice - 5%, sodium isoscorbinate - 0.2%) and animal fat substitutes (oil-gelatin emulsion - 3%) on the course of physico-chemical, biochemical, microbiological, structural-mechanical, organoleptic indicators of boiled sausages from different types of poultry meat. Technological additives gave a characteristic red color, an elastic and tender consistency, contributed to the inhibition of oxidation processes and provided the highest organoleptic evaluation.

The fifth chapter is devoted to the development of innovative technologies for cooked sausages from various types of meat enriched with vegetable raw materials:

- Recipe 1 (boiled sausage with pork meat and taro paste): pork meat - 80%, taro paste - 8%, wheat bran – 1.2% and natural dyes – 0.2%.

- Recipe 2 (boiled sausage with pork and duck meat): pork meat – 50 %, duck meat - 40%, taro paste - 8%, wheat bran – 1.2%, natural dyes - 0.2%.

- Recipe 3 (boiled sausage with boned poultry meat (ducks and chicken), taro paste, antioxidants, gelatin-oil emulsion, natural dyes): duck meat - 56%, chicken meat - 40%, taro paste - 16%, wheat bran - 1.5%, emulsion (gelatin-oil) - 3%, antioxidants - 5.2% and natural dyes -0,5%.

In the sixth chapter, an assessment of the socio-economic effect of the development and implementation at food enterprises of the technology for making cooked sausages from various types of meat with the addition of taro paste was carried out. It is shown that the determined technological principles of new products made it possible to ensure complex processing of Areca taro root crops, which contributed to the reduction of the production cost and increased the efficiency of the technological process.

Keywords: chemical composition of meat, acid number, pork, storage, food fibers, pH, sausage products, mathematical modeling, functional and technological properties, amino acid composition, taro, proteins, non-traditional raw materials, duck and chicken meat, antioxidant effect, oil-gelatin emulsion, quality.

АНОТАЦІЯ

Шань Фейфей. Розробка технології виготовлення варених ковбас з використанням рослинної сировини. Кваліфікаційна наукова праця на правах рукопису.

Дисертація на здобуття наукового ступеня доктора філософії зі спеціальності 181 − «Харчові технології». Сумський національний аграрний університет. Суми, 2023.

У дисертації обґрунтовано методологію та наукові основи виробництва різноманітних м'ясних варених ковбас, збагачених рослинною сировиною.

Варені ковбаси мають насичений смак, високий вміст білка і зручні для щоденного вживання. Основною сировиною для ковбаси є свинина і яловичина. Вони містять значну кількість тугоплавких жирів, холестерину і насичених жирних кислот (переважно стеаринової). Надмірне споживання традиційної сировини та продуктів із неї може негативно вплинути на здоров'я споживачів. Наявні дані свідчать про те, що рослинна дієта знижує фактори ризику атеросклеротичних серцево-судинних захворювань, стримує розвиток ішемічної хвороби серця. Тому використання рослинних інгредієнтів, збагачених клітковиною, білком, природними пігментами та легкозасвоюваними жирами, є актуальним, оскільки це дозволить раціонально зменшити кількість тваринних жирів і підвищити якість ковбасних виробів. Використання рослинних інгредієнтів у необхідній кількості покращує фізико-хімічні, структурно-механічні, біологічні, мікробіологічні, технологічні та органолептичні властивості продукції.

Відповідно до рекомендацій ВООЗ, для задоволення фізіологічних потреб у поживних речовинах, організму людини необхідно споживати більш ніж 20 тисяч сполук рослинного, тваринного та мікробіологічного походження. Саме до таких продуктів можна віднести м'ясні вироби, які складають раціон сучасної людини. Тому використання натуральних рослинних добавок у поєднанні з різною м'ясною сировиною можна вважати перспективним напрямком досліджень.

Метою дослідження є наукове обґрунтування та розробка технології виробництва варених ковбас із різних видів м’яса, збагачених рослинною сировиною.

Об’єктом дослідження є технологія виготовлення варених ковбас із зниженим вмістом тваринних жирів, із використанням функціональної натуральної рослинної сировини. Предметом дослідження були свинина (нежирна свинина, свинячий жир), м'ясо птиці (качок і курей), паста таро, пшеничні висівки, буряковий порошок, сік імбиру та цибулі, рисове вино, ферментований рис, крохмаль, фосфати, ізоаскорбінат натрію та модельні зразки варених ковбас збагачені рослинними інгредієнтами.

Методологія дослідження базується на науково-доказових та експериментальних дослідженнях спрямованих на аналізі та вивченні хімічного складу м’ясної та рослинної сировини. Сформована та обґрунтована наукова гіпотеза, в теоретичній частині дослідження, підтверджена в процесі експериментальних досліджень.

У роботі були використані наступні методи дослідження: фізико-хімічні (вологість, білок, жир, мінеральні речовини, вихід продукту, pH), структурно-механічні (напруга зсуву, твердість, пружність, жувальна здатність, еластичність, зусилля зрізу), кольорові (червоність a*, яскравість L*, насиченість b*), біохімічні (визначення кислотного числа, малонового діальдегіду, DPPH), сенсорні (колір, консистенція, смак, аромат, зовнішній вигляд, комплексна оцінка), мас-спектрометричні (визначення аромату) мікроструктурі і мікробіологічні. За результатами досліджень та отриманих даних обґрунтована інноваційна технологія виробництва варених ковбасних виробів із рослинною сировиною (паста таро, пшеничні висівки, порошок буряка, ферментований рис, імбирний та цибулевий сік, емульсія оліє-желатинова).

Робота проводились у кілька етапів. Перший розділ присвячено аналізу та узагальненню науково-технічної літератури щодо характеристик, функцій та використання м’яса птиці, як сировини для ковбасних виробів. Охарактеризовано натуральну рослинну сировину, як джерел: білка, харчових волокон, барвників, антиоксидантів, а також функціональних інгредієнтів (фосфатів, желатину) та вплив інших добавок на якість та безпечність ковбасних виробів. Проаналізовано традиційні та сучасні технології виробництва варених ковбас.

У другому розділі «Організація, методологія та методи досліджень» наведено об'єкт, перелік матеріалів і методи досліджень та структурну схему, яка відображає послідовність проведення основних етапів досліджень. Експериментальна частина роботи проведена в лабораторних умовах Школи харчових наук Хєнанського Інституту Науки та Технології (Китай). Технологію апробовано у виробничих умовах та впроваджено на ФОП «Клименко Л.О.» та ФОП «Філон А.М.» (м. Суми), Guangxi Zhifu Agricultural Development Co., Ltd та Guilin PLANT Biotechnology Co., Ltd (Guangxi Province, China).

У третьому розділі визначено технологічні режими та проаналізовано процес виробництва пасти таро з коренеплодів «Арека таро» за харчовим складом, органолептичною оцінкою, фізико-механічними показниками, інфрачервоним зображенням, ароматом та проведено дослідження впливу різної кількості пасти таро на якісні характеристики варених ковбас зі свинини. Визначено, що оптимальною кількість пасти таро є 8 %. Зазначена кількість забезпечує мінімальну втрату ваги та вологи ковбас під час варіння, збільшує вмісту білка у 1,34 рази, зменшує кількість тваринних жирів у 1,6 рази, порівняно з аналогом. Для розробки технології варених ковбас було запропоновано, замінити частину м'яса свинини - м'ясом качки у кількості: 40 %. Встановлена кількість м'яса качки, надає ковбасному виробу кращої еластичності та знижує зусилля зрізу у 1,26 рази і сприяє насиченню кольору.

Для збагачення варених ковбас харчовими волокнами та білком використовували пшеничні висівки у кількості 1,2 кг, які забезпечили структурну стабільність білкового каркасу, за рахунок гелеутворюючої властивості, у поєднанні з каркасом білкових тканин.

Обґрунтовано та визначено температурно-часові параметри термічної обробки варених ковбас із рослинною сировиною: температура варіння - 75-85˚С, тривалість - 60-80 хвилин.

У четвертому розділі, на основі отриманих інструментальних результатів, методом ортогонального моделювання, виведено оптимальну формулу рецептурних показників (пасти таро – 16 кг, висівок пшеничних – 1,5 кг, фосфатного комплексу – 0,3 кг). Вивчено вплив ефективності дозування барвників (ферментованого рису – 0,3 %, червоного буряка – 0,2 %), антиоксидантів (імбирево-цибулевого соку – 5 %, ізоаскорбінату натрію – 0,2%) та замінників тваринного жиру (оліє-желатинової емульсії – 3%) на перебіг фізико-хімічних, біохімічних, мікробіологічних, структурно-механічних, органолептичних показників варених ковбас із різних видів м’яса птиці. Технологічні добавки надали характерного червоного забарвлення, еластичної і ніжної консистенції, сприяли гальмуванню окислювальних процесів та забезпечили найвищу органолептичну оцінку.

П’ятий розділ присвячений розробці інноваційних технологій варених ковбас із різних видів м’яса, збагачених рослинною сировиною:

- Рецепт 1 (ковбаса варена з м'ясом свинини та пастою таро): м'ясо свинини - 80%, паста таро - 8%, висівки пшеничні – 1.2% і барвники натуральні – 0.2%.

- Рецепт 2 (ковбаса варена зі свининою та качкою): м'ясо свинини - 50 %, м'ясо качки - 40 %, паста таро - 8 %, висівки пшеничні – 1.2 %, барвники натуральні - 0.2 %.

- Рецепт 3 (ковбаса варена з м'ясом птиці (качки та курки): паста таро, антиоксиданти, желатино-олієва емульсія, барвники натуральні: м'ясо качки - 56%, м'ясо курки - 40%, паста таро - 16%, висівки пшеничні – 1.5%, емульсія (желатино-олієва) - 3%, антиоксиданти -5.2% і натуральні барвники -0,5%.

У шостому розділі проведено оцінку соціально-економічного ефекту від розробки та впровадження на харчових підприємствах технології виготовлення варених ковбас із різних видів м’яса з додаванням пасти таро. Показано, що визначені технологічні принципи виробництва нової продукції дозволили забезпечити комплексну переробку коренеплодів Арека таро, що сприяло зниженню собівартості продукції та підвищувало ефективність технологічного процесу.

Ключові слова: хімічний склад м'яса, кислотне число, свинина, зберігання, харчові волокна, pH, ковбасні вироби, математичне моделювання, функціонально-технологічні властивості, амінокислотний склад, таро, білки, нетрадиційна сировина, м’ясо качки та курки, антиоксидантний ефект, оліє-желатинова емульсія, якість.

LIST OF THE APPLICANT'S PUBLICATIONS

SCOPUS / Web of Science publications

1. **Shang, F.**, Kryzhska, T., Duan, Z. (2022). Study on the effect of baking process on the quality characteristics, moisture distribution and sensory evaluation of bran, duck and pork emulsification sausage. Eastern-European Journal of Enterprise Technologies, 1 (11 (115)), 41–48. https://doi.org/10.15587/1729-4061.2022.253210. (*The applicant participated in research, analysis of the results and writing the article*)

2. **Shang, F.,** Kryzhska, T., & Duan, Z. (2022). Effects of adding different contents of pig rind on physical and chemical properties and sensory qualities of wheat bran chicken sausage. *Eastern-European Journal of Enterprise Technologies*, *4*(11 (118), 6–14. https://doi.org/10.15587/1729-4061.2022.261102. (*The applicant participated in research, analysis of the results and writing the article*)

3. **Shang Feifei**, Tetyana A. Kryzhska, Liu Yan, Duan Zhenhua, Svetlana H. Danylenko, Tetyana M. Stepanova, Olena Yu. Koshel (2022). Effects of different natural food coloring additions on the quality of chicken sausage. *Journal of Chemistry and Technologies*/ 30(2), 265-274. https://doi.org/10.15421/jchemtech.v30i2.244538. (*The applicant participated in research, analysis of the results and writing the article*)

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writing the article)

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6. **Shang Feifei,** Tetiana Kryzhska, Svitlana Danylenko, Nina Usatenko, and Duan Zhenhua (2021). Effects of different duck meat and wheat bran contents on the quality characteristics of sausages. *Food Resources*. 9(17), 6–13. https://doi.org/10.31073/foodresources2021-17-01. (*The applicant participated in research, analysis of the results and writing the article*)

7. **Shang, F.,** Kryzhska, T., & Duan, Z. (2021). Study on the optimization of spray drying process for Areca taro powder with microcystalline cellulose. *Technology Audit and Production Reserves*, *6*(3(62), 39–42. https://doi.org/10.15587/2706-5448.2021.242333. (*The applicant participated in research, analysis of the results and writing the article*)

8. **Shang, F.**, Kryzhska, T., & Duan, Z. (2022). Study on the effect of antioxidants on the quality and antioxidants capacity of duck sausages. *Technology Audit and Production Reserves*, *3*(3(65), 36–42. https://doi.org/10.15587/2706-5448.2022.260198. (*The applicant participated in research, analysis of the results and writing the article*)

9. **Shang, F.**, Bal-Prylypko, L., Kryzhska, T., Danylenko, S., Zhenhua, D., & Korol, T. (2022). Influence of different concentrations of taro paste on the sensory characteristics of poultry meat sausages. *Animal Science and Food Technology*, 13(3), 7-13. https://doi.org/10.31548/animal.13(3).2022.7-13 (*The applicant participated in research, analysis of the results and writing the article*).

Conference papers

10. Kryzhska T., **Feifei Shang**, Zhenhua Duan. Study on the effect of different bran

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LIST OF CONDITIONAL MARKS

PER – powder extraction rate

TP-Taro paste

TPA- Texture Profile Analysis

RDS, rapidly digestible starch

SDS- slowly digestible starch

RS- Resistant starch

XRD- X-ray diffraction

MRI- Magnetic resonance imaging

GC-MS –Gas Chromatography-mass spectrometry

LF-NMR- Low-field nuclear magnetic resonance

SE- Sensory evaluation

Av – acid value

TBARS-Thiobarbituric acid reactive substances

DPPH-1, 1-diphenyl-2-trinitrophenylhydrazine

PV -peakviscosity

TV- troughviscosity

FV -finalviscosity

BV-Breakdown viscosity

SV-Setback viscosity

INTRODUCTION

Actuality of theme. Currently, there are more and more consumers in the world who prefer high-quality and safe products, balanced in composition and calorie content. Duck and chicken meat contains essential nutrients. Rich in essential amino acids and polyunsaturated fatty acids, it promotes better digestion and assimilation by the human body. The specificity of combining meat raw materials from poultry and traditional meat raw materials (beef and pork) does not allow transferring existing technologies for the production of cooked sausages to the production of products with combined raw materials from meat of different types of poultry. A small amount of scientific information in Ukraine and China regarding the use of this raw material and, in fact, technologies for combining meat raw materials from different types of poultry encourages the development of new technologies and the creation of high-quality products.

Sausage products are in great demand and appreciated by consumers. Boiled sausages have a rich taste, high protein content and are convenient for daily use. The main raw materials for sausage are pork and beef. They contain a significant amount of high-melting fats, cholesterol and saturated fatty acids (predominantly stearic acid). Excessive consumption of traditional raw materials and products from them increases the risk of some epidemic and chronic diseases. Therefore, the addition of natural vegetable raw materials, namely, biologically valuable combined vegetable oil to replace animal fats is relevant.

The addition of various vegetable raw materials to the recipes of sausage products has become the focus of attention of food researchers all over the world. The use of plant ingredients, in the required amount, improves the physico-chemical, structural-mechanical, biological, microbiological, technological and organoleptic properties of the products. For example, mushrooms, celery, corn, oats, rice flour, raw fiber, soy isolate, and other vegetable raw materials enriched with vegetable protein and dietary fiber are added to sausage products. These additives improve the quality of meat products. Contribute to the increase of nutritional and dietary properties in products. Taking into account the main trends in the development of the food industry, the use of natural plant additives in combination with various meat raw materials can be considered a promising direction of research.

Therefore, the use of vegetable ingredients enriched with fiber, protein, natural pigments and easily digestible fats is relevant, as it will allow to rationally reduce the amount of animal fats and improve the quality of sausage products.

The technology for the production of boiled sausages involves the regulation of temperature, moisture, biochemical, microbiological processes throughout the entire production and storage cycle. Various methods and protective components (antioxidants, preservatives, dyes) are used to give cooked sausages the necessary technological qualities and to prevent spoilage, which are a guarantor of the quality of the final product. In this regard, it is necessary to search for effective and reliable factors and modes of processing meat raw materials that will ensure guaranteed product quality and safety.

Currently, the creation of such a technology using different types of poultry meat and composition of recipes with enriched (necessary components) vegetable raw materials is relevant. The development of the technology will allow to expand the range of food products and provide the consumer market with high-quality products with combined raw materials.

Connection of work with scientific programs, plans, topics. The dissertation work was developed according to the research plans of the Sumy National Agrarian University, according to research topics of the Department of Food Technology and Safety 0119U101237 "Innovative technological solutions in the production of food products" and 0121U111511 "Management of industrial waste of food production". Scientific research of the dissertation work was carried out on the basis of the School of Food Sciences of the Hezhou University of Science and Technology (China).

The purpose and objectives of the research. The aim of the dissertation is the scientific substantiation and development of the technology for the production of cooked sausages from various types of meat enriched with vegetable raw materials.

In accordance with the set goal, the following tasks were solved:

- choose a research topic, conduct a literature review based on it and analyze literature sources;

- to study and analyze the food composition and technology of plant raw materials processing. Develop regulatory and technical documentation for the production of products from the Areca taro root crop;

- to investigate the technological characteristics of boiled pork sausages with taro paste;

- choose a rational amount of duck meat for cooked sausages with vegetable raw materials according to physico-chemical, structural-mechanical and organoleptic indicators;

- to investigate the temperature-time parameters of the production of cooked sausages with vegetable raw materials according to quality characteristics;

- to develop a recipe for cooked sausages from different types of poultry meat according to physico-chemical, biochemical, structural-mechanical, microstructural and organoleptic parameters;

- choose rational amounts of dyes, antioxidants and animal fat substitutes based on sensory characteristics and oxidation indices (acid number, TBARS, DPPH);

- to develop the technology of cooked sausages from various types of meat enriched with vegetable raw materials and to carry out its approbation in industrial conditions;

- determine the socio-economic effect of the introduction of the technology for the production of cooked sausages enriched with vegetable raw materials.

Object of research. Production technology of boiled sausages with a reduced content of animal fats, using functional natural vegetable raw materials.

Subject of research: pork (lean pork, pork fat), poultry (duck and chicken), taro paste, wheat bran, red beet powder, ginger and onion juice, rice wine, fermented rice, starch, phosphates, sodium isoscorbinate and model samples of cooked sausages are enriched with vegetable ingredients.

Research methods: physical and chemical (moisture, protein, fat, minerals, product yield, pH), structural and mechanical (shear stress, hardness, elasticity, chewing ability, elasticity, shear force), color (redness a*, brightness L *, saturation b*), biochemical (determination of acid number, malondialdehyde, DPPH), sensory (color, consistency, taste, aroma, appearance, comprehensive assessment), mass spectrometric (determination of aroma), microstructure and microbiological.

Scientific novelty of the obtained results. For the first time, a natural vegetable raw material - taro paste, obtained from the "Areca taro" root crop, was scientifically substantiated and introduced into the recipes of cooked sausages from pork and from various types of poultry.

For the first time, it has been determined that the combined vegetable oil mixes with the granules of hot molten gelatin, forms a white emulsion and hides the unpleasant odor of the gelatin. It has been proven that the use of oil-gelatin emulsion increases the quality of sausage and reduces the amount of animal fat.

The application of the main provisions of the developed technology of boiled sausage products with a reduced amount of animal fat due to the addition of vegetable raw materials was further developed.

Practical significance of the obtained results. Based on the results of the work, new recipes and technology for the production of cooked sausages from various types of meat enriched with vegetable raw materials with a reduced content of animal fats were developed. Regulatory and technical documentation was approved - TU U 10.3-04718013-008:2022 "Concentrated and dried taro products. Technical conditions" (Ukraine) and two standards for "Poultry sausage with taro paste" Q/PLD-004S-1 and Q/ZFA-0001S-2022 (China) were approved.

The technology was tested in production conditions and implemented at the FOP "Klymenko L.O." and FOP "Filon A.M." (city of Sumy), Guangxi Zhifu Agricultural Development Co., Ltd and Guilin PLANT Biotechnology Co., Ltd (Guangxi Province, China). In the Guangxi province of China, 1.8 tons of boiled sausages with poultry meat and vegetable ingredients were produced and sold, in Ukraine - 180 kg.

Personal contribution of the acquirer. The work is an independent study of the acquirer, which analyzed the scientific literature, performed the main volume of experimental research, processed and summarized the obtained results. Regulatory documentation was developed with the direct participation of the dissertation student.

Planning of work directions, analysis of results, formulation of the main provisions and conclusions of the dissertation, preparation of normative documentation and scientific articles for publication were carried out together with the scientific supervisor, Ph.D. Kryzhska T.A.

The acquirer took an active part in the approval and discussion of research results. The acquirer's personal contribution is confirmed by production tests and scientific publications.

Separate fragments of the work, performed jointly with Ph.D., associate professor of the Department of Food Technologies and Safety A.O. Helikh (introduction of technologies into industrial production, development of regulatory documentation, socio-economic calculation). Planning of individual areas of work and discussion of the results was carried out with Doctor of Technical Sciences, S.G. Danylenko. Approbation and implementation of the technology was carried out at the FOP "L.O. Klimenko", FOP "Filon A.M." (Sumi), with the support of directors L.O. Klymenko and A.M. Philo. The author expresses sincere thanks to all co-performers.

Approbation of the results of the dissertation. The main provisions of the dissertation work were reported and discussed at: Eurasian scientific congress (Spain, 2020); The 4th Session of International Symposium on Processing & Preserving of Fresh Food (China, 2020); VIII International Internet - conference "Science and innovation" (Liverpool, Great Britain 2020); International Scientific and Practical Internet Conference (Melitopol, 2020); II International Scientific and Practical Internet Conference (Dnipro, 2021); XV International Scientific and Practical Conference (Germany, Berlin, 2021); X International Scientific and Practical Internet Conference (Poltava, 2023).

Publications. Based on the materials of the dissertation work, 17 printed works were published, including: 4 articles - in scientific publications by specialty, included on the date of publication in the list of scientific specialized publications of Ukraine; 4 articles - in periodical scientific publications indexed in the Scopus database; 1 article - in a periodical scientific publication of the countries of the European Union; 8 abstracts of reports - at scientific, scientific-practical and international conferences.

The structure and scope of the dissertation. The dissertation is presented on 220 pages of computer text, illustrated with 67 tables and 22 figures and consists of an abstract, introduction, review of literature, materials and methods, results of own research, generalization, analysis and discussion of research results, conclusions, proposals, list of used literary sources , applications. The list of used literary sources includes 253 items, all from far abroad.

SECTION 1
TECHNOLOGICAL ASPECTS OF THE PRODUCTION OF COOKED SAUSAGES USING DIFFERENT TYPES OF MEAT AND VEGETABLE RAW MATERIALS

1.1 Analysis of traditional and modern technologies for manufacturing products with combined meat and vegetable raw materials

For the production of food products, in particular meat products, innovative solutions are increasingly being used. Creation of new types of meat products is one of the directions of formation of competitive advantages of products of the meat processing industry.

One of the promising directions in the meat industry is the creation of new products based on the use of a wide range of food additives, without which modern production is impossible. In the current conditions, the role of food additives is quite high, with their help it is possible to achieve deeper processing of agricultural raw materials, increase the nutritional value, improve the technological process, reduce production costs, and optimize the cost of products. Specialists in the food and processing industry hope to use food micro-ingredients to meet the population's needs for energy-rich, physiologically functional, balanced, optimally priced food products [1, 2].

At the same time, in the process of improving existing or creating fundamentally new recipes and technologies of meat products, the most common traditional approach is based on a priori or experimental selection of species, quantitative content and ratio of components in the composition of the meat product recipe. The method is subjective, it requires high qualifications, experience, and professional intuition. It is necessary to focus primarily on the indices of organoleptic properties, the degree of expression of the functional and technological properties of individual ingredients of the future recipe, their compatibility in the food system, hypothetically representing the mechanism of structuring, binding and influence on sensory characteristics. One of the main goals of creating a new product remains cost reduction, and such basic indicators as biological, energetic and physiological value, digestibility are not taken into account [3].

Under the existing ecological situation, especially in large cities, the introduction of products created on the basis of the principles of food combinatorics into the daily diet is a necessity. The scientific and technological process of creating new forms of food products is based on three principles [4]:

1) elimination - any component is excluded from the product composition;

2) enrichment - if there is not enough of a food substance, the product can be enriched with it;

3) replacement – instead of one removed component, another similar one with useful properties is introduced.

The term "combined food products" reflects the features of the recipe composition of food products (which in most cases are multi-component and can be a combination of different types of raw materials, ingredients, food additives, etc.), but the specificity of the method of combinatory selection of the method is used to optimize the recipe composition of quantitative proportions individual ingredients in the recipe with a search for structure, with the required level of adequacy.

Modern technologies for the production of meat products involve a combination of various food additives that improve organoleptic, structural-mechanical and physico-chemical indicators of finished products.

Meat products provide the human body with high-quality protein, minerals and vitamins and are a source of energy [5]. With the progress of society and the improvement of the economic level, the choice of consumers regarding meat products is no longer limited to the consumption of only meat [6]. Quality meat is an important component of sausage products. During the development of human society, various types of sausages were developed, such as: emulsified (boiled), semi-smoked, smoked, fermented, combined, etc. With the development of science, the automation of production has led to a high standardization of sausage products. This makes the production of sausage products safe and reliable, providing the necessary characteristics demanded by consumers [7].

A significant place in the total volume of meat products production is occupied by the cooked group of meat products (up to 70% of the total volume of meat products). They are in high demand among the population due to their nutritional value and have an attractive appearance, specific aroma and taste.

According to the general technical terms, cooked sausage is a sausage that can be fried or not followed by cooking [8].

The sausage production process includes the following basic operations [9]:

1. Preparation of raw materials;
2. grinding of meat;
3. preparation of minced meat;
4. formation of sausages;
5. tying sausages with twine (clipping sausages);
6. deposition;
7. frying;
8. cooking;
9. cooling
10. packaging, labeling, storage.

Boiled sausages have a high nutritional value, contain a lot of moisture (55-75%) and a sufficient amount of lard. According to their quality, they are divided into higher, 1st and 2nd grades. The production of cooked sausages is based on various chemical, physical, and thermal methods of influencing raw materials. The quality of the original product depends on the correctness of the manufacturing process and a properly balanced formulation. The quality of the product is affected by the correctness of the production process and balanced formulation. It is necessary to correctly observe the temperature regime, recipes and maintain the required sequence of operations. In the case of improper execution of the production regime and the use of low-quality raw materials, defects occur, such as, for example, mold, spots, lightening, rot of cooked sausages, which does not correspond to a high-quality product [10].

Microbiological spoilage of the product can occur in case of contamination of raw materials, failure or incorrectly set temperature and humidity regime or during violation of packaging conditions.

In accordance with DSTU 4529:2006 "Sausages cooked from poultry and rabbit meat" - sausage products are stored at the manufacturing company and in the retail network at temperatures from 0°C - 6°C and relative humidity from 75% to 78 %. The shelf life of cooked sausages from the moment of the end of the technological process is, for:

- high grade no more than 72 hours;
- first and second grades — no more than 48 hours;
- third grade — no more than 24 hours.

The technology for the production of products with an emulsion structure, such as cooked sausages, involves the process of emulsifying fats in a dispersion medium. At the same time, emulsion products should be aggregatively stable systems, not prone to delamination and coalescence in the technological flow. Today, there is an urgent problem of obtaining emulsion products with specified properties and composition, consistency and texture, nutritional and biological value, caloric content and fat content. The combined recipe composition of sausages will provide the finished products with the necessary properties [11].

In order to develop new nutritious and useful meat products, combined sausages were developed. The technology of their production is borrowed from traditional variations, distinguished by the addition of dietary fibers, cellulose, emulsifiers, minerals and other substances to improve the nutrition, consistency and taste of the product. Combined sausage belongs to the cooked group, according to GB/T20711-2006, and is defined as: contains meat of livestock and poultry as the main raw material, after selection, grinding, addition of auxiliary materials, product formation, cooking, smoking (or without smoking), cooling, packaging and storage. Combination sausages can be adapted to market needs to develop sausage products with different taste characteristics that have promising market prospects [12].

The traditional main meat raw materials for making sausages are pork and beef.

Auxiliary substances of recipes - salt, starch, wheat flour and spices. In recent years, scientists in the country and abroad have been actively engaged in the search and research of other types of raw materials to replace traditional raw materials and auxiliary materials for the production of new combined sausages. Ma et al. [13] developed a low-fat combination sausage using pleurotus eryngii pulp, soy protein, corn starch, carrageenan and other ingredients using chicken as the main raw material.

Shim et al. [14] found that pre-emulsification of duck skin can improve quality characteristics. When the ratio of pre-emulsion to duck skin is 1:1, the qualitative characteristics of duck ham are significantly improved. Vidyanarko and others [15] investigated the effect of a mixture of konjac powder - carrageenan gel and red yeast rice extract on firmness, water retention and color changes of restructured cooked sausage and obtained the best formula through optimization.

Han Rong and others. used Cordyceps militaris, pheasant and chicken meat as the main ingredients for the production of poultry sausages. Optimum storage conditions for sausages were obtained by optimizing the process. Combined sausages have a milder taste than traditional sausages. Lee et al. [16] developed rabbit sausage for children. Rabbit meat was used as the main raw material, quinoa and carrots were added. We optimized the processing technology using the orthogonal test and obtained a combined sausage with a sweet, mild taste enriched with vegetable ingredients.

Ignacio et al. [17] used rabbit meat (0%, 40% and 80%) to replace pork meat to develop combined cooked sausages. The results showed that the addition of 40% rabbit meat to the recipe of pork sausages does not affect changes in its sensory properties and improves the biological value, compared to the analogue.

Shang et al. [18], investigated the effect of adding different amounts of pig skin on the physicochemical properties and sensory qualities of chicken sausages made from wheat bran. It was found that the addition of pork skin, during the process of heating sausages, reduced losses during cooking and contributed to a decrease in the chewiness index of sausage products ($p<0.05$).

Cruxen and others [19] used lamb as the main raw material and starter. By optimizing the process, a combined fermented lamb sausage was developed.

The selection of raw materials and auxiliary materials has an important impact on the quality of the nutritional, technological and safe component of the sausage. Xu et al. [20], found that Tatar buckwheat increases the pH level of chicken emulsion sausage from 6.21 to 6.34, and improves its ability to retain moisture. The firmness of chicken emulsion sausages increases with the amount of buckwheat. Antioxidant activity of chicken emulsion sausage was increased by addition of 1,1-diphenyl-2-picrylhydrazyl and ferrous ion reducing antioxidant capacity (FRAP). Varga-Visi and others [21], used pea fiber and potato starch to partially replace the pork fat content in turkey sausage. It was found that the specific content of pea fiber and potato starch, to replace fat, can significantly improve the structural characteristics of sausage fat content.

Alves et al. [22] investigated the effect of addition of carrageenan and glutamine transaminase on the structure of restructured fish ham and found that the addition of glutamine transaminase contributes to the reduction of cooking losses and increase of firmness, cohesion and chewing ability. Whereas, the addition of carrageenan increases the viscosity, elasticity and tensile strength of the ham. The combination of components improves the consistency of restructured fish ham.

Excessive consumption of lipids (especially animal fats), with a high content of saturated fatty acids and cholesterol, increases the total level of lipoproteins in the body. The level of LDL increases the frequency of various diseases, such as type II diabetes, cardiovascular diseases, and cancer [23, 24]. Due to the need for structural properties and sensory properties, fats are necessary in the daily diet. Plant-based imitation meat products are constantly attracting market attention, due to their ability to satisfy the basic sensory and nutritional needs of consumers, reduce pressure on the environment, due to increased meat consumption, and satisfy consumer demand for health, animal welfare, economy and vegetarianism [25, 26]. Chen et al. used the replacement of animal-based food ingredients with plant-based food ingredients, resulting in a series of products such as margarine, plant-based mayonnaise, and plant-based protein meats. These developments have contributed to reducing the shortage of food ingredients of animal origin and led to the development of a number of related industries.

In recent years, vegetable ingredients have been used to replace animal ingredients in the food industry. Various forms of plant-based meat are gradually making their way out of the laboratory and onto people's dinner tables [27, 28]. Wu et al. [29] used inulin to partially replace fat in fermented sausages. The introduction of inulin reduced the bitterness and gave a loose and smooth structure, enhanced the taste. Fermented sausages with inulin have an increased density, which depends on the consistency. Elasticity is directly proportional to the amount of inulin added, and elasticity increases as the amount of inulin used increases. Inulin is added to fermented sausages to create a gel and improve moisture retention. Addition of inulin in small doses gives sausages better taste, exquisite aroma, attractive color and improves structural and mechanical properties. Thus, the evaluation of the product by consumers is high [30].

Today, the global production of soybeans is almost 336.59 million tons, and the leaders are always Brazil, the USA, and Argentina, which in 2019/2020 MR collected a record 271.67 million tons, which is 80.71% of world production. China (18.1 million tons), India (9.3 million tons) and Paraguay (9.9 million tons) are also among the leading producers.

Currently, the Ministry of Economic Development, Trade and Agriculture of Ukraine promotes the introduction of high-yielding soybean varieties into production. Soy is an extremely useful product, 1 kg of soy replaces 2 kg of meat or fish, 4 kg of wheat or 12 liters of milk in terms of protein. The list of world importers in 2019/2020 MR looks like this: China - 59.77% of world demand, and this share will grow, the European Union - 9.57%, Mexico, Argentina and Egypt - 3.68%, 2.85% and 2 .76% respectively [31].

Consumption of soy fiber and soy products has increased mainly due to increased interest in healthy eating, which has led to increased demand for plant-based foods and fiber-rich products in high-income countries.

Soy proteins are often an ideal solution to the problems of creating new technological properties of raw materials for making sausages due to their similar regulation of the functionality of food systems at a low cost. Soy proteins are characterized by four main functions: emulsification, fat absorption, hydration and texture compaction [32].

Non-protein products, such as starches and gums, are used to increase moisture binding capacity and regulate structure, although they create, to some extent, unnatural chewiness (gums can give meat systems an undesirable slippery texture, and starches - a loose consistency).

All soy concentrates improve the structure of the meat product, and their recommended type depends on the products for which it should be used. In minced meat, textured soy concentrates provide a dense, fibrous consistency compatible with meat and are easily controlled by simply adjusting hydration levels. Textured concentrates remain functionally stable even with numerous heat treatments. They can be used to improve the structure, reduce the fat content of meat products [31].

As a natural preservative for fruits and vegetables, as early as 1995, Gao [33] wrote a review article on the progress of research on natural preservatives for fruits and vegetables, in which he summarized the use of the genus Ninebark of the Aloes family, the Camphoraceae family, the Caryophyllaceae family, the Asteraceae family, and other plant families in canning. Kalgan, konjac, Momordica charantia, maitake, and other herbal decoctions or infusion extracts are used to preserve citrus fruits, apples, grass molds, edible mushrooms, and other fruits and vegetables. Garlic can be used to preserve citrus fruits. Acetic acid and phytic acid, used as raw materials for the preparation of preservatives, extend the shelf life. Also, marigolds, arthropod shell extract, rock salt extract and other fruits and vegetables have the best storage properties.

Mukumbo et al. [34], investigated the inhibition by moringa leaf powder of lipid oxidation of non-fermented pork sausage without nitrites and experimentally optimized the amount of the additive. It was found that the content of thiobarbituric acid in pork sausages was significantly reduced after the addition of monoculture leaf powder, the rate of lipid oxidation and the degree of non-fermented pork sausages were inhibited, and the antioxidant activity of sausages was enhanced.

Bishnoi et al. [35] found that mandarin peel and pepper leaf extracts improved the microbiological parameters of frozen chicken sausage and did not affect the color of the sausage during storage. The sausage had a high overall sensory score. The plant additives used can be used as an alternative to synthetic antioxidants in meat products. Choe et al. [36] investigated the effects of green tea leaves, lotus leaves, and kimchi powder on the quality characteristics of chicken liver sausage. The experimental results showed that compared to the control samples, green tea leaves, lotus leaves, and kimchi powder effectively inhibited lipid oxidation. The use of the specified ingredients helped preserve the freshness and quality of the sausage after two weeks of storage. It is worth noting that the addition of kimchi powder reduces the loss of quality (weight and taste) during sausage preparation.

The quality of processing of meat products is understood as the effect of changes in the internal structure. Indices commonly used to measure the processing quality of meat products include pH value, water content, texture characteristics, and microstructure. No and others [37] found that the addition of individual complex phosphate or soy protein isolate reduced losses during cooking of duck sausage ($P<0.05$). Addition of more than 0.5% glutamine transaminase reduced the water content of duck meat products ($P<0.05$). Lee et al. [38] found that with an increase in dietary fiber (from bamboo shoots), cooking loss decreased, and the water-holding capacity of minced pork increased ($P<0.05$), and gel hardness and strength increased ($P<0.05$). Scanning electron microscopy (SEM) showed that the addition of dietary fiber from bamboo shoots made the microstructure of minced pork uniform and dense. Gupta et al. [39] found that the optimal proportion of restructured chicken pieces made with barley flour in the amount of 8% contributed to a decrease in structural and mechanical parameters (hardness, cohesiveness, stickiness and chewability) compared to the control ($P<0.05$). It has been established that the addition of barley flour gives meat products a tender texture.

Sensory assessment of the quality of meat products is an important factor in determining consumer purchases. Currently, there are both subjective and objective methods of assessing the quality of meat products. Subjective evaluation is the use of sensory evaluation. Thanks to a comprehensive assessment of taste, color, consistency, aroma and organizational status of meat products, the higher the overall score, the higher the acceptability and the stronger the desire to buy.

Due to the vagueness of the sensory properties of meat products, in order to increase the scientific rationality of product taste evaluation, sensory evaluation has usually been combined with electronic nose, gas chromatography-mass spectrometry (GC-MS) to obtain more accurate values of product taste characteristics. Studies show that the flavors of low-temperature sausage processing are mainly aldehydes, esters, ketones, alkenes, and aromatic compounds [40]. Important properties of an aromatized substance are evaporation, digestion and reaction with other substances. As a result, different raw materials and auxiliary materials, processing conditions, storage conditions and other factors will lead to differences in the taste of finished products.

Hu et al. [41] studied the influence of key technological links of Western sausage on the structure and taste adsorption capacity of myofibrillar protein. It was found that the surface of myofibrillar protein in the process of vacuum kneading has strong hydrophobicity and a greater number of hydrophobic groups appear on the surface, which contributes to the combination of protein and flavoring substances. Summo et al. [42] studied the evolution of volatile substances that form the taste of sausage under conditions of different packaging, temperature and duration of storage. It was found that among the volatile compounds there are markers of lipid oxidation, such as: hexal, octylal and nonal. These substances increased during storage ($P<0.05$), and lipid oxidation decreased at low oxygen concentration ($P<0.05$). The formation of volatile compounds was more affected by storage time than by packaging. Ran et al. [43] investigated the volatile aromatic compounds of Western smoked ham at different storage temperatures. Volatile compounds were - olefins, ethers, acids, ketones and esters. At higher storage temperatures, acids, ketones, and esters formed more easily.

Objective indicators of quality assessment include color, tenderness, juiciness, etc. These properties directly affect the quality of meat products during processing and storage. Choe et al. [44] replaced the fat in sausages with a mixture of pork skin and wheat fiber and found a 50% reduction in fat content, 32% in calories, and 39.5% in cooking losses compared to the control group. Sensory evaluation results showed no significant differences in color, taste, tenderness, juiciness, and overall acceptability between the sausage samples and the control group ($P<0.05$). Wang et al. [45], investigated the influence of the amount of added tomato powder and the level of fat on the overall quality of sausage. It was found that the amount of lean meat affects the firmness. The addition of tomato powder reduced the hardness and elasticity of the sausage and effectively improved the L* and a* values of the product.

Food quality and quality of processing are interconnected and inseparable, therefore their use in evaluating the quality of meat products is inevitably important.

The quality and safety of food products is of great importance to producers and consumers, and meat products should be given more attention due to the complex reaction systems involved in the processing process. The loss of sensory and microbiological quality of sausage products is a phenomenon mainly caused by lipid oxidation, enzymatic autolysis and the presence of pathogenic microorganisms, as well as improper processing and storage conditions [46]. Jin et al. [47] investigated the effect of different preservatives on the physicochemical, microbiological properties and sensory evaluation of finished sausages with and without nitrites during refrigeration for 4 weeks. The results showed that the addition of celery powder effectively protects sausages from deterioration during storage. Chen et al. [48] studied the effect of a sodium substitute, a partial replacement of NaCl, on physical, microbial and sensory characteristics. It was found that after 12 days of fermentation, compared to the control and other samples, the moisture content, moisture activity and pH of the finished sausages, which were partially replaced by NaCl (70% NaCl and 30% KCl), significantly increased ($P<0.05$). During fermentation, the microbial diversity of all sausage products decreases, and the dominant species were staphylococci and lactobacilli. In addition, the sausage has a higher L* value and lower firmness and chewability ($P<0.05$).

Nadine et al. [49] investigated the effect of several visible spectra of different intensities on oxygen absorption and surface color of sliced bologna sausages. The results show that the use of suitable LEDs with a specific spectrum to illuminate the displays helps to reduce light-induced quality degradation in cured sausages. Research by Wang [50] showed that low-nitrate emulsified sausage replaced with 4% sauces had lower levels of oxidation (POV value and TBARS value), volatile nitrogen, and total microbial count during storage than traditional emulsified sausage.

Vegetable additives in meat products mainly include grains, legumes, vegetables, fruits, etc. Of these, vegetables and fruits mainly contain a variety of vitamins, minerals and dietary fiber, only making up for the lack of dietary fiber in meat products. By combining plant-based ingredients with meat, combination sausages not only increase the nutritional value of the product, but also promote deep processing and utilization of plant-based ingredients that are sure to appeal to consumers. In addition to the benefits of increased nutrition, improved taste and reduced fat, the addition of plant material to the quality of combined sausages has good properties such as improved gel quality, increased color stability and storage stability.

Zhao et al. [51] added Corderan gum to Western lamb cooked ham. Found that the structure of the cooked ham improved significantly with increasing amount of added gum (<0.05). Chen Jie found that konjac glucomannan increases tissue density, improves ham gel quality, and effectively slows down the increase in hardness and chewiness caused by water loss during storage, etc.

Scientists [52] found that adding 17.5% carrots to steamed lamb sausage had a better color protection effect after fermentation and reduced nitrite residue (P<0.05). But adding carrots is not enough to replace the coloring effect of nitrite.

Lee et al. [53] showed that the addition of 0.4% carrot powder (instead of nitrite) and an antioxidant improves the quality of cooked sausage and reduces the nitrite content. In addition, carrots are rich in fiber, carotenoids, vitamin A, flavonoids, and phenolic compounds, which have good effects on health by strengthening immunity, preventing cardiovascular diseases, slowing aging, etc. [54]. Deda and others [55] found that when 12% tomato sauce was added to cooked sausages, the color of the sausage was the best, the amount of added nitrites decreased, from 150 mg/kg to 100 mg/kg, and there was no negative effect on the quality of the products, throughout the period storage. In addition, tomato paste is used as a fat substitute for the development of low-fat meat products rich in dietary fibers [56].

Oskueia and others [57] studied the chemical and sensory characteristics of beef sausage. The results showed that the addition of tomato powder and flax seed powder, with different contents, to the sausage recipe reduced the value of L*, pH, the content of residual nitrites and the mass fraction of moisture ($P<0.05$). Contributed to an increase in b*, protein, carbohydrates, minerals, fiber and total calories (<0.05). As the storage period increased, the nitrite content decreased. The addition of flax meal increases the content of linolenic acid in cooked sausage. Choe et al. [58], used winter mushrooms, instead of phosphate, to make emulsified cooked sausage. The addition of 1.0% winter mushroom powder increased the pH value of minced meat, effectively prevented fat seepage from the sausage, and inhibited lipid oxidation ($P<0.05$). The structural and mechanical properties of sausages were improved and the use of natural powder of winter mushrooms as a substitute for phosphates in meat products was proposed. Feng et al. [59] investigated different hydrophilic colloids (carrageenan, konjac gum, guar gum and their combinations) on water migration, texture and sensory properties during the processing of Cantonese sausages. Addition of a hydrophilic colloid or a combination thereof increases the water content and rehydration rate of Cantonese sausage. At the same time, the combination of hydrophilic colloids improved the sensory quality, structure properties and rehydration rate of Cantonese sausages.

Hock Eng Khoo, Azrina Azlan and others [60] were engaged in the study of natural and synthetic anthocyanin dyes, their physicochemical characteristics and effects on the body. Technologies for the production of natural dye from grape skins for the production of purple jam, confectionery and beverages are proposed. V.M. Timofeeva conducted research on the chemical composition of chokeberry and elderberry berries with the possibility of using them to enrich and color food products [61].

S.V. Matko, O.V. Benderska, M.G. Pisarev proved the possibility of using concentrated juices and pastes from chokeberry, elderberry, blackberry and blueberry as natural dyes in the production of confectionery, bakery, pasta, dairy products and food concentrates [62, 63].

Scientists have studied the anthocyanin composition of cherries, black currants, grapes, honeysuckle and elderberry. Scientists have also conducted studies on the extraction of dyes from raw materials by extraction and drying with subsequent use as natural dyes [64].

Scientists have proven a higher content of anthocyanins in wild raw materials compared to cultivated varieties. According to the proposed technology, juice was extracted from the wild raw materials, and the resulting extracts were sent for extraction with the aim of extracting phenolic substances and anthocyanins. The obtained extracts were used in the production of non-alcoholic carbonated drinks, blended juices and compotes [65].

Hao et al. [66] investigated the nutritional quality of 7 types of Western cooked ham in domestic and foreign markets. It was found that the moisture content of high-quality Western cooked ham products was 64%~74%, the protein content was 9%~16%, and the fat content was 4.8%~10.0%. Among them, protein is the main nutrient in combined ham. Protein content, amino acid composition and digestibility of protein are used as important indicators for evaluating the nutritional value of protein [67]. Protein digestibility reflects the fermented hydrolysis of food in the stomach. The higher the digestibility, the greater the proportion of food nutrients will be absorbed and used by the human body. This is crucial for evaluating food quality and developing new products.

Factors affecting the digestibility of protein products are: the initial raw material [68], the method of its processing [69], heating temperature, etc. [70]. Rakotondramavo and others [71] investigated protein digestibility during processing of restructured sausages and found that protein digestibility of raw meat was (50±0.38)%, marinated meat was (60±0.60)%, and heat-treated meat was (55 ±0.96)%. These results indicate that salting promotes digestibility of meat proteins. The cooking process causes significant denaturation and oxidation of protein, which leads to a decrease in protein digestibility. Reduced digestibility of proteins impairs the bioavailability of amino acids and contributes to the accumulation of some protein products in the intestines. Harmful fermentation products are formed and the risk of colon cancer increases. This negatively affects the nutritional value of restructured sausages [72]. Different processing can affect the digestibility of the protein in the sausage. Researchers often evaluate the nutritional value of a product based on digestibility and assimilation.

The study of the patterns of influence of new and diverse types of meat and vegetable raw materials on the quality characteristics of combined sausage products improves and forms the necessary functional quality of meat products and provides recommendations for their production.

1.2 Characteristics of poultry meat - an alternative to traditional meat raw materials

Meat products are an important component of a healthy diet because they can offer the body essential nutrients such as protein, fat, and vitamins that are different from those found in foods made from plants [73]. Worldwide, livestock accounts for 14% of total calories and 33% of protein in the human diet, while ruminants, poultry, and pigs account for 96% of all animal protein [74]. Supply and demand can not only reflect changes in the standard of living, but also affect the health of residents.

Because of regional differences and differences between rich and poor, many people cannot eat enough. Compared to other livestock products, poultry production is a very dynamic industry with the lowest feed and labor costs per unit of production. The turnover of funds in the production of poultry meat is 2 months, beef - 18 months, pork - 11 months, mutton - 9 months.

Today, the largest producers of poultry meat in the world are the USA, China, the countries of the European Union and Brazil. Meat production has increased by an average of 12% over the last decade. In 2023, the production of poultry meat will increase by 1.1% compared to the previous year to 1.7 million tons. According to the data received, the United States, China and the European Union are the main producers of poultry meat with an annual production of more than 15 million tone [75].

The poultry sector has changed radically. Birds used to take about 110 days to grow to 1.2 kg, but with improvements in breeding and care techniques, it now only takes 40 days for birds to grow to 2.5 kg. Speaking of sales, 80% of poultry used to be sold whole, but now you can get excellent cuts of meat (chicken legs, chicken breasts, chicken wings, etc.) and poultry meat products everywhere. Large centralized processing machines can now process 15,000 poultry per hour on a single line, compared to 2,500 60 years ago, achieving improved poultry uniformity (size, color, texture) [76].

Poultry meat not only has a short growth cycle, but is also a favorite among consumers. Poultry meat accounts for 56% of total meat consumption in Thailand, 35% in the USA, 39% in Brazil, 37% in Mexico. Poultry meat consumption per capita has increased significantly in EU countries: 80% in Poland, 76% in the Czech Republic and 20% in Hungary [77]. GIRA, an international consulting company that studies the market for meat products, reports that the demand for poultry meat will increase by 60% over the next decade and will dominate [78]. The share of chicken in Ukraine exceeds 85% of the total production of poultry meat and 76% of the total production of pork and beef [79, 80]. It should be noted that from 2000 to 2020, the total poultry population in China and Ukraine increased by 55% [81].

In terms of nutrition, poultry meat is somewhat different from pork and beef [82, 83]. It is high in protein and low in fat and cholesterol. A feature of poultry meat is the presence of a significant amount of protein. According to some researchers [84], the mass fraction can even reach 25%.

A comparative analysis of the chemical composition of different types of poultry meat is given [85] in Table 1. Broiler chickens are the most widespread and studied among types of poultry meat.

The pectoral muscles of the bird are formed by relatively large muscle fibers (25-35 μm) and a large number of myofibrils. Due to insignificant muscle activity, the amount of muscle mass and myoglobin is small. In contrast, femur muscles are composed of thin muscle fibers (20-30 microns) with relatively high muscle and myoglobin content. Unlike pectoral muscles, femur muscles are stronger, because they contain more solid protein, but less than the same meat tissues of slaughtered animals. As a result, poultry meat contains less defective proteins (collagen and elastin). Poultry meat contained the most lysine (8.7%), leucine (7.8%), threonine (5.16%), valine (4.8%), isoleucine (3.9%), methionine (2 .3%). Its composition exceeds the content of lysine in traditional high-quality meat raw materials (leucine, histidine by 1.3 times, threonine by 1.6 times and lysine, arginine, tryptophan) [86].

Table 1.1 - Chemical composition and energy value of poultry meat

Poultry type	Edible part, %	Content, %				Energy nutrition, kJ
		Water	Fat	Protein	Ash	
Chickens	52	65,5	13,7	19	1	200
Broiler chickens	46	67,5	11,5	19,8	1,2	185
Turkeys	51	60	19,1	19,9	1	250
Ducks	48	49,4	37	13	0,6	365
Ducklings	34	56,6	26,8	15,8	0,8	294
Geese	54	48,9	38,1	12,2	0,8	369

Poultry meat is an easily digestible dietary product due to the large amount of protein and the optimal balance of amino acid composition. Chicken protein is digested by the body by 95.7%, adult chicken meat is digested by 72%, duck meat by 68%, turkey meat by 67%, beef, pork, lamb digestibility is no more than 60%. It has also been found that beef is digested by gastrointestinal enzymes within 24 hours, while poultry takes up to 4 hours [87, 88]. Chicken is much lower in fat than most other animals.

Poultry lipids are a valuable source of essential polyunsaturated fatty acids (linoleic, linolenic, arachidonic). The total level of unsaturated fatty acids is 70% in pectoral muscle (43-44% linoleic acid, up to 23-28% oleic acid, up to 0.7% arachidonic acid) and -60% in thigh muscle. Therefore, poultry fat has a low melting point from 30°C to 34°C (beef, mutton - at 50°C-60°C) and a soft consistency that ensures its quick assimilation by the body, which is - 93.5. %. In terms of quality, it is superior to other animal fats, especially beef and lamb, which contain a large amount of stearic acid [88]. Mineral substances and vitamins confirm the high value of poultry meat. Meat is an excellent source of phosphorus, potassium, which plays an important role in ensuring the work of the heart muscle, calcium, sodium, magnesium, contains a small amount of iron, selenium, cobalt, molybdenum, etc. Regarding poultry meat, chicken has a slightly better P:Ca ratio [89] of 11.4-11.6:1 (10:1 according to other data), while beef and veal have a ratio of 20.9-17, 1:1 respectively.

Poultry protein proteolysis and fat oxidation play an important role in the formation of aromatic substances. Sulfur-containing amino acids (methionine, cystine, cysteine) form hydrogen sulfide, methyl sulfide, and dimethyl sulfide. Aromatic substances of poultry meat form the following compounds: hydrocarbon heterocyclic compounds, carbonyl compounds, alcohols and phenols, salts and lactones, esters, sulfur-containing compounds [90]. Jayasena and others. studied the properties of boiled chicken. Various volatile substances were detected (aldehydes, ketones, alcohols, amines, acids, sulfur-containing substances, etc.). The results showed that the composition of volatile substances in white and red meat has certain features: 32 volatile components were identified in red meat and 27 in white meat in different proportions. These scientists suggest that the breast muscle flavor is considered a typical "chicken" flavor, while the red muscle flavor is a beef-like flavor. The authors suggest that when removing sulfur-containing components from volatile substances obtained from broilers, the disappearance of the "meat" taste was observed. Removal of the carbonyl component eliminates the "chicken" flavor and enhances the "meat" - beef flavor [91].

Duck farming is an important and scientific reserve of poultry meat.

Poultry farming, both in Ukraine and abroad (China, France, Italy, Denmark, Canada, etc.), shows interest in the production of duck meat. The high content of fat in carcasses pushes poultry farmers to active selection work. As a result of the intensive work of the breeders, ducks of breeds - colored, whose fat content in the carcasses was reduced by 4-6%, were bred [92]. Preference is given to musk ducks with low fat content and very tasty meat, which has a characteristic taste of game.

Muscovy ducks are characterized by high meat qualities: more hardy; almost not susceptible to many infectious diseases; the disadvantage is a long fattening period of up to 12 weeks, a long incubation period of 33-35 days.

Ideal for fattening on foie gras is the hybrid Moulard duck, which has the following qualities: high vitality, resistance to diseases; less fatty meat, juicier and tastier; low energy diet; accelerated recruitment of live mass.

In terms of dimensions, the mulard duck breed surpasses both the Muscovy and the Peking duck. The body has a lean, strong physique. Mullards have a longer and thinner neck than the Pekingese. Weight is gained very quickly - in 2 months they weigh about 3.5 kg. The weight of males and females is almost identical. Birds whose carcass weight is 4-7 kg (depending on feeding) are considered adults. The weight of the offal - liver, from a duck, reaches 500 grams [93].

Based on literature data [94], it was established that the chemical composition of different species of ducks differs (table 1.2).

Duck meat is rich in nutrients. The protein content ranges from 17% to 22%, the fat content is about 25% (except for the mulard breed - 5.26%), contains vitamins B, E and has a low melting point of fatty acids, easily absorbed by the body. Eating duck meat contributes to the body's resistance to vitamin deficiency, neuritis, rejuvenation and other effects.

Table 1.2 Chemical composition of muscle tissue of ducks

A breed of ducks	Chemical composition, %			
	Protein	Fat	Water	Mineral substances
Musky	17,06	17,46	64,21	1,37
Beijing	17,06	24,73	56,93	1,08
Mullard	21,51	5,26	70,65	1,23

Mullard ducks have a high moisture content in muscle tissue of 70.65% and a low fat content, comparable to Peking and Muscovy ducks.

The low level of fat in the meat of mulard ducks allows it to be considered as dietary, and makes it possible to use meat products of functional value in recipes.

Duck fat contains unsaturated fatty acids. The ratio of saturated fatty acids to unsaturated fatty acids is close to 1:1. Cholesterol in duck is the lowest among all types of meat. Duck meat contains taurine, which contributes to the growth and development of babies [95].

Research has established that the hardness index of boiled duck is - 15,000 units, elasticity - 0.6 units, stickiness - 10 units, cohesion - 7,000 units, chewing ability - 5,000 units, renewability (0.4 units) and elasticity (0.7 units) [96].

The meat of the mulard duck and the justification of its use in modern technologies of meat products, which can be interesting and in demand not only in Ukraine, but also abroad, are relevant.

Therefore, poultry meat is a high-quality, competitive meat raw material that can be used to make a variety of products, including cooked sausages, and to expand their range.

1.3 Natural biologically valuable meat substitutes for the production of meat products

The history of food additives goes back several thousand years (pepper, nutmeg, cloves, honey, cinnamon, acetic acid, table salt, etc.). Only in the 20th century, food additives attracted mass attention and took a stable position in the food industry as the most important micro-ingredients. The wide distribution of food additives began to require the introduction of their classification, hygienic regulation, development of production and application technology.

Food additives are natural compounds or chemicals that are not normally consumed on their own, but are specifically added to other foods in limited amounts. More than 500 food additives are used in food production in different countries. Supplements are developed by microbiologists and chemists, then tested over several months or even years. If the tests are successfully passed, then the regulatory organization where the supplement was developed recommends it for widespread use.

The main functions of food additives are preservatives, antioxidants, structural thickeners, emulsifiers, dyes, leavening agents, etc.

1.3.1 Characteristics of the root crop "Areca taro" and wheat bran

The need to regulate the technological properties of meat products and obtain high-quality products is determined by various additives and fillers. Recently, the practice of introducing various additives to the composition of meat products - combined products, construction of analogs and substitutes for meat - has become widespread. In this regard, the technological properties of additives, their effect on the structure, taste characteristics, weight loss during heat treatment and other indicators are studied. Today, this direction is actively developing and gaining more and more demand [97].

The introduction of vegetable fiber additives into the minced meat helps to stabilize its moisture- and fat-holding capacity and improves the quality of meat products. In order to provide various types of products based on meat and vegetable raw materials, mutual enrichment of their composition, improvement of quality and reduction of cost is necessary. As of today, the enrichment of meat raw materials with dietary fibers contained in plant products is an urgent issue that needs to be resolved. Dietitians' attitudes toward dietary fiber revisited [98].

The term "dietary fibers" was coined by scientists in 1980. Dietary fibers are the remains of plant cells that are not digested by digestive enzymes of the human gastrointestinal tract, and therefore are able to resist hydrolysis by human digestive enzymes. The American Association of Cereal Chemists, in 2000, introduced a more objective term and characterization of dietary fiber. The edible part (carbohydrates) of 17 plants resistant to digestion and adsorption in the human small intestine was found. Their fermentation takes place in the large intestine under the action of special microflora [99].

The list of such substances includes: polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibers have different composition and properties and perform certain functions [100]:

- soluble fibers have the ability to remove various substances, cholesterol, radioisotopes, heavy metals;

- insoluble fibers retain water better, contributing to the formation of a soft elastic mass in the intestines and improving its elimination;

- cellulose has the ability to absorb water, help rid the body of toxins and impurities, and regulate glucose levels;

- lignin promotes the removal of cholesterol and bile acids that are in the gastrointestinal tract;

- gum and gum arabic dissolve in water, creating a feeling of satiety; - pectin prevents excess cholesterol and bile acids from entering the blood.

Food rich in dietary fiber, as a rule, is less caloric, contains little fat, and many vitamins and minerals. Foods with a high fat content increase the risk of a number of diseases, such as obesity, hyperlipidemia, hypertension, stroke, myocardial infarction, and coronary heart disease [101]. Raw materials with a high content of cellulose and starch are relevant for replacing fat in food production [102]. Whole grains are considered useful for regulating blood sugar [103]. More and more scientists are paying attention to whole grains, and whole grain consumption is part of national dietary recommendations [104, 105].

Thus, together with proteins, polysaccharides are the main components of food that determine its structure, degree of digestion and assimilation, and organoleptic indicators. Adsorption properties of polysaccharides provide products with radioprotective and slag-removing functions, which is one of the aspects of their use in diets for correction and maintenance of health. Therefore, the annual increase in dietary fiber in diets is about 3.9% with a tendency for further growth.

The introduction of dietary fibers into the product as a functional ingredient is advisable in appropriate physiological quantities. The daily rate of their use, as a food additive, is small and requires research to achieve specific technological goals. The main task facing technologists who develop new products with dietary fibers is balancing between meeting the needs of the human body in dietary fibers as a functional ingredient and preserving the traditional quality of the enriched product. New physiologically functional products require solving a number of technological problems [106].

Simultaneously with the enrichment of meat products with food fibers, the technological task of improving the functional properties of these products and forming the necessary consistency is solved. In the production of meat products, plant fibers are used - stabilizing systems. These systems provide the necessary structural and mechanical, organoleptic characteristics, increase product storage. They increase the biological and nutritional value and therapeutic and preventive properties of finished products. Among the physico-chemical characteristics of dietary fibers, moisture-retaining capacity, ion-exchange and sorption properties are distinguished [107]. Dietary fibers are characterized by numerous functional groups: hydroxyl, carboxyl, carbonyl, etc. An important factor in favor of their creation is the presence affinity of functional characteristics (water- and fat-binding capacity, emulsifying and gel-forming properties, etc.) of meat proteins and dietary fiber components. This allows, when obtaining combined meat products, to bring their structural-mechanical, organoleptic and other quality indicators as close as possible to traditional [108].

Areca taro is a perennial aroid plant, grows underground and weighs 1-1.5 kg. The main production areas are located in the southern Chinese provinces of Guangxi, Guangdong, Hunan and Fujian. Yield per hectare is 30,000-45,000 kg. It has a tough skin, red and purple stripes inside the tuber, and contains starch and dietary fiber. During heat treatment, a pleasant smell is revealed. In the area of Areca root processing, taro is processed into taro chips, fried chips, frozen chips, canned taro, taro milk tea and other products [109]. At the moment, however, there are few public reports of the powder. It contains more starch and dietary fiber and is a food additive to sausages, bread and other products.

It has been proven that dietary fiber is a substitute for fat and a structural component in the meat industry. A small amount of dietary fiber can improve the nutritional quality of meat products to some extent, but an excessive increase in dietary fiber will significantly decrease the acceptability of meat products [110]. Therefore, the reasonable control of dietary fiber is a problem that needs to be solved in the field of development of new meat products.

Wheat bran is an important byproduct of flour production. It is a mixture of wheat bran - endosperm and wheat germ. Wheat bran is rich in protein, fat, dietary fiber, vitamins, minerals, oligosaccharides, enzymes and phenolic compounds. Compared to flour, the protein content of wheat bran is 1.6 times higher than that of wheat flour, and the distribution of protein components is more uniform, the nutritional value is higher, and the content of minerals is more than 20 times higher than that of flour [111]. Data from Chinese laboratories show that wheat bran contains fiber (31.4%) and protein (18%) and only 0.6% fat. Wheat bran is a great ingredient for balancing nutrients in food. Adding wheat bran to sausages (as a source of dietary fiber) fills their deficiency in human consumption and improves health. Jing et al. investigated the different concentration of dietary fiber suspension in Frankfurt sausages. The addition of slurry increased the viscosity of the sausages, but decreased the pH. The values of cooking losses, protein, collagen content and sensory evaluation of sausages remained stable [112]. Gao et al. investigated the effect of purified dietary fiber of wheat bran in emulsified sausages. Sausages made with 6% wheat bran dietary fiber added to pork (fat to lean meat ratio 1:9) had original taste, rich color and increased nutritional properties [113].

1.3.2 Functional properties of gelatin

Gelatin is practically the only protein gelling agent widely used in the food industry. Gelatin is a protein product that is a mixture of linear polypeptides with different molecular weights (50...70 kDa) and their systems - 300 kDa, has no taste and smell. The amino acid composition of gelatin includes up to 18 amino acids, including glycine (26...31%), proline (15...18%), hydroxyproline (13...15%), glutamic acid (11...12%), aspartic acid (6...7%), alanine (8...11%) and arginine (8...9%) [114].

The raw material for food gelatin is mainly pig, cow and donkey skin, among which the latter are dominant. Gelatin is a product of partial hydrolysis of collagen and is an important biopolymer. Gelatin is a gelling agent. Gelatin molecules, with a long chain, cross-link with each other, forming a three-dimensional network that can fix the liquid inside, so it has an excellent gel-forming property [115]. It has a variety of functional characteristics, such as gelling, foaming, and emulsifying properties, so it is widely used in food, medical, cosmetic, and other fields [116]. It is usually used in combination with additional additives in the food industry [117].

Different colloids can form different taste characteristics. The gel formed by carrageenan and agar is fragile and transparent. Starch gel is brittle and opaque, while gelatin gel is transparent and elastic. A combination of different colloids can overcome the deficiency of one colloid. Different types of colloidal compounds create various colloidal systems of new types and expand their scope of application. It also gives consumers more choice. The protein content of pig skin is 33%, of which the collagen content is 87.8%, while the protein content of lean pork meat is only about 18%. In addition, collagen has good water and emulsion retention properties. Adding gelatin to meat products improves their quality and increases the protein content [118]. Gelatin is a water-retaining colloid of animal proteins. Fermented bone gelatin has a delicate taste, hardens at room temperature and dissolves when heated. It is used in meat products, which not only improves the problem of water in the circulation of products, but also ensures the taste of products. The addition of bone gelatin, in the amount of 0.6%, improves the consistency of the product [119].

The most interesting property of gelatin is the formation of thermally reversible gels. The gelation of gelatin is independent of pH and does not require the presence of other reagents such as sugars, salts or divalent cations. In the food industry, gelatin is used as a thickener, which is added to various formulations in the amount of 1.5...2.2%. Gelatin is used in meat and fish products to stabilize their structure [114].

1.3.3 Vegetable oil is a source of essential fatty acids

Vegetable oils are an important ingredient in the daily diet of consumers and a source of fatty acids. A balanced consumption of fatty acids promotes health [120]. The relative content of fatty acids is an important indicator for evaluating the quality of vegetable oils. Saturated fatty acids have a positive effect on human health, but their excessive consumption will lead to increased blood lipids, hyperlipidemia, high cholesterol, atherosclerosis and other diseases [121], leading to obesity and other symptoms that affect insulin content in the blood body and cause fatty liver [122]. Unsaturated fatty acids can be antithrombotic and reduce the “three highs” and at the same time have antioxidant effects, among which α-linolenic acid is a polyunsaturated fatty acid [123].

There are the following types of edible vegetable oils: soybean, canola, peanut, cottonseed, sunflower, sesame, camellia seed, linseed, corn, rice bran. Vegetable oils contain trace elements, including sterols, phytosterols, squalene, polyphenols, etc. [124]. Sterols are a natural antioxidant [125]. Phytosterol can lower cholesterol in the body and has physiological functions such as lowering serum cholesterol, lowering blood lipids, anticancer, anti-inflammatory, and immune regulation [126]. This is an necessary indicator for evaluating of oil, and sterols in vegetable oil are useful for the human body. Thus, the content of sterols in vegetable oil reflects its quality, based on the content of sterols. It has been studied that rapeseed sterol (40%) weakens the effect of sitosterol and lowers cholesterol [127]. Squalene has a regulatory effect on the body's metabolism and immune system, and also has an antioxidant effect and the ability to absorb free radicals [128]. Polyphenolic compounds contribute to the removal of excess free radicals in the body [129]. The nutrient in rice bran oil is gluten, which lowers cholesterol and improves cardiovascular disease [130]. Sesame lignans and its oil have the ability to induce apoptosis of cancer cells and exhibit antioxidant capacity [131]. Phenolines in flaxseed oil reduce the incidence of tumors by regulating gene expression. The replacement of animal fats with vegetable oil mixtures is the direction of of healthy nutrition.

Fatty foods contain a certain amount of natural antioxidants, the most necessary of which are tocopherols (vitamin E), which are especially rich in vegetable oils. Tocopherols (E306, E307, E308, E309) are natural antioxidants present in a number of vegetable oils. In the form of a mixture of isomers, tocopherols are found in large quantities in vegetable fats (500...100%): wheat germ oil, corn oil, sunflower oil, etc.;

their content in animal fats is negligible. From the mixture of tocopherols, α-tocopherol exhibits the greatest E-vitamin activity and the least antioxidant activity, while δ-tocopherol, on the contrary, exhibits the least E-vitamin activity and the greatest antioxidant activity. Tocopherols are well soluble in oils, resistant to high temperatures, their losses during technological processing are small. They are the most important natural antioxidants [114].

1.4 Functional and technological additives in the production of meat products

1.4.1 Use of antioxidants and preservatives for the safety of meat products

Antioxidants are substances that are included in the process of auto-oxidation of various products and form stable intermediate compounds, thereby blocking the chain oxidation reaction. Antioxidants, like preservatives, are ingredients that help prolong the storage of food products. Preservatives perform this function by inhibiting the growth of microorganisms; the mechanism of action of antioxidants is different - they interrupt the self-oxidation reaction of food components in the food product. This reaction in food products occurs as a result of the contact of the food product with oxygen contained in the air and the product. In the process of self-oxidation, a change in food substances is observed, biologically valuable components, in particular vitamins, are destroyed, lipids, fatty acids, fatty substances are oxidized and split, as a result of which decomposition and decomposition products with a specific smell and taste are formed. Quite often these products are toxic. Thus, the change in appearance, smell and taste of the product reduces its nutritional value. Enzymes, heavy metal ions, light, heat, and oxygen catalyze oxidation processes [114].

Sodium erythorbate, multifunctional, biological food antioxidant and preservative, thermostable, safe, non-toxic, highly effective. It is widely used in the industry. In the production of smoked meats, a number of sausages, canned meat and other meat products. It helps inhibit oxidative and unwanted microbiological processes, improves the color and taste of the product, affects the extension shelf life [132]. Qing Mingming and others. different amounts of sodium erythorbate were added and the effectiveness of antioxidants was determined. Addition of 0.4% sodium erythorbate decreased the TBARS value in fish, and its antioxidant effect was better than in other samples with a lower amount of additive [133]. Shang Xiaolan and others sodium D-erythorbate was added to sausages and the oxidation index was measured at different times. It was established that the effective amount of antioxidant is 0.1%, compared to 0.05% added to sausage mince [134].

Ginger juice is the juice obtained from the ginger root. The nutritional properties of the juice are similar to the fresh root crop. Contains: polysaccharides, gingerol, vitamins, ginger oil ketone, protein, etc. It has the following properties: bactericidal detoxification, antioxidant action, slows down the aging and inflammatory processes, stops nausea, lowers blood sugar, promotes blood circulation, helps digestion, suppresses the activity of cancer cells. The antioxidant effect of raw ginger juice and ginger powder extract was found to be similar to BHT. Inhibits oxidation of animal and vegetable oils, such as lard, rapeseed oil, and tea oil [135]. Bai Jian [136] investigated the effect of ginger polysaccharide on the quality and antioxidant effect of chicken meatballs. Ginger polysaccharide has a positive effect on the elasticity, brightness and taste of chicken meatballs, and also suppresses the oxidation of lipids and proteins during storage. It was determined that ginger polysaccharide has the best antioxidant effect in the amount of 0.6%.

Some scientists [137] studied the properties and effects of onion juice. Onion juice was obtained in the following way. The onion was washed, cut into small pieces, juice was squeezed out (with the help of a food processor), and filtered through cheesecloth. Onion juice contains vitamins, proteins, minerals, polysaccharides, flavonoids, phenolic compounds, which have the functions of lowering blood sugar, blood pressure, blood lipids, anti-inflammatory, bactericidal and antioxidant [137]. Experimental results of Deng Siyang et al. [138] showed that during the cooking of pork steak, with an increase in onion juice, the loss of mass fraction of moisture tends to decrease and then increase. Boiling losses reached the lowest value when the amount added was 9%. POV and TBARS values for steak were lower than steak without onion juice, fully demonstrating the antioxidant effect of onion juice.

1.4.2 Natural dyes in the production of food products

Dyes occupy a special place among food additives. Currently, food dyes are used in many food products - confectionery, pasta, bakery, meat, alcoholic and non-alcoholic beverages, canned food, margarine, spreads, snacks, yogurt, etc. The natural red color of meat is due to the pigment - myoglobin. When there is a lack of muscle pigment in the sausage recipe, dyes are additionally used to restore the natural color, lost during their processing and storage. The purpose of their use is to increase the intensity of the natural color or restore it after technological processing or storage; improvement of organoleptic properties; coloring of colorless products [139,140].

Food dyes are divided into natural (obtained by physical methods from plant or animal raw materials), synthetic (organic substances synthesized chemically that do not occur in nature), and inorganic (obtained from mineral raw materials of natural origin). Also, substances that affect the color of the product include color fixers and bleaches [141].

Currently, the spectrum of synthetic dyes is quite wide. The advantages of their use are cheapness, small dosages, resistance to the effects of temperature, light, changes in the pH of the environment, obtaining various shades by mixing. However, none of them is characterized by indisputable biological safety, and the maximum permissible level in the product has been established for such food additives [142].

All natural pigments of plant origin are divided into three groups: chlorophylls, carotenoids and anthocyanins.

Carotenoids are resistant to changes in pH and temperature and withstand heating (without loss of color up to 1300C), they are reducing agents, and when antioxidants such as ascorbic acid and tocopherol are introduced into the system, they significantly increase their stability. To date, the most advanced technology for obtaining-carotene is microbiological synthesis [143,144]. Beta-carotene has high biological activity. As a strong antioxidant, beta-carotene performs various functions in our body: it protects against free radicals, increases stress resistance, helps the body to adapt faster in unusual and difficult conditions, mitigates the effects of radiation, electromagnetic and chemical pollution, strengthens immunity and increases the body's ability resist infections. The prevention of oxidative stress with the help of functional nutrition is gaining special relevance today [145].

Compared to synthetic dyes, they contain biologically active, can have taste and aroma substances that give products not only an attractive appearance, but also a natural aroma, taste and additional nutritional value. However, the assortment of natural dyes, especially of domestic production, is very small[146].

Fermented rice is a staple Chinese ingredient with a history of over 1,000 years [147]. It contains a red pigment - anthocyanin [148]. It has a positive effect on the functional activity of the spleen, helps to cleanse the stomach, and relieve swelling. Medical research has established that the effective ingredient in red fermented rice is lovastatin. It contributes to lowering the level of cholesterol and triglycerides, increases the level of high-density lipoproteins and lowers blood pressure, the level of lipids in the blood [147, 149].

The Food Safety Authority of the European Union has approved the use of fermented rice as a food additive to control cholesterol levels in the human body. Fermented rice is a common ingredient in Chinese dishes: stewed pork, fermented bean curd, red rice wine, red steamed bread, red rice sausage, etc. [150, 151].

The basic raw materials for the production of red fermented rice are the following types of rice: indica, Japanese, glutinous, etc. Basically, fermented rice is obtained in the following stages: the rice is cleaned, soaked in clean water (60 minutes), steamed at a temperature (55-58 °C), added monask, mixed and left for fermentation (temperature 55 °C, 3-4 days). Next, the fermented rice is dried [152, 153].

China and Ukraine are the source of beet cultivation and processing. Beet red pigment is a natural pigment made from edible red beet through extraction, separation, concentration and drying. Beet pigments are anthocyanins and betaxanthin. Dry beetroot powder has a red-purple or dark purple color. Beet pigments are natural, safe, non-toxic.

Fabre.C.E and others. it has been proven that the addition of fermented rice to meat and meat products has a better coloring ability than artificial dyes [155, 156].

Yang Huijuan et al. studied the effect of nitrite substitutes on the color of minced meat. Three dyes were added to different samples: 100 mg·kg-1 nitrite, addition of 0.5% beetroot powder and 50 mg·kg-1 nitrite, addition of 0.1% beetroot powder and 0.06% glycosylated acylhemoglobin. According to indicators: myoglobin content, general color formation and other indicators, it was established that the finished products - with the addition of 0.1% beet powder and 0.06% glycosylated acylhemoglobin, had a redder color and replaced part of sodium nitrite [157].

Xiao Chaogeng et al used glycosylated acylhemoglobin (0.04%, 0.06%, 0.08%) and red beet powder (0.1%, 0.3%, 0.5%) in meat Chinese sausages. The effectiveness of the action was measured by the content of total pigments and residual sodium nitrite. It was established that 0.06% of glycosylated acylhemoglobin and 0.1% of red beetroot powder replace 100 mg/kg of sodium subnitrate and have a positive effect on the quality of sausages [158].

To date, the combined use of fermented rice and red beet powder in meat systems instead of sodium nitrite has not been sufficiently studied and is a promising direction.

1.4.3 Characteristics of structure-forming ingredients

Structure-forming additives are colloidal moisture-binding reagents that mainly perform the function of retaining moisture in the product in a hard-to-evaporate form, and in addition, serve as fat emulsifiers, contributing to the elasticity of the product's consistency. This factor is important for reducing the mass loss of minced meat products in the process of heat treatment. In domestic production, phosphates, potato, wheat, rice, corn and wheat flour, varieties of soy products are most often used to increase the viscosity and moisture-retaining capacity of minced meat [159].

Phosphates are good emulsifiers that improve the emulsifying and gelling properties of meat systems and affect the quality of the product. Phosphates normalize the pH indicator, contribute to: water-holding capacity, reduce the loss of moisture by mass during cooking, improve sensory properties (tenderness, juiciness, color and taste) and extend the shelf life [160]. The US Department of Agriculture's Food Safety and Inspection Service approved the use of phosphates as a food additive in 1982 [161].

The use of phosphates depends on the value of active acidity and the degree of shift of the reaction of the environment in meat systems from the isoelectric point of proteins (mainly towards the alkaline side). Basically, the use of phosphates and their mixtures ensures a pH value of 6.3-6.4 units, a pH above 6.5 units - gives the product an unpleasant alkaline aftertaste. The effectiveness of using phosphates for raw materials with signs of PSE and frozen meat and meat of lean animals has been proven [159].

The mechanism of action of phosphates is that it helps to attach water molecules to the polar groups of the protein. The limitation of muscle tissue hydration is explained by the presence of bridges formed by calcium ions between the polypeptide chains, which block the access of water to the polar groups of the protein. Under the action of phosphates, these bridges are destroyed as a result of detachment and binding of calcium ions, polypeptide chains move away from each other, opening the passage for water molecules to the accessible polar groups of the protein. As a result, the hydration of the meat increases by 5-10%. In addition, the specific hydrating action of phosphates is based on the ability of some of them (pyro- and tripolyphosphates) to participate in the process of splitting the bond between actin and myosin, which leads to the elongation of protein micelles and unwinding of polypeptide chains. Phosphates are also capable of binding metal ions present in meat and blood pigments, which catalyze the oxidation of fats in meat. Phosphates also make it possible to work with frozen block meat [162].

Most often, technologists seek to increase the yield due to a higher dosage of phosphates by using a phosphate-containing mixture in combination with pure phosphate (double dose). Also, phosphates calculated for 100% of the mass of minced meat without counting on muscle tissue are often used in meat-vegetable recipes. Also, phosphates can be added by manufacturers to increase weight (frozen meat) [162].

Starch is a mixture of amylose and amylopectin polysaccharides, the monomer of which is alpha-glucose. Starch is synthesized by various plants in chloroplasts under the influence of light during photosynthesis. It comes not only from potatoes, but also from corn, rice, wheat, cassava fruits and soybeans. There are 2 groups of starch: native (natural) and modified. In fact, all starches are first obtained either from grain or from tubers, and then, by means of change (modification), other types are obtained [163].

Starch derivatives obtained from it by various types of processing for the necessary change in properties are called modified (altered) starches and dextrins. So, for example, split starches (low-boiling) form pastes of low viscosity; they are produced by splitting polysaccharide chains with acid, oxidizing agents, amylases, some salts, etc. As a result of this action, there is a chaotic or directed cleavage of glucosidic and other bonds, the molecular weight decreases, internal and intermolecular bonds appear - carbonyl and carboxyl groups appear, but, as a rule, the granular form of starch is preserved [164].

As a result of the reaction of hydroxyl groups of starch with organic and inorganic substances, simple and complex esters are formed, including amylphosphoric esters, which are often called phosphate-modified starches, as well as starch oxidation products. Esterified starches are obtained by introducing a small number of ester linkage groups into the starch molecule for substitution. These are mainly acetyl and phosphoric groups. Starch acetates are obtained by treating starch grains with acetic acid or acetic anhydride in the presence of a catalyst. solutions of starch acetates are very stable, since the presence of acetyl groups prevents the association of two amylose molecules and long side chains of amylopectin. Acetates of starch have a reduced ability to retrogradation, form transparent and stable pastes; used in frozen products, bakery products, instant powders [114].

Research on determining the influence of starch content on the physicochemical parameters of minced meat showed that the optimal concentration of starch is 2-4%. When added to raw minced meat, starch helps reduce its moisture-binding capacity. But after heat treatment, the role of starch in moisture retention increases significantly. Due to its molecular structure, when heated, starch decomposes into dextrins, which are able to form a paste, which increases the proportion of bound moisture and fat. At the same time, the fat-retaining capacity of minced meat increases significantly. The addition of starch increases the viscosity of the minced meat and the proportion of dry substances in it. An increase in the proportion of starch to 8-12% leads to an increase in moisture and, to a lesser extent, protein in the product [159].

Jairat et al. [165] investigated the replacement of buffalo fat with corn starch in cooked sausage. At cornstarch supplementation levels of less than 6%, cooking rate, pH value, moisture content, protein content, and sensory scores were higher than the control ($P<0.05$). While the content of reagents thiobarbituric acid and fat were significant (<0.05), compared to the control ($P<0.05$), the quality of the sausage improved, the calorie content decreased by 43%. Lim et al. [166]investigated the effect of the combination of potato starch and glutamine transaminase on the physicochemical properties and texture of emulsified sausage. The results showed that with the addition of the indicated technological additives in emulsified sausages, the pH level, moisture-retaining capacity, hardness and elasticity increased and cooking losses decreased.

Conclusions to Section 1

Thus, modern methodological approaches to the construction of new combined meat products should be based on the principles of modern nutrition science, the theoretical foundations of food combinatorics, and the results of expert research. Ensuring the specified quality characteristics is a very real task in compliance with the conditions of maintaining the cost price and safety of finished products.

SECTION 2
ORGANIZATION, METHODOLOGY AND RESEARCH METHODS

2.1 Organization of experimental research

The experimental part of the research was conducted at Hezhou University in China and Sumy National Agrarian University in Ukraine. Solving the tasks in the work was carried out according to the general scheme shown in figure 2.1, which reflects the sequence of the main stages of experimental work and research methods.

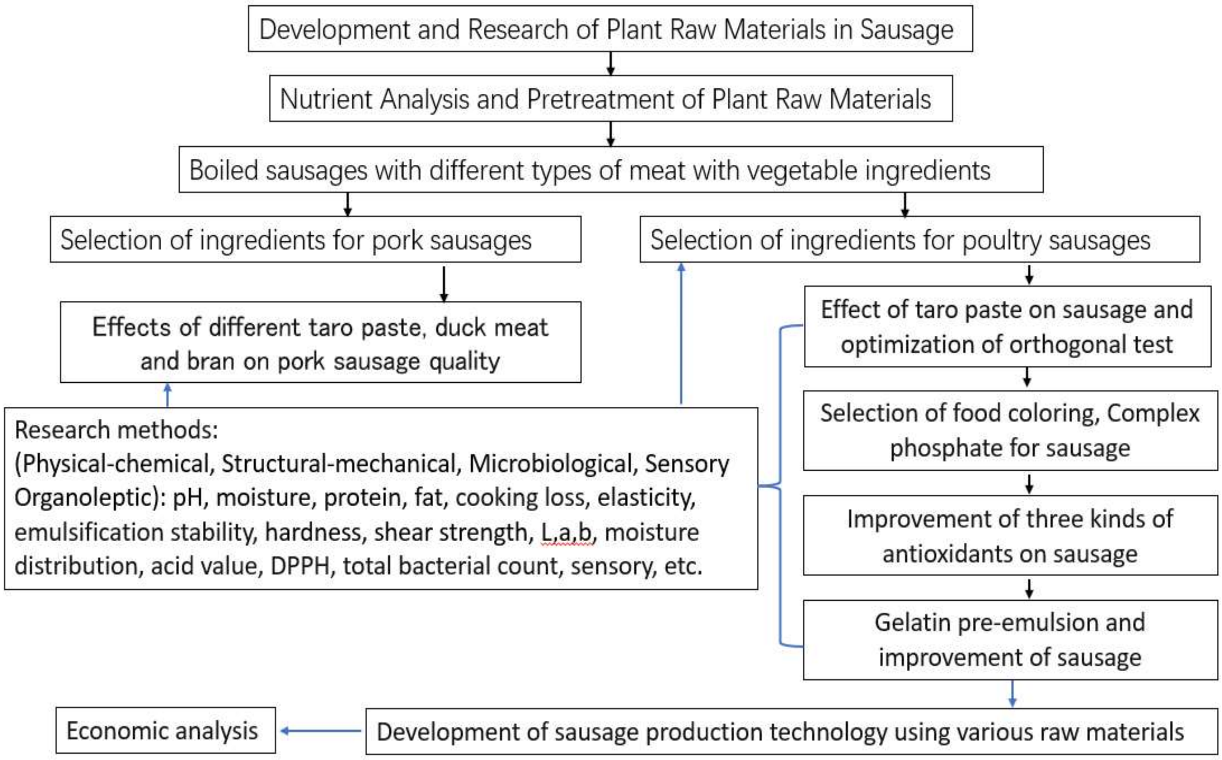


Fig. 2.1 Research scheme

The work was carried out several stages. The first stage was devoted to the analysis and generalization of the scientific and technical literature regarding the characteristics, functions and use of poultry meat as raw material for sausages. Natural plant raw materials were characterized as a source of dietary fibers, dyes, antioxidants, as well as functional ingredients (phosphates, gelatin) and other additives for the quality and safety of sausages. Traditional and modern technologies for the production of boiled sausages were analyzed.

At the second stage of the work, technological regimes were determined and the process of production of taro paste from the root fruit "Areko taro" was analyzed in terms of nutritional composition, sensory evaluation, physical and mechanical parameters, infrared imaging, aroma, and research was conducted on the effect of different amounts of taro paste on the quality characteristics of cooked sausages with pork. Research was carried out on the influence of thermal - temperature and time parameters (in the range of 74-76 °C. A study of the influence of temperature-time parameters (in the range of 74-76 °C during - 40, 60, 80 and 100 minutes, respectively) of cooking cooked sausages from plant components on the regularity of the course of physico-chemical, structural-mechanical, color and sensory indicators was carried out. 40, 60, 80 and 100 minutes, respectively) of cooking boiled sausages with vegetable components, on the regularity of the course of physico-chemical, structural-mechanical, color and sensory indicators.

The third stage of the study was the study of the influence of different contents of taro paste, wheat bran and complex phosphates on the quality of cooked sausage from different types of poultry meat. On the basis of the obtained instrumental results, the optimal formula of prescription indicators was derived using orthogonal modeling. The effect of the dosage efficiency of dyes, antioxidants and animal fat substitutes on the course of physico-chemical, biochemical, microbiological, structural-mechanical, organoleptic indicators of cooked sausages from different types of poultry meat was studied.

At the fourth stage of the work, the technology of new cooked products from various types of meat enriched with vegetable raw materials was developed. The dynamics of changes in physico-chemical, structural-mechanical, sensory and microbiological characteristics on the quality and safety of sausages were studied.

2.2 Object, subjects and research materials

The object of the research is the technology of making boiled sausages with a low fat content using natural vegetable raw materials.

The subject of the study: pork meat (lean pork, pork fat), poultry meat (ducks and chickens), taro paste, wheat bran, beetroot powder, ginger and onion juice, rice wine, fermented rice, starch, phosphates, sodium isoscorbinate, and model samples of cooked sausages are enriched with vegetable ingredients.

The following research materials were used in the work, listed in Table 2.1.

Table 2.1 - Properties and sources of experimental materials

Name	Characteristics	Production address
Taro paste	Starch and fiber rich cooking products, 50% water	Food Processing Laboratory, Hezhou University
Wheat bran	Screening after crushing (80 mesh)	Henan Jinyuan Grain and Oil Company,China
Duck meat/ Duck legs	Duck breast, skin and oil removed (0 - 4 ºC)	Duck breast from a southern Chinese water duck
Chicken meat	Chicken thigh (0 - 4 ºC)	China Guilin frozen food factory
Pork meat	Lean pork and pork fat (0 - 4 ºC)	Hezhou Farmers Market
Casings	fresh Pig small intestine	Hezhou Farmers Market
Compound spice	Thirteen plant spices mixed and crushed	Wang Shouyi thirteen Spices Group Co., LTD
White pepper	Hezhou Farmers Market	Hainan province of China
Rice wine	20 degrees alcohol	Guilin Sanhua winery
Red yeast rice power	Natural red pigment	Hezhou Farmers Market
Beet red powder	The beets are microwave dried and crushed	Food Processing Laboratory, Hezhou University
Potato starch	Starch content 100%	Fanshi Yikang local specialty Co., LTD
Tapioca starch	Cassava modified starch	Guangxi Mingyang starch Co., LTD
Complex phosphate	Sodium pyrophosphate 60%,sodium tripolyphosphate 39%, sodium hexametaphosphate 1%	Harsen Foods (Hongkong) Co.,LTD, Shantou, China
Ice water	Laboratory manufacture	Food Processing Laboratory, Hezhou University
Salt	Sodium chloride, potassium iodate; In line with China GB2721 standard	Guangxi Salt Industry Group

Sodium isoascorbinate	D-isoascorbate sodium is greater than 98% ,Food grade , China GB1886.28-2016 standard	Jiangxi Dexing Baiqin different vc sodium Co., LTD
Gelatin	Gelatin granules made from the bones and skins of animals	Zhejiang Jiawang Biotechnology Co., LTD
Blended vegetable oil	Including soybean oil 68%, Rapeseed oil 21%,peanut oil 3%, sesame oil 0.6%, rice oil 3%,corn oil 2.0%, sunflower oil 2%, , flaxseed oil 0.4%, 8 kinds of vegetable oil	Yihai Jiali Golden dragon fish grain and oil food Co., LTD
Hydrochloric acid	For the test of amino acid	Damao Chemical Reagent Factory,tianjin, China
Potassium hydroxide	For the test of acid value	Guangzhou Chemical reagent Factory
Phenolphthalein	For the test of acid value	Guangzhou Chemical reagent Factory
Ethyl ether	For the test of acid value	Guangzhou Chemical reagent Factory
Ethyl alcohol	For the test of acid value	Guangzhou Chemical reagent Factory
Tetraethoxypropane	For the test of TBARS	Guangzhou Chemical reagent Factory
Thiobarbituric acid	For the test of TBARS	Guangzhou Chemical reagent Factory
Glutathione reducibility	For the test of TBARS	Guangzhou Chemical reagent Factory
1, 1-diphenyl-2-trinitrophenylhydrazine	For the test of DPPH	Shanghai Chuangsai Technology Co., LTD
Anhydrous ethanol	For the test of DPPH	Guangzhou Chemical reagent Factory
Potassium dihydrogen phosphate	For the test of pH	Guangzhou Chemical reagent Factory
$CuSO_4$	Kjeldahl method for the test of protein	Guangzhou Chemical reagent Factory
K_2SO_4	Kjeldahl method for the test of protein	Guangzhou Chemical reagent Factory
Concentrated sulfuric acid	Kjeldahl method for the test of protein	Guangzhou Chemical reagent Factory
H3BO3	Kjeldahl method for the test of protein	Damao Chemical Reagent Factory,tianjin, China
Ammonium hydroxide	Ross Gottrell Method for the test of fat	Damao Chemical Reagent Factory,tianjin, China
α- amylase	Enzyme-gravimetric method for the test of dietary fiber	Damao Chemical Reagent Factory,tianjin, China

Chemical reagents are commonly used laboratory chemicals, analytically pure grade.

2.3 Equipment, regulatory documents and research methods.

2.3.1 Basic equipment: 1. Physical property tester (TA.XTPLUS, P5/P50 probe, Stable Micro System UK); 2. Electronic balance (FA2004B, Shanghai Jingke Tianmei Scientific Instrument Co., LTD); 3. Centrifugal air spray dryer (DFRP-5 Model, Da-feng Spray Drying Equipment Co., Ltd. Wuxi city, China); 4. meat grinder (ZY-001,Langfang Jiapai Electrical Co., LTD, China); 5. Chromometer (CR-400, Konica Minolta Holdings LTD); 6. RVA (TecMaster rapid viscosity analyzer, Perten, Sweden); 7. XRD (D8 ADVANCE X-ray Diffractometer Bruker GMBH, Germany); 8. Fourier transform infrared spectrometer (Nicolet iS50, Thermo Fisher Technology, LTD); 9. MRI Analyzer (NMI20,Shanghai Niumai Electronic Technology Co., LTD).

2.3.2 Normative documents for determining indicators.

GB 5009.5-2016 National Food Safety Standard (China), Determination of Protein in Food or AOAC Method 2011.04; GB 5009.6-2016 National Food Safety Standard (China), Determination of Fat in Food or AOAC Method 991.36; GB 5009.88-2016 National Food Safety Standard (China), Determination of Dietary fiber in Food or AOAC Method 985.29; Ash (AOAC Method 920.153); Amino acid determination method (AOAC Method 994.12) ; Moisture (AOAC Method 950.46) [167, 168, 169].

2.3.3 Analysis method of physical parameters of taro power.

(1) Calculation method of taro powder extraction rate:

$$PER(\%)=PW/(TSC + EM) \times 100 \qquad (1)$$

where *PER* – powder extraction rate; *PW* – power weight; *TSC* – total solid content before spray drying; *EM* – Embedding agent. [170]

(2) Determine the fluidity of taro powder

Refer to [171,172] to determine the fluidity of taro powder. Fix the funnel to keep it vertical. The height of the funnel mouth (1 cm in diameter) from the table top is about 8 cm. Put a piece of clean white paper, add 40 g of taro powder from the funnel, measure the bottom diameter of the cone formed by the taro powder on the white paper, and use the diameter to determine the fluidity of the taro powder. The larger the diameter, the fluidity of taro powder is better.

(3) Bulk density measurement

The bulk density measurement was to scatter the taro powder into a 10 mL measuring cylinder, measure the weight of 10 mL taro powder, and calculate the bulk density [173].

2.3.4 Aroma study of taro paste by mass spectrometry SPME-GC-MS

SPME extraction conditions: The 4.5g taro paste sample was weighed and placed in a 20 mL headspace bottle and placed in a constant temperature heated magnetic agitator water bath at the rotation speed of 100 r/min. The aged 65 μm CAR/PDMS Blue extraction head was inserted into the headspace bottle seal, extracted at 80 °C for 40 min, and immediately inserted into GC injection port. The analysis was carried out for 3 min. Three parallel tests were performed for each group of samples. GC conditions: TG-5MS column (30 m×0.25 mm×0.25 μm); The inlet temperature was 250 °C. The carrier gas was high purity helium (purity ≥99.999%) at a flow rate of 1.000 mL/min. Shunt mode: no shunt injection; Programmed temperature rise: initial temperature 45 °C, keep for 3 min, then rise to 150 °C at 3°C/min, keep for 0 min, then rise to 250 °C at 8°C/min, keep for 3 min. (sampling procedure) MS condition: an elector ionization source (EI); Electron ionization energy 70 eV; Ion source temperature 230 °C, transmission line temperature 280 °C, quadrupole temperature 150 °C; Scanning mode was full scanning monitoring mode, quality scanning range m/z 30~500; The mass spectrum library was NIST11 [174,175].

2.3.5 Study of gelatinization characteristic

Refer to Hu's method[176], 2.5 g taro powder (particle size < 200 mesh, modified according to 14% wet basis) was put into an aluminum bucket, 25 ml distilled water was added, and then the aluminum bucket was put into the instrument after mixing with a stirring paddle. The measured values include peak viscosity, valley viscosity, final viscosity, disintegration value, recovery value and gelatinization temperature.

2.3.6 Study of physical and chemical properties

Cooking Loss and Emulsification Ability: Losses during cooking were measured according to the method [177,178]. Approximately 35 g of the sample was placed in a 50 ml centrifuge tube and centrifuged at 3000 rpm - 5 min. to remove bubbles from the tube. The test tubes were heated at 75 °C for 30 min. and cooled to a temperature of 21 °C for 3 hours. The liquid from the centrifuge tube was transferred to a glass plate (9 cm), weighed and losses during boiling were calculated. The stability of the emulsion was analyzed by the method of cooking losses. The water loss is the weight reduced by the cooking lost liquid 105 °C for 16 h, while the fat loss is the remaining sample weight after the cooking liquid is dried.

Cooking Loss (%)=[W0(g)–W1(g)/W0(g)]×100. (2)

Moisture Loss (%)=(W2–W3)/W0×100. (3)

Fat Loss (%)=W3/W0×100, (4)

where W_0 is the weight of raw minced meat, W_1 is the weight of cooked minced meat, W_2 is the weight of cooking liquid, W_3 is the weight remaining after heating.

Color: Minced meat and sausage were stored at 4°C and kept for 1 hour. The color of minced meat and cooked sausage was determined with a colorimeter (CR-400; b*=+1.9, L*=+97.8, a*=−0.4) [179]. Indicators were determined: yellowness (b), lightness (L), redness (a).

TPA: Samples were cut into 2 cm × 2 cm. Texture profile analysis was performed on an analyzer (TA. XT PLUS) [180,181]. A P/50 (Ø 50 mm) probe was used for sample analysis; speed before measurement - 5 mm/s; measuring speed - 1 mm/s; deformation coefficient - 75%; release force - 5 g. Measured: elasticity, hardness, cohesiveness, chewing, stickiness, chewing, elasticity [182].

Shear strength: according to the method of J. Song et al. [183] with minor modifications. The sausage was cleaned and cut into 2 cm pieces. The measurement parameters are as follows: speed before measurement – 2 mm/s, speed of testing – 1 mm/s, speed after testing – 2 mm/s, measurement distance – 60.0 mm, descent force – 10 d, probe model – HDP/BSW.

X-ray diffraction analysis: The crystal structure of the samples was determined using an X-ray diffractometer (D8 ADVANCE) according to Chen's method [184]. Taro powder (particle size < 200 mesh) was pressed at an angle of 2θ, the scanning range was 5° to 80°, the scanning speed voltage was 40 kV, the current was 40 mA, the scanning speed was 0.02°, the testing speed was 0.1 s/ step. A copper target was used: the wavelength of the input beam was 0.15 nm. Jade 6.0 software was used. Calculation formula [185]:

Relativecrystallinity=Ac/(Ac+Aa)×100% (5)

Where: Aa is the total area of the amorphous region, Ac is the total area on the X-ray diffraction pattern.

Starch digestion in vitro: Starch digestion in vitro was determined according to the following methods: Englyst [186], Zhang [187], Wang et al. [188]. 500 mg of taro powder sample was weighed and dispersed in 10 ml of 0.2 mol/l CH3COONA buffer (pH=5.2). It was heated in a water bath for 30 minutes, mixed with 10 ml (300 units/ml) of α-amylase and 40 liters (10,000 units/ml) of pig pancreas glycosidase. The samples were subjected to oscillation in a water bath (37 °C and 170 rpm) for - 20 minutes and 120 minutes. The enzyme was inactivated in a boiling water bath for 5 minutes, and centrifuged (2000 rpm). The content of glucose in the supernatant was determined by the GOPOD method. The formula for calculating RDS, SDS, and RS in a sample is as follows:

$$RDS = \frac{G_{20} - G_0 \times 0.9}{TS} \times 100\% \quad (6)$$

$$SDS = \frac{G_{120} - G_{20} \times 0.9}{TS} \times 100\% \quad (7)$$

$$RS = 100\% - RDS - SDS \quad (8)$$

Where: TS—total mass of the sample, mg; 0.9- conversion factor; G_0 - the amount of glucose in the sample before enzymolysis, mg; G_{20} - the amount of glucose in the sample 20 min after enzymolysis, mg; G_{120} - the amount of glucose in the sample 120 min after enzymolysis, mg.

pH: Weigh 5 g of sausage samples and crush them, put them into a 50 mL beaker, add 20 mL of distilled water, magnet-ically stir for 5 minutes, and stand still for 30 minutes. Use a pH meter to measure the intermediate liquid. After the reading is stable, read directly and record the data. All determinations were performed in triplicate [189].

Moisture: the mass fraction of moisture was determined by the standard method (AOAC, 2006). A 0.3 g sample was placed in an oven at a temperature of (103±2)°C and dehydrated to a constant weight.

2.3.7 Study of Moisture distribution and Magnetic resonance imaging

Moisture distribution: Low-field nuclear magnetic resonance (LF-NMR) tech-nology was used to determine the dynamic distribution ofmoisture inside sausages. The sausage was cut into 0.8 cmwide and 3 cm high and placed in a nuclear magnetic testtube (the diameter of the test tube was 1.5 cm, the height was20 cm), the magnetic field strength was 0.47 T, and the protonresonance frequency was 20 MHz. The Carr-Purcell-Meiboom-Gill (CPMG) program was used to determine thesample relaxation time (T2). When each sample was measured,the program automatically scans 100 times, and each scantime was 100s. The T2 was inverted through CONTIN soft -ware to reflect the corresponding relaxation times (T2b, T21,and T22) and amplitudes (A2b, A21, and A22) [177, 190].

Magnetic resonance imaging: Magnetic resonance imaging: informs about the distribution of water within the product and visualizes the flow of water by proton density (PDWI) [191]. PDWI reflects the difference in proton density relaxation between tissues. The samples were scanned using MRI using low-field nuclear magnetic resonance technology. The results were processed using pseudo-color software (IPT.2014).

2.3.8 Sensory evaluation of sausage

The tasting committee consists of 10 people. Evaluating sensory preferences of products (color, smell, fabric condition, taste and general acceptability) that are randomly numbered and selected. The highest rating index is 9 points, the lowest rating is 1 [192]. The study protocol was approved by the committee of Hezhou University, in accordance with the Declaration of Helsinki and the policy of China. The characteristics of sensory indicators are given in table 2.2.

Table 2.2 - Sensory indicators [253]

Index	Evaluation score		
	1-3	4-6	7-9
Flavor	No sausage taste	Average sausage taste	Suitable sausage taste
Color	No appetite, poor color	Average appetite, normal color	Appetite, attractive color
Viscosity	Sticky teeth	Slightly sticky teeth	Non-sticky teeth
Texture	The taste is rough and hard	The taste is slightly rough and hard	The taste is fine and elastic
Overall acceptability	Not accept	Accept	Like

2.3.9 Determination of antioxidant capacity and Microbiological of sausage

Determination of acid value : determined by the method of Li Yalei et al. [193]. A sample sample, 50 ml of a neutral solution of diethyl ether-ethanol (2:1) was added to the container and mixed. Next, 3 drops of phenolphthalein were added to the solution and titrated with a standard solution of potassium hydroxide 0.05 mol/l until a red color appeared (color exposure 30 s). Calculation formula:

$$A_v = \frac{v \cdot c \cdot 56.1}{m} \qquad (9)$$

where Av is the acid value (mg/kg); v - volume (ml) of the standard solution of potassium hydroxide, which is consumed by the sample to determine the required value;

c – concentration (mol/l) of standard potassium hydroxide solution; m - mass (g) of the sample; coefficient 5.61 is the molar mass (g/mol) of potassium hydroxide.

TBARS measurement: determined by the method of GU Xinzhe et al. [194; 195]. 10 g of the sample was weighed on the scales, crushed and 50 ml of a 7.5% solution of trichloroacetic acid was added. The sample was stirred with a magnetic stirrer for 30 minutes. The resulting supernatant was extracted through dehydrated two-layer filter paper. 5 ml of supernatant was collected in a test tube and 5 ml of thiobarbituric acid solution was added. It was heated in a water bath at a temperature of 90 °C for 40 min. and cooled. Centrifuged - 5 min. at the speed of rotation - 4000 rpm.

DPPH determination: The rate of free removal of DPPH (1,1-diphenyl-2-trinitrophenylhydrazine) was determined according to the method of Sridhar Kandy [196]: 2.0 ml of the extract was mixed with 1,1-diphenyl-2- and a solution of trinitrophenylhydrazine (2.0 ml) in a dark in the room [197]. The absorbance value of A1 (517 nm) was determined after 20 min. exposure Under the same conditions, the absorbance of control A2 (anhydrous ethanol instead of DPPH) and the absorbance value of control A0 (anhydrous ethanol) were determined. Calculation formula:

$$DPPH = \left[1 - \frac{A1 - A2}{A0}\right] \cdot 100\ \% \qquad (10)$$

where A_0 is the absorption value of the blank sample; A_1 – sample absorption value; A_2 is the absorbance value of the control.

Microbiological indicators: The total number of microorganisms, CFU in 1.0 g of product, not more than DSTU ISO 4833:2006 (ISO 4833:2003, IDT); Bacteria of the E. coli group (coliforms), in 1.0 g of product DSTU ISO 4832:2015(ISO 4832:2006, IDT; Sulfite-reducing clostridia, in 0.01 g of product DSTU 8381:2015; Bacteria of the genus Proteus, in 0.1 g of product DSTU EN12824:2004; Staphylococcus aureus, in 1.0 g of product DSTU ISO 6888-1:2003; Pathogenic microorganisms, in particular bacteria of the genus Salmonella, in 25 g of product DSTU EN 12824:2004; L. monocytogenes, in 25 g of product DSTU ISO 11290-1:2003.

2.4 Statistic analysis

The obtained results were analyzed using a data processing system (DPS V8.5.lnk, China) and the standard error was determined. Differences between the average values of experiments were determined by Duncan's multiple test ($p<0.05$).

SECTION 3
JUSTIFICATION OF THE CHOICE OF RAW MATERIALS AND CONDITIONS FOR THE PRODUCTION OF COOKED SAUSAGES FROM DIFFERENT TYPES OF MEAT

Sausage is a multi-component complex food system. The content of the components of the sausage recipe affects its properties: color, taste, aroma, consistency, appearance. These factors depend on both the main meat raw material and secondary recipe ingredients: vegetable additives, phosphates, etc. Finding and using new components prompts their analysis and use. Therefore, research in the field of composition of raw materials among themselves is a relevant issue today.

3.1 Justification of the use of a new type of vegetable raw material for the production of cooked sausages

Two plant components were investigated in the work, namely: the root crop from the Areca taro plant and wheat bran. Adding these ingredients will increase the nutritional composition and quality of meat products. Table 3.1 shows the biological composition of plant raw materials.

Table 3.1- Biological composition of plant raw materials

Test results	Areca taro power	Wheat bran
Protein，g/100g	6.25	18.5
Fat，g/100g	0.1	0.6
Dietary fiber，g/100g	20.1	31.4
Total sugar，g/100g	12.3	8.6

Note: The analysis results were verified and certified by Wuzhou Institute for Food and Drug Control from China

It was determined that the content of protein and dietary fiber in wheat bran is 2.9 and 14.9 times, respectively, higher than that in taro areca powder. The advantage of taro powder is its 6 times lower fat content and high sugar content - 1.4. The combination of these two ingredients, in the recipe of cooked sausages, will contribute to the saturation of the product with a high content of protein and dietary fiber. Taro areca powder will give meat products a special and pronounced aroma and improve their taste properties [198, 199].

3.1.1 Optimization of the taro powder manufacturing process

3.1.1.1 Plan of a one-factor experiment on the production of taro powder

Taro powder was obtained using an air flow spray dryer (centrifugal air spray dryer, model DFRP-5, Dafeng Spray Drying Equipment Co., Ltd. Wuxi City, China).

Univariate experimental design:

– Dosage of embedding agent: xanthan gum - 0.01% and microcrystalline cellulose MC - 0.9%, 1.2%, 1.5%;

- Spray drying parameters: liquid concentration in the material - 28%, inlet air temperature - 180 °C, air supply speed - 40 ml/m, spray speed - 20,000 rpm;

– Estimated air supply speed parameters - 25, 45, 65, 85 ml/min;

– Calculated parameters of air intake temperature - 150, 170, 190, 210 °C;

– Parameters of calculation material and liquid concentration - 25%, 30%, 35%, 40%;

– Estimated speed of atomizer parameters - 12000, 15000, 18000, 21000 rpm.

By checking indicators of water activity, flour yield, color and other results, the quality of taro powder was determined.

3.1.1.2 Optimization of taro powder drying

Select the best result of the single factor test, and use the orthogonal test to optimize the spray drying parameters (Feed rate, Wind temperature, Material liquid concentration, Atomizer speed). The orthogonal test is shown in table 3.2.

Table 3.2.—Factor and level of orthogonal test of spray drying of areca taro powder

Level	Factor			
	Atomizer speed, r/min	Feed rate, mL/min	Wind temperature, °C	Material liquid concentration, %
1	16000	55	180	22
2	18000	65	190	25
3	20000	75	200	28

The results of the orthogonal test were shown in table 3.3.

Table 3.3.— Results of the orthogonal experiment of spray drying of taro powder

No.	Factor				result	
	A: Atomizer speed, r/min	B: Wind temperature, °C	C: Material liquid concentration, %	D: Feed rate, mL/min	Fluidity, cm	Powder extraction rate, %
1	1	1	1	1	11	14.84
2	1	2	2	2	10.8	13.93
3	1	3	3	3	11.2	15.48
4	2	1	2	3	10.5	15.35
5	2	2	3	1	10.8	12.48
6	2	3	1	2	10.8	14.58
7	3	1	3	2	10.8	15.08
8	3	2	1	3	10.9	15.12
9	3	3	2	1	10.7	12.85
k_1	33	32.3	32.7	32.5	–	–
k_2	32.1	32.5	32	32.4	–	–
k_3	32.4	32.7	32.8	32.6	–	–
R	0.9	0.4	0.8	0.2	–	–
Factor priority	A>C>B>D					
Optimal combination	$A_1B_3C_3D_3$					

The primary and secondary order that affects Fluidity: the speed of atomizer >the concentration of material liquid >the inlet wind temperature >the Feed rate. The optimal combination of process parameters is the formula A1B3C3D3. The following optimal drying parameters were set: atomizer speed - 16,000 rpm, wind temperature - 200 °C, liquid material concentration - 28%, air supply speed - 75 ml/min [178]. Since there was no optimal combination in the orthogonal test, three verification tests were carried out under the optimal conditions.

The results were averaged, and the yield of the whole powder of taro was 11.8cm. Compared with the data of the orthogonal test group, the yield was significantly increased, and the yield of the whole powder of taro was 0.6cm higher than that of the optimal group. Other authors used the following parameters to obtain strawberry powder: the inlet temperature was 200 °C, the material flow rate was 60 ml/s, and the nozzle speed was 25,000 rpm, which obtained the best operating parameters [200].

Therefore, to obtain taro powder, it is necessary to: clean the root crop of dirt and skin on a roller cleaning machine (MW2100 model, production capacity 0.5-2 t/h, Shandong Zhucheng Mingwei Food Machinery Co., LTD). Cut the cleaned root crop into slices 1 cm thick, on an industrial electric vegetable slicer (model: OP-6600, production capacity 300 kg/h). Send to cook in an autoclave (model RT 700-1200, production capacity 100 kg/h, Zhucheng Ritong Machinery Co., LTD) at a temperature of 110 °C for 20-30 minutes and cool. Homogenize the resulting mass in a cutter for 3-5 minutes. and dried in a spray dryer (model DFRP-5, production capacity 5 kg/h. Da-feng Spray Drying Equipment Co., Ltd., China). Grind the dry taro powder using a mill and sift it on a perforated sieve with a hole size of 80 mesh.

The parameters of the spray drying process of taro powder were optimized using a one-factor orthogonal experiment. The results showed that the addition of 0.01% xanthan gum and 1.2% microcrystalline cellulose (immersion medium) increased the yield of taro powder, accelerated drying, and prevented sticking to the walls. The optimal parameters of the spray drying process were determined: air temperature - 200°C, spray speed - 16,000 rpm, liquid material concentration - 28%, air supply speed - 75 ml/min. Under the indicated regimes, the taro powder had the following properties: saturated light purple color, better flowability, smooth consistency, pronounced aroma and taste of the Areko taro root. The main characteristics of taro powder: color indicators (2.9 - a*, 19.7 - L * and 3.3 - b*), water activity - 0.416 units, bulk density 0.4 g/ml, fluidity of the powder - 14 ,0 cm, extraction rate - 15.4%. The use of taro areca powder is a promising direction in the food industry [178].

3.1.2 Effect of different cooking temperature on quality of taro paste

3.1.2.1 Sensory evaluation of taro paste

Taro was cooked and mashed at different temperatures (100, 110, 121℃) according to sensory evaluation. The actual image of taro paste is shown in Figure 3.1, and the evaluation of taro paste is shown in Table 3.4 and Figure 3.2.

Figure 3.1-Pictures of taro paste at different cooking temperatures

It can be seen from figure 3.2 that the taro paste at 121℃ has lost its original lilac color and turned yellow, and the color of the taro paste at 100℃ and 110℃ was better. The 110℃ taro paste color was darker. As can be seen from the scoring results in table 3.4, the comprehensive score of poi at 110℃ is the highest, followed by 100℃ and 121℃.

Table 3.4-Sensory score of taro paste

Sample	Color	Texture	Arome	Taste	Overall review
100 ℃	8.73±0.45a	6.36±0.43b	8.27±0.36a	6.55±0.47b	5.98±0.27ab
110 ℃	7.36±0.28a	8.00±0.19a	8.09±0.25a	8.00±0.27a	6.29±0.11a
121 ℃	5.36±0.53b	8.27±0.36a	6.45±0.41b	7.27±0.47ab	5.47±0.24b

According to the results of the sensory assessment (table 3.4 and figure 3.2), it was established that the highest general assessment of the production of taro paste was obtained at a temperature of 100 °C. The paste obtained at this temperature stood out among other samples (110 °C, 121 °C) with its dense structure, rich aroma and taste.

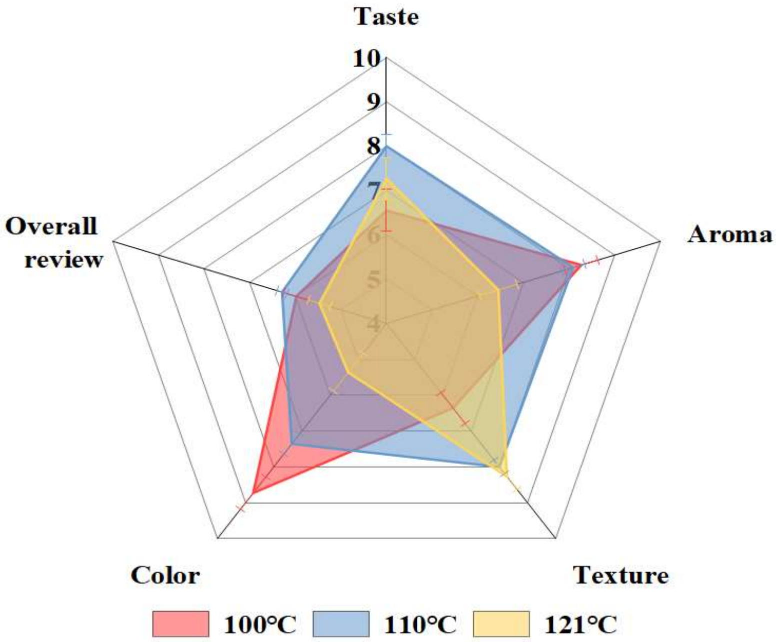


Figure 3.2-Radar chart of taro paste sensory evaluation

3.1.2.2 Gelatinization characteristic of taro paste

Formation of structural characteristics of taro paste depends on many factors. The studied temperature range (100°C -121°C) affected the gelation of taro paste.

Table 3.5-Gelatinization characteristics of taro paste different temperatures

Sample	PV/cp	TV/cp	FV/cp	BV/cp	SV/cp
100°C	803.67± 12.25a	757.67± 9.39a	1037.00± 16.82a	46.00± 6.66a	279.33± 9.94a
110°C	600.33± 13.86b	565.67± 5.46b	802.67± 6.44b	34.67± 8.76a	237.00± 2.52b
121°C	390.33± 8.76c	371.33± 6.01c	566.67± 3.18c	19.00± 8.50a	195.33± 3.18c

It can be seen from the results in table 3.5 that the viscosity of taro paste showed a decreasing trend with the increase of temperature, and there were significant differences in peak viscosity, valley viscosity, final viscosity and rebound value among different treatment groups, but no significant differences in disintegration value. And the viscosity of taro paste boiled at 100℃ is more than 2 times that of 121℃ treatment group.

However, Cui Wen-xue et al. [201] found that the starch of Long taro and Hexiang taro were heated at 50-95℃ and the viscosity values showed an increasing trend with the increase of temperature. The PV of the dragon taro at 50℃ was 1647 cp and that at 95℃ was 4183 cp, and the results were opposite.

There are two reasons for the analysis. First, the high temperature makes the areca taro starch gelatinized. Second, unlike the starch, areca taro contains more than 1% dietary fiber, which has better resistance and water retention, which can accelerate the disintegration of the starch.

3.1.2.3 Texture Profile Analysis of taro paste

The texture properties of paste prepared from taro at different temperatures changed significantly (except for recovery). Hardness values were 110℃ taro paste greater than 121℃, greater than 100℃ (table 3.6). The elasticity, cohesiveness, adhesiveness and chewability increased with the increase of temperature, and the difference was significant. The main reason is that the water content of taro paste at 100℃ was large.

Table 3.6-TPA of taro paste different temperatures

Sample	Hardness (N)	Springiness	Cohesiveness	Gumminess(N)	Chewiness (N)	Resilience
100℃	321.49± 2.04b	0.38± 0.003c	0.39± 0.002c	126.17± 0.63c	49.50± 0.70c	0.08± 0.001a
110℃	339.37± 4.22a	0.61± 0.021b	0.49± 0.008b	159.48± 1.09b	103.67± 2.93b	0.08± 0.001a
121℃	333.53± 5.53ab	0.83± 0.012a	0.57± 0.005a	196.26± 2.38a	162.05± 0.59a	0.08± 0.001a

There are also different structural characteristics of rice cooked at different temperatures. However, the result is the opposite, the hardness decreases as the pressure increases (the temperature increases) [202].

3.1.2.4 X-ray diffraction of taro paste

The crystal configuration of starch in taro paste can be analyzed by XRD pattern (Figure 3.3).

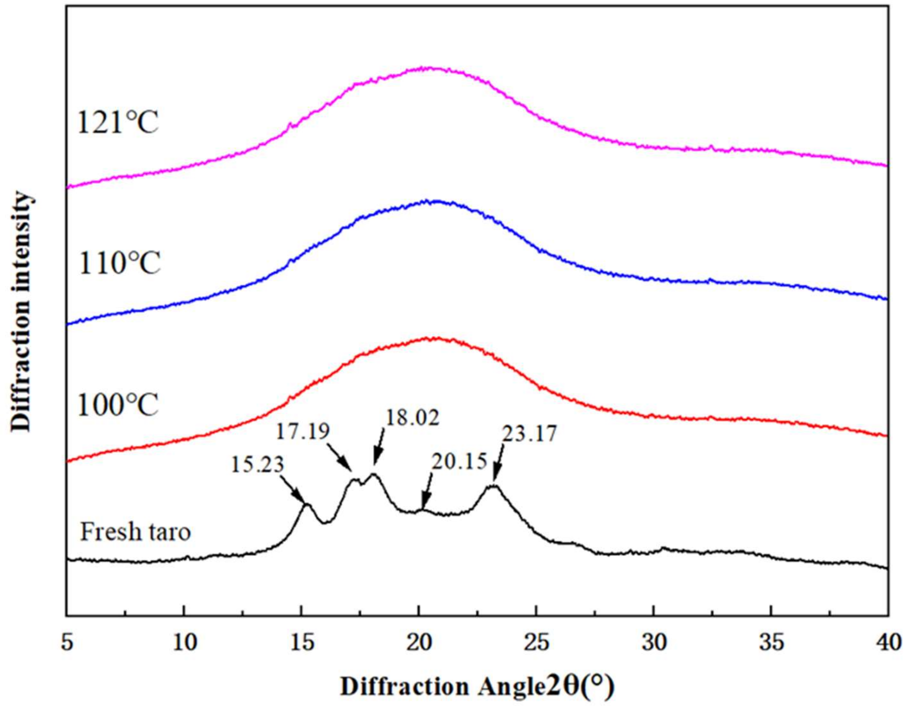


Figure 3.3- X-ray diffraction of taro paste

X-ray diffraction of dried and pulverized areca taro samples and areca taro treated at different temperatures. As can be seen from Figure 3.4, the 2θ angles of areca taro starch had obvious peaks around 15°, 17°, 18° and 23°, the diffraction peaks at 17° and 18° were connected double peaks, and the crystal structure of Areca taro starch was A-type crystal structure [203, 204].

After heating at different temperatures, the characteristic diffraction peak of the areca taro starch disappeared completely, but the V-crystal peak of areca taro starch at 20° increased significantly. Crystallinity decreased from 50.89% to 3%-6%. The crystallinity of fresh taro was 50.89%, and the crystallinity of 100℃, 110℃ and 121℃ is 3%, 6.29% and 5.03%, respectively. The results showed that the crystal region of areca taro starch was destroyed when treated at different temperatures from 100 ℃ to 121℃.

3.1.2.5 External digestion of taro paste

RDS is rapidly digestible Starch, SDS is slow digestible starch, and RS is resistant starch. SDS refers to starch that can be completely digested and absorbed in the small intestine but is slow, so it has a certain function of prevention and control for patients with diabetes and obesity [205]. The results showed (table3.7) that different temperatures had significant effects on the digestive characteristics.

Table 3.7- External digestion of taro paste

Sample	SDS, %	RDS, %	RS, %
100℃	16.2±1.0c	56.0±0.3a	18.8±0.3a
110℃	23.2±0.5a	59.4±0.1c	17.4±0.6ab
121℃	20.1±0.2b	64.2±0.3b	15.1±0.2c

The starch content of taro paste cooked at 110 ℃ was the lowest in rapid digestion and the highest in chronic digestion. The two results were significantly different ($P< 0.05$). Therefore, Taro paste cooked at 110℃ was more beneficial to health. Wang Weiliang, the study also showed that moist heat treatment could significantly reduce the content of fast-digestible starch in Lipu taro starch. When the moisture content of moist heat treatment was 25%, the content of fast-digestible starch in Lipu taro starch decreased by 7.63%, while the slow-digestible starch and resistant starch increased by 4.52% and 3.33%, respectively, to achieve the best effect [206].

3.1.3 Analysis of nutrient and aroma components of taro paste

3.1.3.1 Analysis of nutritional health index and physical property parameters of taro paste

Taro paste is another form of raw taro. Compared with taro flour, taro paste and frozen taro paste can preserve the natural flavor and improve the taste of the product. In addition, the water content of taro paste was 64.4%, which was compatible with other components (Table 3.9). The content of amylopectin in taro paste was 41.33 mg/g.

Based on the results of Table 3.9, the content of 16 types of amino acids in taro paste was analyzed. The highest content of aspartic acid was 0.38 g/100 g, followed by glutamic acid, arginine, phenylalanine and serine, which were 0.22, 0.18, 0.13, 0.12 g/100 g, respectively.

Table 3.8—Nutritional and Hygienic Indexes of Taro Paste

Sample	Nutrition and hygiene indicators	Treatment	Amino acid g/100g	Treatment	Amino Acid g/100g
Protien g/100g	2.42	Aspartic acid	0.38	isoleucine	0.07
Fat g/100g	0.2	threonine	0.08	leucine	0.16
Amylose mg/g	4.28	serine	0.12	Tyrosine	0.03
Amylopectin mg/g	41.33	glutamate	0.22	Phenyla-lanine	0.13
Moisture content %	64.40	glycine	0.1	Lysine	0.11
Total number of Colonies CFU/g	80	alanine	0.09	histidine	0.05
Total number of Molds CFU/g	<10	valine	0.1	Arginine	0.18
Escherichia coli MPN/g	<3.0	Methio-nine	0.02	proline	0.06
Total amino acids					1.90

According to the results of the work, the main physico-chemical, structural-mechanical and color characteristics of taro paste were determined (table 3.9). It was determined that taro paste has the necessary viscosity, which is - 54.43 mPa/s, has moisture retention capacity and has a sufficient red color (6.38). Therefore, in the process of developing sausage products, introducing taro paste into the recipe - it will improve the quality of cooked sausage.

Table 3.9—The physical parameters Indexes of Taro Paste

Sample	Result	Treatment	Result
Water holding capacity %	6.63	L*	62.19±2.29
Freezing loss %	0.93	a*	6.38±0.44
Unfreeze loss %	23.84	b*	2.86±0.33
Viscosity mPa.s	54.43±1.29	△E	35.99±3.06

3.1.3.2 Analysis of aroma components of taro paste

Chromatographic studies were conducted to understand the effect of temperature on taro aroma The effects of different heating temperatures (100°C, 110°C, 121°C) on the aroma of paste are shown in table 3.10, Appendix A.

As can be seen from Table 3.10, depending on the manufacturing temperature of 100°C, 110°C, 121°C, taro paste has a different content of flavor and aroma components, which is - 49 types, 71 types, 39 types of organic compounds, respectively. The aromatic components in the taro paste made at a temperature of 110 °C were the most. These are mainly alcohol, ether, acidic aromatic substances, their total content is 71 units, in the other two samples - (100°C - 49 units, 121°C - 39 units). The number of alkanes was the highest at a temperature of 110 °C - 31 units, and the relative content was not higher than other samples, and was - 228.46 units.

Table 3.10– Qualitative and quantitative content of organic compounds in taro paste

Sample		100°C	110°C	121°C
Aldehyde	Quantity	9	9	9
	Content/(ng/g)	257.33	128.44	271.44
Alcohols	Quantity	6	11	5
	Content/(ng/g)	18.42	85.12	40.8
Esters	Quantity	2	9	2
	Content/(ng/g)	7.49	46.1	10.21
Acids	Quantity	0	6	1
	Content/(ng/g)	0	448.61	19.08
Ketones	Quantity	1	2	1
	Content/(ng/g)	18.44	20.93	30.79
Alkanes	Quantity	29	31	19
	Content/(ng/g)	431.88	228.46	447.67
Heterocycles and other classes	Quantity	3	3	2
	Content/(ng/g)	266.42	42.34	180.01
Total	Quantity	49	71	39

In the taro paste obtained at a temperature of 100 °C, no organic acids were detected, only 1 - at a temperature of 121 °C and 6 - at a temperature of 110 °C. 9 types of esters of taro paste obtained at a temperature of 110 °C and only 3 other types were detected. Taro paste made at a temperature of 121 °C had the highest flavor rating, followed by taro paste made at 110 °C. Although the taro paste made at 110°C had the most aromatics, the characteristic flavors were insignificant. Li Xiaochun studied the effect of cooking time on the flavors of red sphingolum. After cooking, the main flavors were: nonaldehyde, capric aldehyde, octyl aldehyde, (Z)-2-nonenal, benzaldehyde, (E,Z)-2, 6-nonenal, phenylacetaldehyde, d-limonene, which showed different from fresh odor sample characteristics such as fat flavor, flavoring, and meat flavoring. Aldehydes accounted for more than 45% of the total number of samples of the two groups [207].

In pursuit of the goal of preserving the biological value of taro root products, in future work it is recommended to use taro paste rather than powder.

3.1.4 Main normative indicators and quality characteristics of taro products

According to the results of the research, two types of product were produced according to the processing of the Areco taro root: taro paste and dry taro powder. A visual diagram of the production of taro products is shown in figure 3.4.

Fig.3.4-Diagram of the process of making taro paste

The peculiarity of obtaining taro paste from powder (clause 3.1.1.2) is the use of an energy-efficient industrial drying cabinet (model SH-1 BeeStar). Drying at a temperature of 60 ºC makes it possible to obtain a product with a moisture content of 45-55%, with better quality and organoleptic characteristics. The resulting product is packed in polymer bags and stored in cooling chambers at a temperature of 6-8°C for 12 months.

According to research data, relevant regulatory documentation was developed - TUU 10.3-04718013-008:2022. "Concentrated and dried taro products" for the specified products (Appendix B).

Concentrated taro products (puree, paste) are products made from whole or crushed, coarsely grated or grated taro roots or by reconstitution of taro powder.

Dried taro products (powder) is a product made from pre-prepared, dried and ground taro root particles.

In terms of organoleptic, physico-chemical indicators, the content of toxic elements and mycotoxins, and safety indicators (microbiological indicators), concentrated and dried taro products must meet the requirements specified in Appendix C.

Thus, taro and bran are useful plant materials. Analysis of the nutritional composition of taro and bran is useful for further product development. The high-quality raw material and auxiliary material of sausage is a high content of dietary fiber and protein. Taro powder and taro paste are commonly used as auxiliary materials in the food industry. In this section, the processing technology of taro powder was optimized, and the physical properties, nutritional and health components, and aroma of taro paste prepared at different temperatures were analyzed. The comprehensive consideration of many indices of taro paste at 110°C is good and can be used in the development of sausage making technology.

3.2 Justification of the technology of making cooked sausages from different types of meat with vegetable raw materials

The addition of vegetable raw materials with a high content of dietary fiber and protein improves the nutritional composition of cooked sausages. In order to obtain the best amount of addition and ensure the quality and safety of sausages, it is necessary to study and analyze the properties of the product in terms of physico-chemical, structural-mechanical, color, sensory and microbiological indicators. This section examines the influence of vegetable raw materials on the quality of cooked sausages from different types of meat.

3.2.1 Characteristics of cooked pork sausage with different contents of taro paste

To develop the technology for making boiled sausages with vegetable ingredients, the recipe for boiled pork sausages was chosen as the basis. The sausage recipe contains, (kg): 80 - of lean pork, 20 - of pork lard, 1.6 - of wheat bran, 1.5 - of potato starch, 1.4 - of salt, 0.3 - of phosphate, 0.2 - of pepper, 0.2 - of red yeast rice, 4 - of rice wine.

To determine the efficiency of using taro paste in cooked pork sausages, it was proposed to introduce taro paste in the amount of 0% (Control), 4% (T1), 8% (T2), 12% (T3), 16% (T4), 20% (T5), respectively (table 3.11) and its effect on quality characteristics was investigated. Increasing the amount of taro paste decreased the amount of potato starch, kg: (1.5; 1.2; 0.9; 0.6; 0.3 ;0).

Table 3.11-Recipes for cooked pork sausage with different contents of taro paste

Raw material,（kg）	Control	T1	T2	T3	T4	T5
Lean pork	80	80	80	80	80	80
Pig fat	20	20	20	20	20	20
Taro paste	0	4	8	12	16	20
Wheat bran	1.6	1.6	1.6	1.6	1.6	1.6
Potato starch	1.5	1.2	0.9	0.6	0.3	0
Ice water	20	20	20	20	20	20
Salt	1.4	1.4	1.4	1.4	1.4	1.4
Phosphate	0.3	0.3	0.3	0.3	0.3	0.3
Pepper	0.2	0.2	0.2	0.2	0.2	0.2
Rice wine	4	4	4	4	4	4
Red yeast rice	0.2	0.2	0.2	0.2	0.2	0.2

The cooking losses and stability of the sausage emulsion after the addition of taro paste are presented in Table 3.12 [217].

As shown in table 3.13, the cooking losses of the samples in each experimental group were significantly lower than in the control when a portion of the potato starch was replaced by another content of taro paste in the pork sausage. Among the five experimental samples, the sample with taro paste had the best result – T2 [217]. The starch and dietary fibers contained in taro paste contributed to some extent to the fat stability and water-holding capacity of the minced meat [208]. Li Yudong and other scientists found that bran fiber helps increase water absorption and product yield [209].

Table 3.12—Physical parameters of cooked sausages with different content of taro paste [217]

Sample	Moisture loss, %	Fat loss, %	Cooking loss, %
Control	4.75 ± 0.04^{a}	0.93 ± 0.03^{a}	14.58 ± 0.06^{a}
T1	4.67 ± 0.15^{ab}	0.52 ± 0.48^{a}	13.58 ± 0.07^{a}
T2	4.21 ± 0.21^{bc}	0.11 ± 0.54^{c}	9.16 ± 0.51^{bc}
T3	4.37 ± 0.02^{abc}	0.20 ± 0.00^{b}	9.27 ± 1.73^{c}
T4	4.56 ± 0.01^{c}	0.17 ± 0.00^{bc}	9.43 ± 0.63^{c}
T5	4.73 ± 0.02^{a}	0.23 ± 0.10^{b}	10.61 ± 0.69^{ab}

Color is one of the important quality indicators of meat products. Table 3.13 shows that in raw minced meat with taro paste, indicators of redness and yellowness had lower values than in the control. No significant changes were detected in terms of brightness. Taro paste has a light color, which affects the quality of minced meat. As the proportion of taro paste increased, the L * value of the sausage increased, the b * value showed unstable fluctuations, and the a * value did not change significantly. The amount of taro paste affects the final color of the product [217].

Table 3.13 - Color characteristics of cooked sausages with different content of taro paste [217]

Sample	Brightness value (L*)		Redness value (a*)		Yellowness value (b*)	
	Raw meat	Sausage	Raw meat	Sausage	Raw meat	Sausage
Control	54.90	60.25	21.36	10.15	11.51	12.36
T1	54.74	62.79	20.19	11.18	9.75	11.70
T2	54.81	63.58	20.08	11.78	10.19	12.38
T3	54.26	65.49	19.88	11.59	9.28	11.19
T4	54.43	65.29	19.17	11.86	9.99	12.94
T5	54.78	67.00	20.41	12.06	9.48	12.08

As shown in table 3.14, the hardness of the control sausage is 163.23, which is significantly higher than the values of the other samples. In experimental sample T4, the hardness of the sausage was 82.38, which was significantly lower than that of other samples. In terms of elasticity, there was no significant difference between the test samples and the control. In terms of elasticity, the measured elasticity value of the sausages in the control was 1.61, which was significantly higher than that of the other test samples. There was no significant difference between the measured values of the elasticity of the experimental samples. In terms of stickiness and chewability, the stickiness and chewability of the control sample were 102.39 and 175.25, respectively, which were significantly higher compared to the control [217]. Chen Jingxin and others [210] suggested that changes in sausage elasticity and viscosity may be caused by different sausage varieties and processing technology. The result that the chewability of the sausage prepared in this experiment shows irregular changes is contrary to the tendency of the chewability of the test, which may be caused by different test materials [211].

Table 3.14 - Structural and mechanical characteristics of cooked sausages with different content of taro paste [217]

Sample	Hardness (N)	Springi-ness	Cohesive-ness	Gummi-ness(N)	Chewi-ness(N)	Resili-ence
Control	163.23± 1.74a	1.61± 0.54a	0.63± 0.01a	102.39± 2.69a	175.25± 3.10a	0.04± 0.00a
T1	156.16± 7.35b	1.05± 0.08a	0.60± 0.01a	93.13± 5.03b	105.81± 2.36b	0.03± 0.01a
T2	106.27± 1.24d	1.19± 0.19a	0.63± 0.01a	66.58± 1.02c	76.75± 2.01c	0.03± 0.00a
T3	98.12± 1.51e	1.10± 0.18a	0.59± 0.05a	57.70± 4.01d	54.48± 1.35d	0.03± 0.00a
T4	82.38± 0.52f	1.19± 0.27a	0.63± 0.01a	49.74± 0.86d	53.78± 0.96d	0.03± 0.00a
T5	120.08± 3.53c	1.06± 0.10a	0.59± 0.02a	70.30± 1.20c	70.51± 1.64c	0.03± 0.00a

According to the test data, the T1 sample had the best viscosity and chewability indicators, and the hardness indicator was higher than the other samples. The T4 sample was the lowest in terms of sausage hardness, and the cohesiveness and elasticity were the best compared to other samples [217].

According to the results in figure 3.5, the bound water of sausage prepared by replacing starch with taro paste moves in the direction of short relaxation time, indicating that the content of semi-bound water added to taro increases, the water retention of the sausage increases, while hard-flowing water and free water have no significant changes [217].

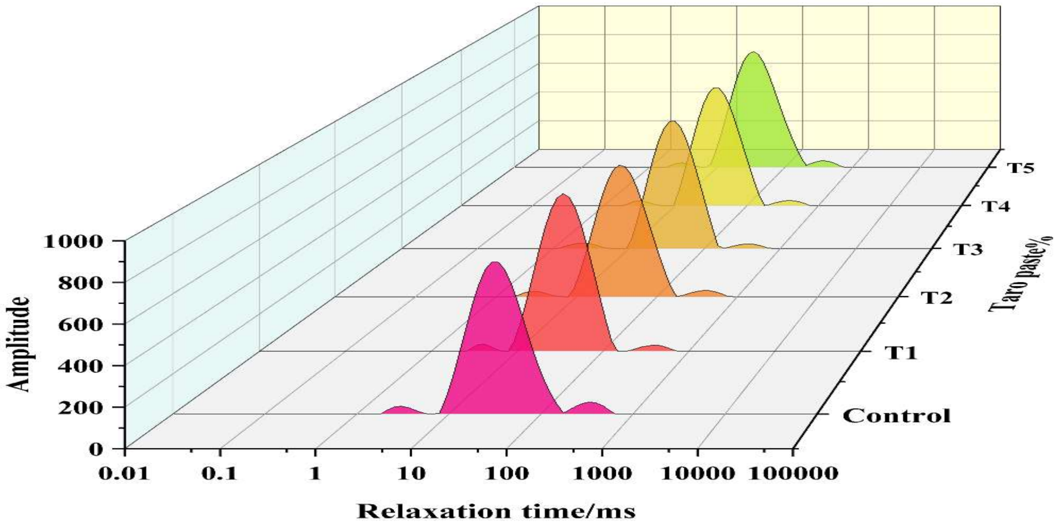


Figure 3.5 - Dependence of the relaxation time on the dynamic distribution of water in boiled sausages with different contents of taro paste.

Numai MRI software for unified and pseudo-color image processing was used to visually assess moisture distribution in cooked pork sausages with different taro paste content, the results of which are shown in Figure 3.6 [217].

The red part of the pseudo-color image indicates the highest moisture content and the strongest NMR signal. Next was the yellow part. The blue part was the weakest [212]. The red zone with the highest water content indicates the distribution of water molecules in the minced sausage and sausage after replacing starch with taro paste in different proportions. As the amount of taro paste added increases, the red and yellow areas on the pseudo-color diagram become larger and the water molecules in the sausage become more apparent. It showed that the water-holding capacity of ground sausage and sausage was improved after taro paste replaced part of the potato starch. The distribution of water in the red zone on the pseudo-color diagram is mostly distributed on the periphery. The central position was mostly yellow, indicating that the distribution of water in different parts of the minced meat is different, which is consistent with the research results of Gai Shengmei et al. [213].

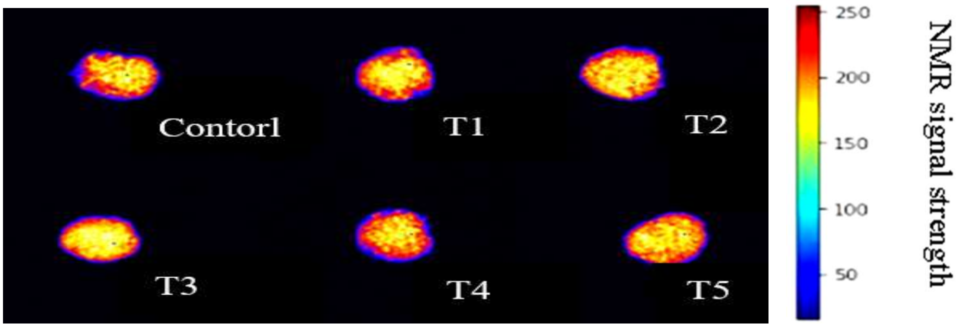


Figure 3.6 - Pseudo-color diagram of water distribution in pork sausage with different amounts of added taro paste

As shown in table 3.15, in the studied samples, according to the general assessment of sensory indicators (appearance, smell, taste, consistency), the values were higher (6.5-7.4) than in the control group - 6.30. The results showed that the addition of taro paste (16 kg) to a certain extent improved the appearance, smell, taste and overall acceptability of the pork sausage. The sample T2 using 8 kg taro paste had the highest score of 7.54. This indicates that the use of taro paste, instead of starch, in sausage can not only reduce the loss of water, fat and nutrients, but also improve the quality characteristics of the product. Even if the starch in the sausage is completely replaced by taro paste 20 kg, the nutritional quality of the sausage will not deteriorate, and the overall acceptability of the sausage will be perfect [217].

Table 3.15— Sensory characteristics of cooked pork sausages and taro paste [217]

Sample	Flavor	Color	Appearance	Consistency	Overall acceptance
Control	7.17±0.02[a]	6.68±0.95[ab]	6.52±0.02[ab]	6.24±0.08[b]	6.30±1.06[b]
T1	7.31±0.01[a]	7.05±0.67[a]	6.56±0.03[ab]	7.41±0.04[a]	7.40±1.43[a]
T2	7.80±0.04[a]	7.14±0.19[a]	6.79±0.01[a]	7.52±0.06[a]	7.57±1.20[a]
T3	7.77±0.00[a]	7.11±0.20[a]	6.79±0.03[a]	7.43±0.19[a]	7.10±1.37[ab]
T4	7.63±0.02[b]	6.86±1.05[ab]	6.38±0.01[b]	7.49±0.06[a]	6.90±0.88[ab]
T5	6.80±0.04[b]	6.16±0.15[b]	6.52±0.04[ab]	6.6±0.15[b]	6.52±0.04[b]

Taro paste is rich in high-quality dietary fiber, starch, water-soluble polysaccharides, vitamins, and inorganic salts [214]. Therefore, the use of taro paste in sausage is more appropriate (in terms of nutritional composition) than the use of starch. The results of the nutritional composition of taro paste sausage are shown in table 3.16 [217]. The protein content increases significantly with an increase in the proportion of taro paste, which is consistent with the results of a study by the University of the State of Campinas on the production of sausages with a reduced fat content [215].

Table 3.16—Physico-chemical properties of boiled pork sausages and taro paste [217]

Sample	Protein	Ash	Moisture	pH	Fat
Control	18.68	1.67	56.24	6.25	17.68
T1	19.05	1.77	56.41	6.38	15.05
T2	20.14	1.80	57.12	6.39	11.14
T3	22.05	1.81	57.33	6.39	8.05
T4	23.86	1.93	57.49	6.52	8.86
T5	24.16	1.94	57.56	6.62	6.16

From the results of the table, we can see an increasing trend in the content of the mass fraction of protein in the sausage from 18.68% to 24.16% with an increase in the fraction of added taro paste. With an increase in the proportion of taro paste, the pH value of the pork sausage increased gradually - 6.25-6.62. The results show that the addition of taro paste increases the pH value of the sausage, which is consistent with the conclusion that taro is an alkaline food. The content of mineral substances in the sausage increased due to the replacement of potato starch with taro paste. An increasing trend was observed, from 1.67% to 1.94% in mineral content, mainly because taro paste is a plant component, compared to refined starch. The indicator of the mass fraction of moisture in pork sausage increased (56.41 – 57.56%) after adding taro paste [217]. The fat content in the experimental samples was 1.2-2.9 times lower compared to the control, which was similar to the results of the study by Li Junke et al. [216].

It was found that at taro paste content 8 kg sausage cooking losses were the lowest, emulsion stability was the best, firmness and chewability were moderate, and elasticity was the best. As a result, the amount of starch decreased by 1.7 times compared to the control formulation. The results of this part of the data were published in [217].

3.2.2 Characteristics of boiled sausages using duck meat

Different raw materials significantly affect the quality characteristics and taste of sausages. Most sausages are made from pork as the main raw material. Recently, they use meat from chicken, duck, rabbit, nutria, etc. Nowadays, breeding and processing of ducks is growing rapidly. A significant amount of duck meat is exported to Japan, South Korea, Europe and elsewhere, providing a direction for the development of duck meat products [218]. Therefore, the use of duck meat in the production of boiled sausages is relevant.

To develop the technology of boiled sausages, it was proposed to replace part of the pork meat with duck meat in the following quantities: 10%, 20%, 30%, 40%, which are shown in table 3.17.

The quality of sausages with the addition of duck meat was evaluated according to the following indicators: sensorial, cooking losses, moisture and fat losses, and sausage hardness (table 3.18). The values of sensory indicators increase with an increase in the amount of duck meat in the recipe. The overall sensory evaluation of sample T4 reaches the maximum value - 6.15 points, compared to other samples. This is due to the fact that the content of protein and water in duck meat is higher compared to pork meat. Therefore, the taste of duck products has improved, as evidenced by organoleptic indicators.

Table 3.17— Cooked sausage recipe with added duck meat

Ingredients, (kg)	Control	Sample			
		T1	T2	T3	T4
Pork meat	100	80	70	60	50
Duck meat	0	10(10%)	20(20%)	30(30%)	40(40%)
Pig fat	10	10	10	10	10
Taro paste	0	8	8	8	8
Rice wine	4	4	4	4	4
Potato starch	1.4	0.7	0.7	0.7	0.7
Salt	1.4	1.4	1.4	1.4	1.4
Ice water	20	20	20	20	20
Other ingredients	3	3	3	3	3

Cooking losses in experimental samples with duck meat first increased and then decreased. When the addition amount reaches 30%, the cooking loss, water loss and fat loss reach the maximum, that is, the addition of 30% duck meat greatly reduces the water-holding capacity of the sausage. It was found that the addition of 40% duck meat reduces cooking and water losses and improves moisture retention compared to the control. Consistency properties affect the quality of sausages. Research results show that replacing a part of pork with duck meat reduces the hardness and cohesiveness of sausages (except T2). This may be due to the fact that the protein in duck meat holds water better than in pork. Homogeneity, thereby reducing the hardness and improving the elasticity of the product.

Table 3.18 - Qualitative indicators of boiled sausages with different content of duck meat

Sample	Color	Flavor	Text-ure	Taste	Integrate dgrade	Cooking loss, %	Water loss,%	Fat loss,%	Hard-ness,N
Control	5.8	5.9	5.6	5.2	5.62± 0.27	0.63	0.29	0.03	96.5± 4.55
T1	5.4	5.9	5.6	5.4	5.57± 0.20	0.77	0.51	0.09	64.6± 6.64
T2	6	5.8	5.7	5.6	5.77± 0.15	1.06	0.63	0.09	97.6± 15.42
T3	5.8	6.4	5.7	5.9	5.95± 0.27	1.20	0.97	0.14	90.5± 11.23
T4	6.5	6.1	5.6	6.4	6.15± 0.35	0.49	1.10	0.06	76.26± 2.60

Thus, the rational amount of replacing pork meat with duck meat is 40%, which ensures the guaranteed quality of the finished product. The results of this part of the data were published in [219].

3.2.3 Determining the amount of wheat bran for cooked sausage from different types of meat

To enrich cooked sausages with food fibers and protein, it was suggested to add wheat bran in the amount of 0.6 kg, 1.2 kg, 1.8 kg, 2.4 kg to the mass of raw materials. To determine the required number of sausages, quality characteristics of sausages were studied. The composition of sausage with different content of wheat bran is given in table 3.19.

The results in Table 3.20 show that the cooking loss and water loss in samples T1-T4 (with added bran) were significantly increased compared to the control group, while the fat loss results were the same (except for T3). Due to the presence of cellulose in the bran, the pores of the protein gel expand, as a result, the level of losses during cooking gradually increases with the increase in the number of bran [220].

Table 3.19 - Recipe for cooked sausage with the addition of wheat bran

Ingredients, (kg)	Control	Sample			
		T1	T2	T3	T4
Pork meat	50	50	50	50	50
Duck meat	40	40	40	40	40
Pig fat	10	10	10	10	10
Taro paste	8	8	8	8	8
Wheat bran	0	0.6	1.2	1.8	2.4
Salt	1.4	1.4	1.4	1.4	1.4
Ice water	20	20	20	20	20
Rice wine	4	4	4	4	4

The L* brightness value in sample T1 increased, and in the other three samples (T2, T3, T4) it changed, compared to the control. As the number of bran increased, their yellowness index b* increased slightly. In addition, the value of redness a* in the sample T3 - decreased, but the overall color value did not change. Adding a small amount of bran did not significantly change the color of the sausage. As the amount of wheat bran added increases, the pH value increases slightly, but the difference was not obvious (Table 3.20).

Table 3.20 - Physico-chemical parameters of boiled sausages with the addition of wheat bran

Sample	Cooking loss, %	Water Loss, %	Fat Loss, %	Brightness value (L*)	Redness value (a*)	Yellowness value (b*)	pH
Control	6.49	1.11	0.06	53.77±0.29	18.15±0.37	17.43±0.31	6.62±0.01
T1	1.34	0.51	0.09	56.40±1.47	17.35±0.94	18.2±1.19	6.62±0.02
T2	2.06	0.63	0.09	53.09±0.1	17.46±1.89	20.11±1.65	6.76±0.01
T3	3.06	2.34	0.03	54.60±0.29	16.57±0.55	20.01±0.18	6.66±0.02
T4	5.11	0.71	0.09	54.37±0.39	18.16±0.15	20.84±0.49	6.63±0.01

The results of the study in Table 3.21 showed that the addition of bran increased the viscosity, chewability, firmness, elasticity, cohesion and springiness of sausages, except for sample T1, as well as the viscosity, chewability and firmness of T2. Sample T1 had the highest elasticity and viscosity, and elasticity was second only to sample T3. The hardness of sausage products is affected by changes in moisture. The addition of bran to sausage is useful for improving the support of the tissue structure and increasing the firmness of the meat [220]. Song Dawei and others. believed that excessive addition of dietary fibers would easily lead to the destruction of the gel system formed by fiber and protein [221].

Table 3.21—Structural and mechanical characteristics of cooked sausages with the addition of wheat bran

Sample	Hard ness(N)	Springi ness	Cohesive ness	Gummi ness(N)	Chewi ness(N)	Resili-ence
Control	76.26± 2.60	0.48± 0.06	0.27± 0.04	20.72± 3.13	10.07± 2.69	0.057± 0.01
T1	66.73± 1.96	0.75± 0.16	0.44± 0.07	29.18± 4.47	22.93± 7.73	0.13± 0.03
T2	134.43± 25.18	0.68± 0.06	0.38± 0.06	52.32± 16.53	34.54± 8.20	0.09± 0.03
T3	90.73± 14.64	0.61± 0.02	0.41± 0.01	37.08± 5.31	22.68± 3.92	0.14± 0.01
T4	101.63± 5.33	0.58± 0.01	0.38± 0.03	38.75± 5.41	22.49± 3.51	0.10± 0.01

In summary, sample T2 sausages had the best gel properties, the highest chewability and firmness scores, moderate elasticity and springiness, and the best sausage structure properties.

The moisture content of sausages in samples control and T1-T4 was: 56.97%, 61.07%, 57.37%, 60.56%, 65.15%. From the results of research, it was established that the moisture content of sausage products with bran has increased. The results of the relaxation time of moisture distribution, in Figure 3.7, showed that the relaxation time of sausages T1-T4 with the addition of bran shifted to the left, indicating that the semi-bound water increases, and the bran can combine with water to form semi-bound water, keeping sausage moisture. The results of the moisture content study were consistent.

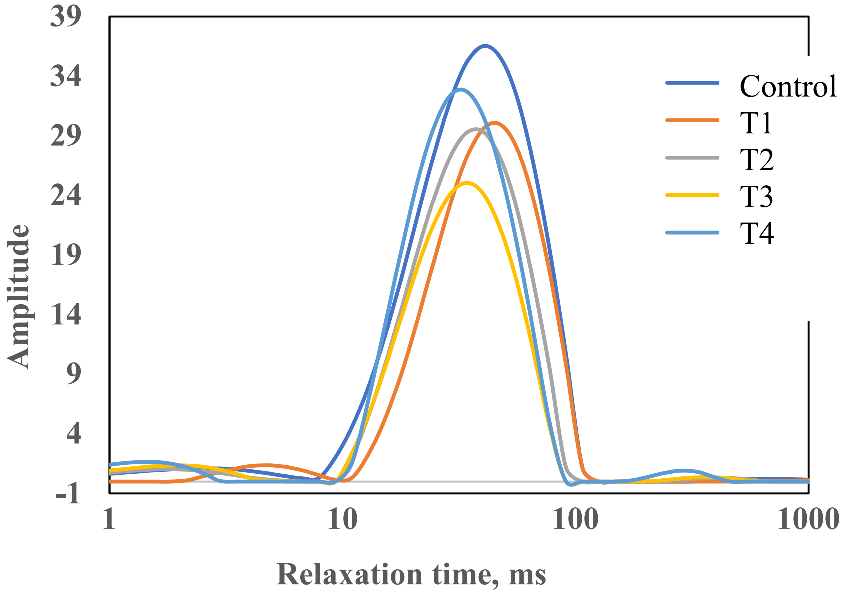


Figure 3.7 - Dependence of relaxation time on dynamic water distribution in cooked sausages with different types of meat and wheat bran

Table 3.22 shows the influence of the amount of bran on the sensory evaluations of sausages. With the increase of bran to 1.2 kg, the organoleptic indicators increased and had a higher total score of - 6.75. For their quantity of 1.8-2.4 kg, the sensory evaluation decreased - 6.02-5.82. Therefore, 1.2 kg of wheat bran is optimal for cooked sausages with different types of meat (pork and duck).

Table 3.22— Sensory evaluation of cooked sausages with wheat bran

Sample	Color	Flavor	Texture	Taste	Integrated grade
Control	5.7	5.8	5.4	5.4	5.57
T1	5.5	5.3	6.1	6	5.72
T2	5.9	7.2	6.6	7.3	6.75
T3	5.5	6.2	6	5.6	5.82
T4	5.7	6	6.2	6.2	6.02

In sample T2, the addition of wheat bran - 1.2% increased the viscosity, chewability, firmness, elasticity, cohesiveness and springiness of the sausages. Chewability and firmness were the highest, and sensory evaluation was the best. The results of the research can become a guideline for the development of new Ukrainian and Chinese sausage products. The results of this part of the data were published in [219].

3.3 Justification of the thermal parameters of the production of cooked sausages using different types of meat

Heat is used to promote gel formation. Heating affects the change in the rheological properties of minced meat [222]. The intermolecular chemical forces, protein conformation, and water distribution and migration of minced meat are closely related to gelation during heating. It can reflect the structural characteristics of protein molecules during gel formation [223]. In China, Cantonese-style sausages are dried with hot air. This is not a simple dehydration and drying process. It includes various reactions that affect quality: taste, color and texture. Modes of production of the specified products: temperature - 60 °C, duration - 30 hours [224]. The best technological conditions for making duck sausage by mixed bacterial fermentation (Lactobacillus sake and Pediococcuslactis - 2:1) are fermentation temperature - 35 °C, duration - 20.3 hours. The baking temperature is 76 °C, for 5.4 hours [225]. For a saturated smoked taste, the wood of fruit plants is used [226, 227]. Temperature treatment brings the product to readiness and improves taste and aroma. It is appropriate to study temperature-time processes.

For sausages based on: duck, pork, taro paste, and wheat bran, temperature and time modes of production were established. By changing the baking time, the following were investigated: losses during cooking, changes in texture, sensory and other characteristics. Sausage loaves were heated (fried) at a temperature of 90-100°C in a thermal chamber for 30 minutes. Further, rational parameters for the duration of the sausage cooking process at a temperature in the chamber of 75-85 °C for 40, 60, 80 and 100 minutes were investigated and established.

According to the recipe of sample T3 (section 3.2.3), rational modes of the cooking process were established. Their effectiveness was determined by quality indicators (table 3.23). Emulsification stability of sausages is indirectly assessed by water and fat loss. The results of this part of the data are published in [5].

Table 3.23 - Temperature-time modes of production of cooked sausages with different types of meat

Samples	Moisture loss, %	Fat loss, %	Cooking loss, %
40 min	1.81±0.14*a*	0.57±0.04*ab*	2.38±0.03*a*
60 min	1.43±0.04*b*	0.63±0.04*ab*	2.06±0.07*b*
80 min	1.47±0.10*b*	0.54±0.04*b*	2.01±0.03*b*
100 min	1.32±0.04*b*	0.65±0.06*a*	1.99±0.05*b*

As the baking time increases, the loss of the cooking process decreases. In the samples, during the cooking time - 60–100 minutes, the weight loss decreases, compared to the sample - 40 minutes. The trend of water loss and weight loss was the same, the difference in fat loss was insignificant. The longer the cooking time, the smaller the loss and the better the emulsification stability. The complexation reaction forms a denser three-dimensional framework structure, which additionally binds water molecules [228, 229]. According to the obtained results, the sample with a cooking time of 60 minutes was the best.

The color of the meat product is an important indicator. Table 3.24 shows the effect of cooking time on color characteristics of sausages.

Table 3.24 - Color characteristics of cooked sausages with different types of meat and cooking modes

Samples	Redness value (a*)	Yellowness value (b*)	Brightness value (L*)
40 min	16.72±0.18*a*	18.65±0.42*b*	56.29±0.36*a*
60 min	17.45±1.89*a*	20.11±1.65*a*	53.09±0.10*b*
80 min	16.85±0.36*a*	20.46±0.79*a*	54.06±0.75*b*
100 min	16.97±0.19*a*	19.09±1.51*ab*	53.72±3.41*b*

The results showed that with the increase of baking time, the brightness of sausages had a decreasing trend, and baking 60 min was significantly lower than 40 min. The value of red color increased, but the difference was not significant. According to indicators of yellowness b, no special changes were observed in the samples. Therefore, baking time could reduce the brightness of the sausage, and the red and yellow changes were not obvious.

The mass fraction of moisture in sausages depends on the cooking time, the results are shown in Figure 3.8.

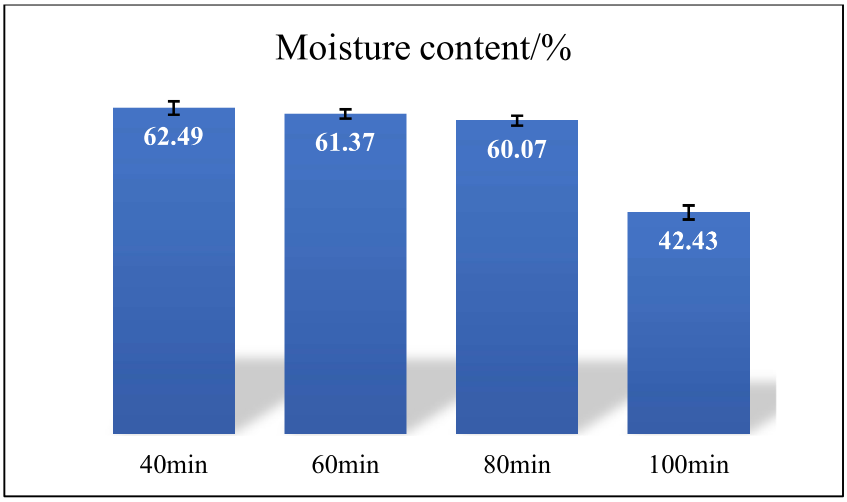


Fig.3.8 - Dependence of the mass fraction of moisture on the duration of cooking in cooked sausages with different types of meat

The moisture content of the sausage, for the duration of cooking 40 min. was 62.49%, and in 60 min., 80 min., 100 min. — 61.37%, 60.07%, 42.43%, respectively, showing a downward trend. It is better to choose a cooking time of 60 minutes. This is evidenced by the required readiness temperature in the center of the sausage loaf - 71 ºC [177].

Temperature and time regimes affect the active acidity of the internal environment of sausages (figure 3.9).

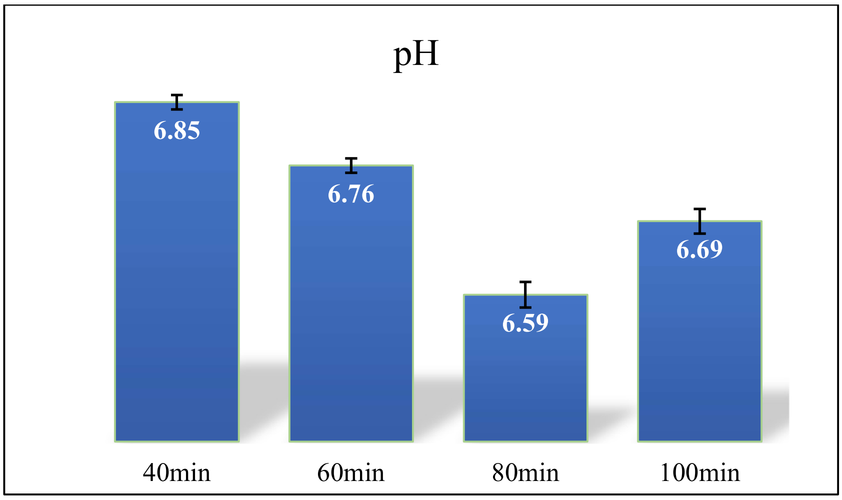


Fig.3.9- Dependence of the pH indicator on the duration of cooking in cooked sausages with different types of meat

The pH level of the sausages ranged from 6.85 to 6.59. With increasing cooking time, pH tended to decrease. Differences between samples were significant. When the cooking time was 80 min, the pH value of the sausage was the lowest - 6.59.

People like the elasticity and firmness of sausages. The influence of cooking modes on the consistency of sausages is shown in Table 3.25.

Table 3.25 - Table 3.25 - Structural and mechanical properties of cooked sausages with different types of meat and cooking modes [177]

Samples	Hardness (N)	Springiness	Chewiness (N)	Gumminess (N)	Resilience	Cohesiveness
40 min	101.4± 11.6*b*	0.5± 0.02*a*	15.81± 2.81*a*	31.55± 4.91*a*	0.07± 0.02*a*	0.31± 0.01*a*
60 min	134.4± 30.8*a*	0.68± 0.08*a*	34.54± 10.05*a*	52.32± 20.24*a*	0.09± 0.03*a*	0.38± 0.07*a*
80 min	81.3± 1.16*b*	0.57± 0.07*a*	18.04± 6.14*a*	31.06± 6.73*a*	0.09± 0.03*a*	0.38± 0.08*a*
100 min	92.7± 9.09*b*	0.74± 0.26*a*	32.36± 22.26*a*	40.50± 14.69*a*	0.11± 0.04*a*	0.43± 0.11*a*

The results of the study showed that the values increased after the cooking time reached 60 minutes, but the values decreased slightly when the cooking time reached 80 minutes, and the values began to increase again after 100 minutes. In addition to being firm, the sausages were also sticky and chewy. Properties, elasticity, cohesion and recovery reached a maximum after cooking for 60 min. There was no significant difference in hardness between 40 and 60 minutes of cooking. A similar trend was found in the samples with a manufacturing time of 60 minutes and 80 minutes for the cohesion index. The viscosity and springiness of the two samples were similar when cooked for 60 minutes and 100 minutes [177]. To improve the structural and mechanical properties (density) of meat products, xanthan gum, agar, gelatin, etc. are introduced [230, 231].

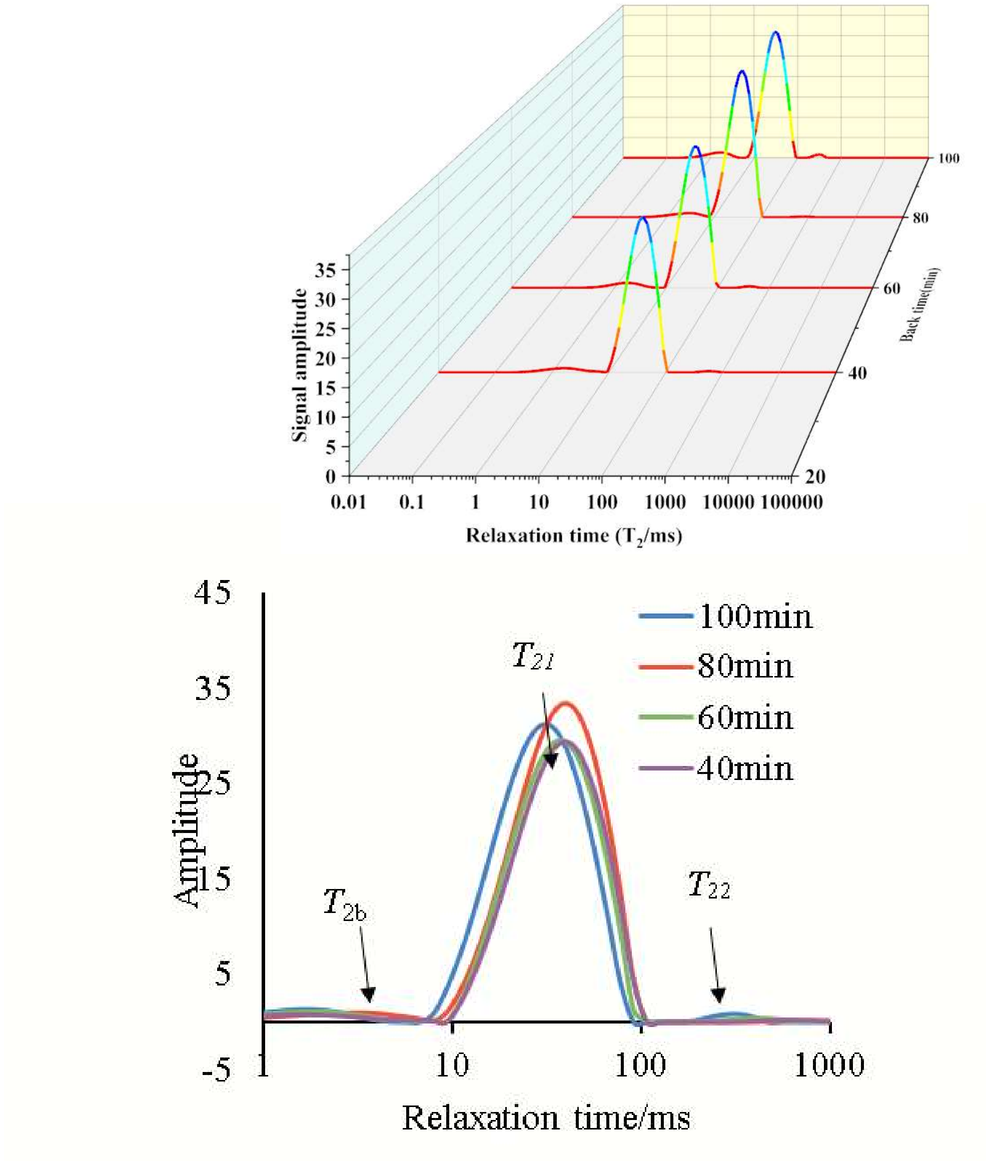
In general, the sample has the best quality and taste with a baking time of 60 minutes. Since cooking was mainly to improve consistency, elasticity and chewability improved significantly after 60 minutes of cooking [177].

Using low-field nuclear magnetic resonance technology to measure water distribution in sausages can elucidate the binding state of water and proteins and reflect the water-holding capacity of protein gels. The fitted T2 distribution presents three peaks corresponding to the relaxation time. According to the different degree of free movement of water molecules, they denote bound water (T2b), non-flowing water (T21) and free water (T22) from left to right. The relaxation time (T2) corresponding to hydrated, fixed, and free water was in the range of: 0.1–9.3 ms, 10–91 ms, and 175–900 ms, respectively, for the peaks (Figure 3.10).

In Figure 3.10 (A), samples with cooking times of 80 and 100 minutes shift to the left (Z axis). During the relaxation time - 10 ms, the peak became shorter, and the distribution of bound water increased. This indicates that increasing the cooking time better combines the protein and water and increases the bound water content, and the free water changes to water that does not drain easily[177].

Figure 3.10 (B) above clearly shows that the peaks at 80 and 100 minutes cooking time have been shifted to the left [177]. Between 10 and 100 ms, the sample with a manufacturing duration of 80 min had the largest peak area, followed by the 100, 60, and

40 min samples with the smallest peak area and a small difference. The semi-bound water content in the 80-min samples was the highest and the distribution was the widest [177].



(B)

Fig. 3.10 - Dependence of the duration of cooking on the distribution of moisture in the products:

(A) – three-dimensional graph of the T2 transverse relaxation time wave;

(B) is a two-dimensional plot of T2 transverse relaxation time.

The cooking process can distribute the fat in the sausage mince, help mature the protein and improve the sausages. Sensory evaluation directly reflects the acceptability. The results of [177] in Table 3.26 showed that as the cooking time increased, the sensory evaluation score was higher. Samples with a cooking time of 100 minutes had the highest score - 6.15. The taste was less pronounced in the sample with a cooking time of 40 minutes. The viscosity and texture of the 100-minute cooking samples were lower than the others [177].

Table 3.26 — Sensory evaluation of cooked sausages with different types of meat and cooking parameters [177]

Samples	Color	Flavor	Texture	Viscosity	Acceptability
40 min	5.7	4.8	5.8	5.6	5.47
60 min	5.9	5.6	5.7	5.8	5.75
80 min	5.8	5.7	5.9	6.1	5.87
100 min	5.7	6.0	5.9	6.9	6.15

In addition, heat treatment of sausages contributes to color saturation and appearance formation. Although the color scores did not differ between the samples, it was visually observed that prolonged cooking imparted a darker color to the sausage. Based on the results of research on the quality of cooked sausages, the optimal cooking time is 60-80 minutes [177].

Summarizing of the research, loss of meat juice during cooking in samples with a cooking duration of 60–80 minutes was significantly lower than in samples of 40 minutes. Samples from 60 min. duration of cooking, had the lowest values of lightness L*, the highest value of redness a* and the best color. Samples with cooking time: 40 minutes had the highest water content, after 100 minutes - the lowest. The pH value of the sample with a cooking time of 80 minutes was the lowest. The hardness of sausages with a cooking time of 60 minutes increased by 32.5%, and the difference was significant ($P>0.05$). When the cooking time is 80 minutes, the peak area corresponding to the T2 relaxation of the sausage was the largest together with semi-bound water [177].

Based on the above results of the sausage quality research, the optimal sausage cooking time was 60-80 minutes. This study provides a technical solution for the preparation of cooked sausages from various meats [177].

Conclusions to Section 3

1. In this section, a rationalized processing technology for taro powder and taro paste was proposed. The physicochemical, biological, microbiological properties and aromatic compounds of taro paste prepared at different temperatures were analyzed. Comprehensive consideration of many indices of taro paste made at 110 °C is optimal and can be used in the development of sausage technologies.

2. It has been proven that the optimal amount of taro paste is 8 kg in the recipe of pork sausages. The specified amount ensures minimal weight and moisture loss of sausages during cooking by 37.2% and 11.36%, respectively, compared to the analogue. Contributes to the improvement of emulsion stability, increases water-binding capacity by 20%, protein content by 1.34 times and reduces the amount of animal fat in sausage by 1.6 times, compared to the analogue. According to the results of the textural profile of the sausage products, it was determined that the indicators of cutting force, chewing ability and elasticity are reduced by 35%, 56.2% and 25%, respectively, compared to the analogue. With the addition of taro paste, the amount of potato starch was reduced by 60%.

3. According to the results of the work, it was established that a rational substitute for pork meat is duck meat in the amount of 40%. The set amount of duck meat gives the sausage product better elasticity and reduces the cutting effort by 1.26 times, compared to the analogue. The selected amount of duck meat in the sausage recipe achieves the highest organoleptic score of 6.15.

4. The specified rate of bran – 1.2% did not contribute to a significant loss of mass of sausage products during heat treatment and ensured the structural stability of the protein framework, due to the gel-forming properties, in combination with the tissue protein framework. The selected amount of bran (1.2%) did not significantly affect the change in color characteristics, comparing it with the analogue.

5. As a result of studies of the temperature-time parameters of the heat treatment of cooked sausages with vegetable raw materials, it was established that the rational cooking temperature is 75-85˚C with a duration of 60-80 minutes. Under these modes,

the loss of meat juice is reduced by 1.26 times (due to the binding of loosely bound moisture) and contribute to a 1.15 times greater output of the product, compared to the duration of cooking - 40 minutes. The addition of vegetable components to the recipe of sausage products affected the consistency of the product. The structural and mechanical characteristics of sausages had better values of indicators: shear strength and elasticity (increase by 1.3 times compared to exposure of 40 minutes). With a longer cooking time (100 minutes), a significant loss of weight, moisture and deterioration of the consistency of the product was observed. High-quality sausages are obtained after cooking in the interval of 60-80 minutes, as evidenced by the results of the organoleptic evaluation, which was 5.87 points.

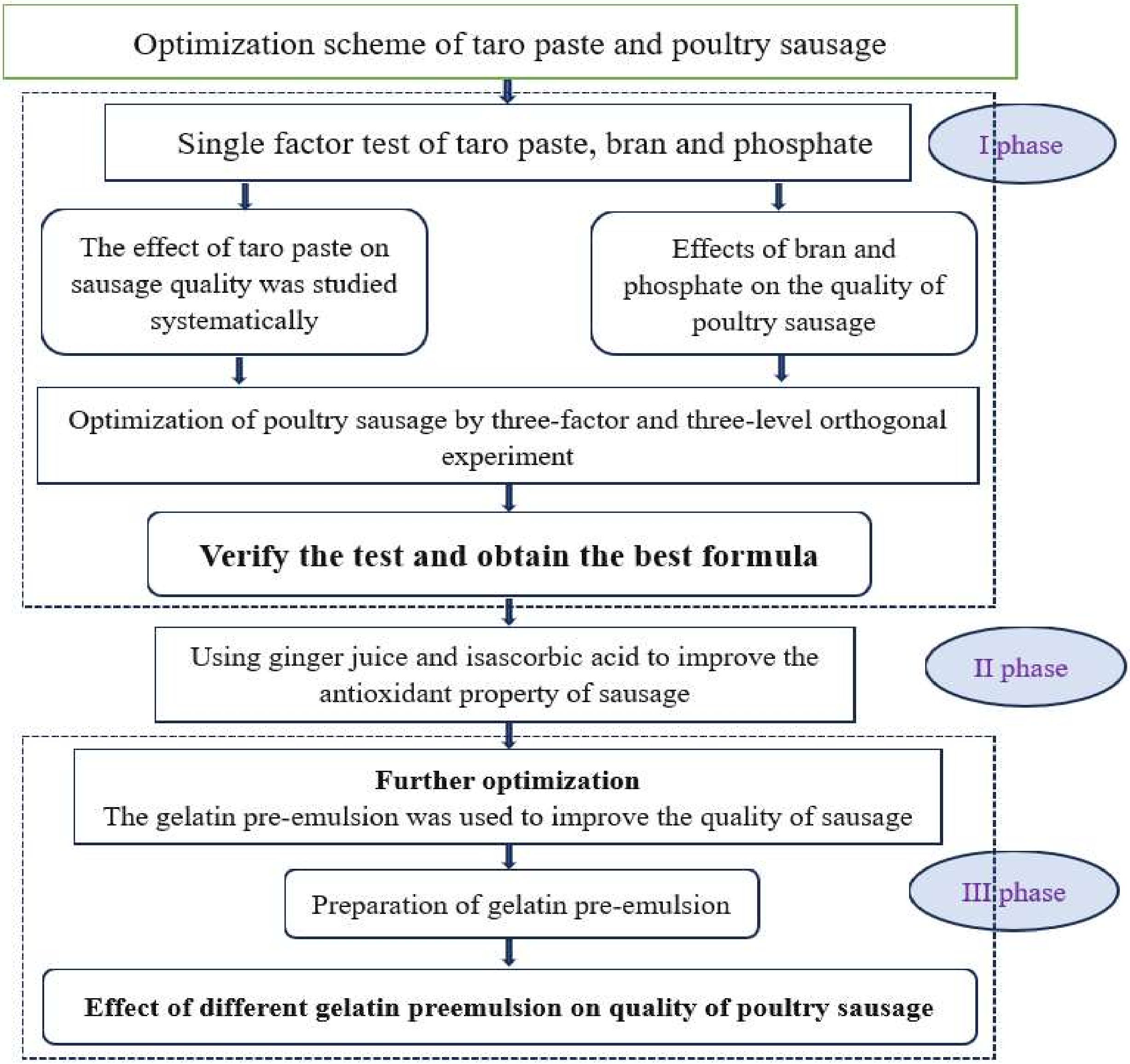
6. Based on the results of the work, two new recipes of cooked sausages with vegetable products (taro paste and bran) were developed: the first one is made from pork; the second - with combined raw materials (duck and pork meat) - table 3.27.

Table 3.27 - Recipe for cooking boiled sausages with different types of meat

Raw material, kg	Pork sausage (Control)	Pork-Taro paste-Bran sausage	Pork-Duck-Taro paste-Bran sausage
Raw meat, kg, (calculated as 100kg)			
Lean pork	80.0	80.0	50
Duck meat	——	——	40
Pig fat	20.0	20.0	10
Taro paste	——	8	8
Wheat bran	1.6	1.2	1.2
Potato starch	1.4	0.7	0.7
Salt	1.4	1.4	1.4
Complex phosphate	0.3	0.3	0.3
Complex spices	0.8	0.8	0.8
Pepper	0.3	0.3	0.3
Rice wine	4	4	4
Ice water	20	20	20
Red yeast rice	0.2	0.2	0.2

SECTION 4
OPTIMIZATION OF THE RECIPE OF COOKED SAUSAGE FROM DIFFERENT TYPES OF POULTRY MEAT ENRICHED WITH VEGETABLE RAW MATERIALS

The addition of various vegetable raw materials to the recipes of sausage products has become the focus of attention of food researchers all over the world [232, 233]. The optimization scheme for developing the technology of cooked sausages from different types of poultry meat enriched with vegetable raw materials is shown in figure 4.1.



Figureь 4.1-Experimental scheme

According to the diagram in figure 4.1, the optimization of the technology of cooked sausages from different types of poultry meat was carried out in 4 stages:

Stage 1: determination of the optimal amount of taro paste, wheat bran and phosphate complex using orthogonal analysis.

Stage 2: determining the rational dose of dyes (beetroot powder, fermented rice, red wine), antioxidants (ginger and onion juice, sodium isoscorbinate).

Phase 3: oil-gelatin emulsion preparation technology and determination of its concentration.

4.1 The influence of different concentrations of taro paste on the quality parameters of poultry meat sausages

Adding taro paste to cooked sausages can change their nutritional content and create a special product. Guo Xiaoting et al. [234] investigated the quality of pork rolls from different amounts of taro puree. The results showed that under the conditions of adding a larger amount of the functional ingredient - pureed taro, the structural-mechanical (firmness and elasticity) and organoleptic properties of the pork roll tended to increase, and then to decrease. Mashed taro has changed the quality of pork knuckles. Therefore, the development of a new product from duck and chicken meat (as the main raw material) and taro paste (as an auxiliary raw material) is relevant.

As the meat component of the recipe of cooked sausages from poultry meat, duck and chicken meat was taken in a ratio of 3:2. Taro paste in different amounts was added to give cooked poultry sausages the necessary quality characteristics (structural-mechanical, physico-chemical and organoleptic).

The studied samples differed among themselves in the amount of added taro paste: 12 kg, 14 kg, 16 kg, 18 kg, 20 kg to the weight of the raw material (100 kg). Sample T1 was a control - without taro paste in the formulation. The amount of potato starch in the recipe was reduced from 15 kg to 5 kg, according to the amount of taro paste.The product formula was shown in table 4.1.

Table 4.1 - Recipe for boiled poultry sausages

Ingredients, (kg)	Sample					
	T1 (Control)	T2	T3	T4	T5	T6
Duck meat	60	60	60	60	60	60
Chicken breast	40	40	40	40	40	40
Taro paste	0	12	14	16	18	20
Potato starch	1.5	0.9	0.8	0.7	0.6	0.5
Salt	1.5	1.5	1.5	1.5	1.5	1.5
Rice wine	4	4	4	4	4	4
Pepper	0.4	0.4	0.4	0.4	0.4	0.4
Complex spices	0.6	0.6	0.6	0.6	0.6	0.6
Ice water	16	16	16	16	16	16

In table 4.2. the effect of various additives of taro paste on parameters: pH, moisture content, losses during cooking, and emulsion stability of poultry sausages is given. The addition of taro paste had a significant effect on the values of indicators: moisture content, pH, cooking loss and emulsion stability of poultry sausage ($P<0.05$), compared to the control (T1). As the amount of taro paste increased, the pH value of the sausage first increased and then decreased. For quantitative taro paste - 16 kg (sample T4), the pH value of the sausage reached the highest value, the moisture content of the sausage first decreased, and then increased. When the addition amount of taro paste was 14 kg (T3 group), the moisture content was the lowest, and there was no significant difference with the sausage moisture content of T4 group ($P>0.05$). The cooking loss and emulsion stability of sausage did not change regularly. When the addition amount was 16 kg, the cooking loss, water loss and fat loss reached the lowest value, which was significantly different from the control group ($P<0.05$), which may be related to the water absorption characteristics of dietary fiber in taro paste. When the amount of taro paste was more than 16 kg, the sausage losses during cooking gradually increased. This is explained by the fact that the water retention of the sausage decreased and led to a significant loss of sausage juice. The study by Li Junke et al. [235] showed that when 10% taro was added to the pork patty, the cooking yield was the highest, and when the addition amount exceeded 10%, the steaming yield of the pork patty decreased. This shows that the addition of taro paste can effectively improve the quality of poultry sausage. The T4 group (the addition amount of taro paste is 16 kg) has the highest pH value, the lowest cooking loss rate, and the highest emulsification stability (P<0.05). The optimum addition amount of taro paste in poultry sausage is 16 kg.

Table 4.2 — Physico-chemical parameters of poultry sausages

Sample	pH	Moisture content, %	Cooking loss, %	Water loss, %	Fat loss, %
T 1 (Control)	6.06 ± 0.15^{d}	64.69 ± 0.33^{b}	0.18 ± 0.01^{d}	0.15 ± 0.02^{e}	0.03 ± 0.02^{ab}
T 2	6.07 ± 0.15^{cd}	67.20 ± 0.45^{a}	0.17 ± 0.01^{d}	0.16 ± 0.01^{d}	0.01 ± 0.01^{ab}
T 3	6.10 ± 0.15^{b}	59.58 ± 0.73^{d}	0.25 ± 0.01^{c}	0.24 ± 0.01^{c}	0.02 ± 0.02^{ab}
T 4	6.20 ± 0.15^{a}	60.50 ± 1.14^{d}	0.11 ± 0.01^{e}	0.10 ± 0.00^{f}	0.01 ± 0.01^{b}
T 5	6.11 ± 0.10^{b}	62.99 ± 0.17^{c}	0.29 ± 0.00^{b}	0.26 ± 0.01^{b}	0.03 ± 0.01^{ab}
T 6	6.09 ± 0.12^{bc}	63.07 ± 0.16^{c}	0.36 ± 0.02^{a}	0.32 ± 0.01^{a}	0.04 ± 0.01^{a}

Color is an important qualitative characteristic of meat products. Table 4.3 shows the effect of various taro paste additives on the color parameters of poultry sausage. The results showed that the indicators of brightness L* and redness a* first increased and then decreased (P<0.05). The value of the yellowness index b*, had a tendency to decrease at the beginning and increase (P<0.05) values with increasing amount of taro paste. It can be seen from the results that adding 16 kg of taro paste (T4 group) can significantly increase the brightness value L* and redness value a* of poultry sausage, and reduce the yellowness value b* of sausage, which shows that adding a certain amount of taro paste can significantly increase the brightness of poultry sausage. The reason is a decrease in the brightness of the color, due to the content of purple fibrous filamentous substances in taro areca [236].

Table 4.3 — Color characteristics of boiled poultry sausages

Sample	Brightness value (L*)	Redness value (a*)	Yellowness value (b*)
T1 (Control)	56.32±0.05^{d}	8.28±0.20^{c}	11.14±0.12^{ab}
T2	60.31±0.14^{c}	10.20±0.11^{b}	11.42±0.24^{ab}
T3	62.59±0.96^{a}	10.32±0.25^{b}	11.66±0.59^{a}
T4	62.46±0.50^{ab}	11.29±0.09^{a}	10.32±0.40^{c}
T5	61.68±0.24^{b}	10.98±0.39^{a}	10.78±0.13^{bc}
T6	59.59±0.41^{c}	10.20±0.29^{b}	11.13±0.40^{ab}

The addition of taro paste had a significant effect (Table 4.4) on the firmness, stickiness and chewability of poultry sausage (P<0.05), but no significant effect on elasticity, cohesion and recovery (P<0.05), compared to the control.

Table 4.4 — Structural and mechanical properties of cooked sausage from different types of poultry meat

Sample	Hard ness(N)	Springi ness	Cohesive ness	Gummi ness(N)	Chewi ness(N)	Resili-ence
T1 (Control)	9564.08± 54.82a	0.92± 0.05^{ab}	0.82± 0.04^{a}	7884.15± 441.72^{a}	7222.20± 753.52^{a}	0.46± 0.03^{a}
T2	7395.92± 68.39b	0.94± 0.03^{a}	0.79± 0.07^{a}	5874.45± 447.70^{b}	5515.97± 502.21^{b}	0.43± 0.04^{a}
T3	7261.53± 54.98b	0.88± 0.03^{ab}	0.84± 0.04^{a}	6114.56± 286.59^{b}	5368.97± 414.37^{b}	0.45± 0.03^{a}
T4	5284.02± 106.95e	0.86± 0.02^{b}	0.82± 0.04^{a}	4338.90± 215.08^{d}	3712.84± 223.07^{d}	0.44± 0.03^{a}
T5	5522.35± 81.03d	0.87± 0.03^{ab}	0.81± 0.04^{a}	4453.19± 272.37^{d}	3871.33± 303.49^{cd}	0.42± 0.03^{a}
T6	6277.13± 157.44c	0.91± 0.05^{ab}	0.83± 0.07^{a}	5176.56± 339.22^{c}	4719.49± 571.30^{bc}	0.42± 0.05^{a}

Guo Xiaoting and others.[234] showed that the addition of taro paste had a significant effect on stickiness and chewiness of taro meatballs, but no significant changes in springiness, firmness, and cohesion. The indicators of hardness, stickiness and chewiness of the sausage first decreased and then increased due to the addition of more taro paste compared to the control. The indicators of elasticity, cohesion and recoverability decreased. It shows that the addition of taro paste can effectively reduce the hardness, stickiness and chewiness of poultry sausage. The poultry sausage in group T4 (the addition of taro paste was 16 kg) was firm and elastic, and has the best texture and taste.

In addition, the shear force value is an important index for evaluating the tenderness of meat and meat products, and the smaller the value, the better the tenderness of the meat. As can be seen from figure 4.2, compared with the control group T1, the shear force of the sausage showed a trend of first decreasing and then increasing with the increase of the amount of taro paste ($P<0.05$), indicating that the taro paste can improve the sausage within a certain range of addition. the tenderness of the sausage, but it will reduce the tenderness of the sausage beyond a certain range. The results showed that the addition of 16 kg of taro paste (T4 group) had the lowest shear force of the sausage, indicating that adding 16 kg of taro puree could make the poultry sausage tenderness the best, which was consistent with the measurement results of texture.

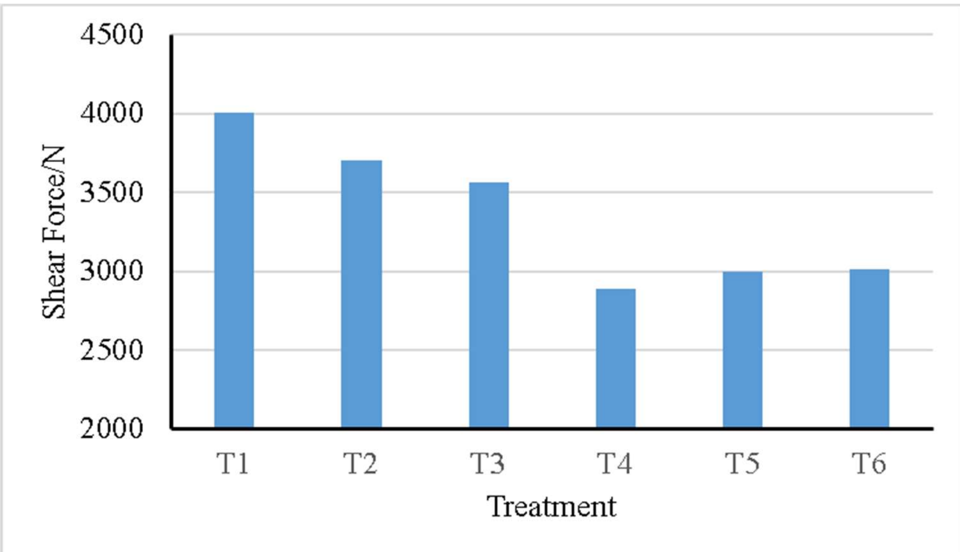


Figure 4.2 - The dependence of different amounts of taro paste on the shear strength of cooked sausages made from different types of poultry meat

The water distribution results of the sausage after adding the taro paste were shown in figure 4.3. It can be seen from figure 4.3 that the poultry sausage has 3 peaks, and the 3 peaks from left to right are bound water (T2b), difficult to flow water (T21) and free water (T22). Compared with the control group T1, different additions of taro paste can change the internal water distribution of the sausage. The relaxation time of bound water in sample T3 shifted towards a longer relaxation time. Whereas, the relaxation time of bound water in other samples (T2, T4, T5 and T6) shifted towards a shorter time. Sample T4 had the shortest relaxation time for bound water, indicating that water was tightly bound to the protein and not easily lost. From the area of the peak of heavy-flowing water, it can be seen that the content of non-flowing water in the sausage in the experimental samples is higher, compared to the control. The content of flowing water was no significant change in the relaxation time of free water, which indicated that the addition of taro paste changed the bound water and difficult-to-flow water in the sausage, so that the water in the sausage was tightly combined with the protein. Chen Yichun et al. used the pre-emulsion to replace the fat in the frankfurter sausage. The results also showed that the three water relaxation times were in the direction of shorter relaxation times, which also showed that the original non-flowing water in the sausage was more closely combined with the protein in the meat [236].

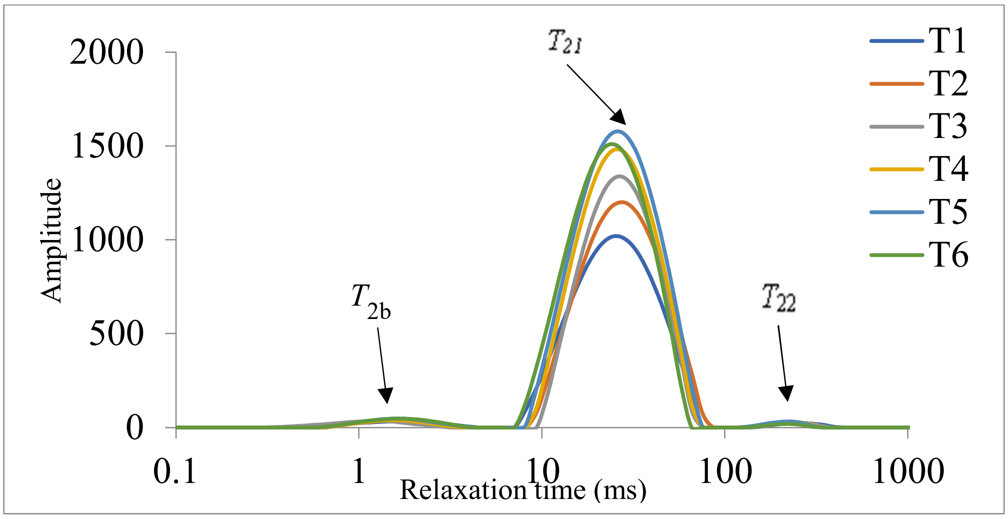


Figure 4.3 - The results of the effect of adding taro paste on the moisture distribution of poultry sausages

In Figure 4.4. the results of the microstructural analysis of poultry sausage with different contents of taro paste and potato starch are given. It can be seen from figure 4.4. that compared with T1 in the control group, the addition of taro can improve the structure of poultry sausage. The sausage in the control group has loose structure, many holes and uneven distribution. The addition of taro paste can effectively improve the internal structure of sausage, make the sausage structure compact and uniform, reduce holes, and improve the color of sausage, which is consistent with the structure of chromaticity value; However, when the taro paste exceeds a certain addition range, the structure of sausage will be loose again. Cooked sausage from different types of poultry meat sample T4 (16 kg of taro paste) had a better appearance on the cut. The consistency of the sausage was dense, homogeneous, without pores, which proves the effectiveness of the determined amount on the quality of the finished products.

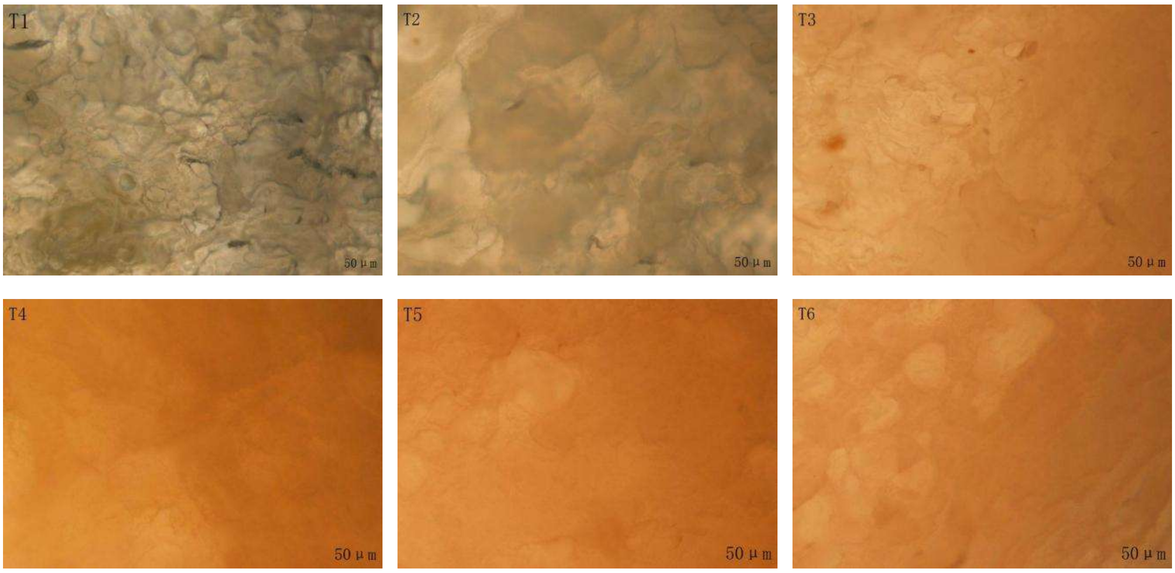


Figure 4.4 - The effect of different amounts of taro paste and potato starch on the microstructure of poultry sausage

According to the results of the sensory evaluation of cooked sausage, it was found that the indicators increased with the addition of taro paste, in the amount from 12 kg to 16 kg. With an increase in the application (18-20 kg) of taro paste, a tendency to decrease the sensory indicators was observed. Sample (T4), with the addition of 16 kg of taro, had the highest sensory evaluation score (Table 4.5). When the amount of taro paste added was low, the flavor of the taro paste in the sausage was too light, and the fragrance of taro paste can hardly be felt, with a heavy fishy smell and more pores. Looseness, decreased elasticity, and more pores; when the amount of taro puree added was 16 kg, the taro paste in the sausage had a moderate aroma, less fishy smell, firm texture, better elasticity, and higher overall acceptance. Therefore, a small amount of taro paste improves the sensory evaluation of poultry sausage.

Table 4.5 — Sensory evaluation of poultry sausages

Sample	Color	Flavor	Texture	Integrated grade
T1 (Control)	5.87 ± 0.15^{d}	6.47 ± 0.21^{d}	6.43 ± 0.12^{d}	6.77 ± 0.12^{c}
T2	6.63 ± 0.21^{c}	6.93 ± 0.15^{c}	6.87 ± 0.21^{bc}	7.23 ± 0.21^{b}
T3	6.97 ± 0.15^{b}	7.37 ± 0.12^{b}	7.13 ± 0.15^{b}	7.50 ± 0.20^{b}
T4	7.57 ± 0.21^{a}	8.07 ± 0.21^{a}	7.77 ± 0.25^{a}	8.13 ± 0.15^{a}
T5	7.13 ± 0.15^{b}	7.70 ± 0.20^{b}	7.03 ± 0.15^{b}	7.40 ± 0.20^{b}
T6	7.03 ± 0.21^{b}	7.57 ± 0.21^{b}	6.67 ± 0.21^{cd}	7.23 ± 0.15^{b}

In summary. Different concentrations (12 kg - 20 kg per 100 kg of poultry meat) of taro paste on the quality of poultry sausages were studied according to parameters: pH, microstructure, shear force, cooking, weight loss, emulsion stability, color, sensory evaluation and dynamics of moisture distribution. The results of this part of the data have been published [219].

4.2 Justification of the amount of wheat bran and phosphate complex for the recipe of cooked sausages from different types of poultry meat

Taro paste contains fiber, improves the nutritional composition of the sausage, but does not contribute significantly to the formation of a gel, which affects the organizational structure of the structure of the poultry meat sausage. Therefore, for better structuring of the experimental recipe with taro paste (80 g per 500 g of poultry meat), the synergistic effect of adding different amounts of wheat bran and phosphates on the quality of cooked sausages was studied.

4.2.1 Determination of the effect of different amounts of wheat bran on the spectral, structural-mechanical and sensory properties of cooked sausages from different types of poultry meat

In order to improve the quality characteristics (spectral, structural-mechanical and sensory) of cooked sausages from different types of poultry meat, the addition of a vegetable gel-forming ingredient - wheat bran - is proposed. For effective interaction with taro paste and poultry meat, it is suggested to add bran in the amount of 3 g, 6 g, 9 g, 12 g to the mass of raw materials. The control was a sample without bran - 0 g.

As shown in figure 4.5A, with the increase of bran addition amount, the redness value (a*) of sausage showed a downward trend, the brightness value (L*) showed a trend of first rising and then decreasing, and the yellowness value (b*) showed a trend of first decreasing and then increasing. When the addition amount was 6.00 g, the red value of sausage was the best, and the yellow value was the lowest. It showed that the addition of bran could reduce the brightness value (L*) and redness value (a*) of sausage, and when the addition amount exceeded a certain degree, the dirt yellow of bran itself would occupy the main position in the sausage system, so as to cover the color of sausage and affect the quality of sausage. This is consistent with the results of a study by Ye Dan [237, 238] et al., who compared the effect of unfermented and fermented bran on the difference in the color index of pork meatballs.

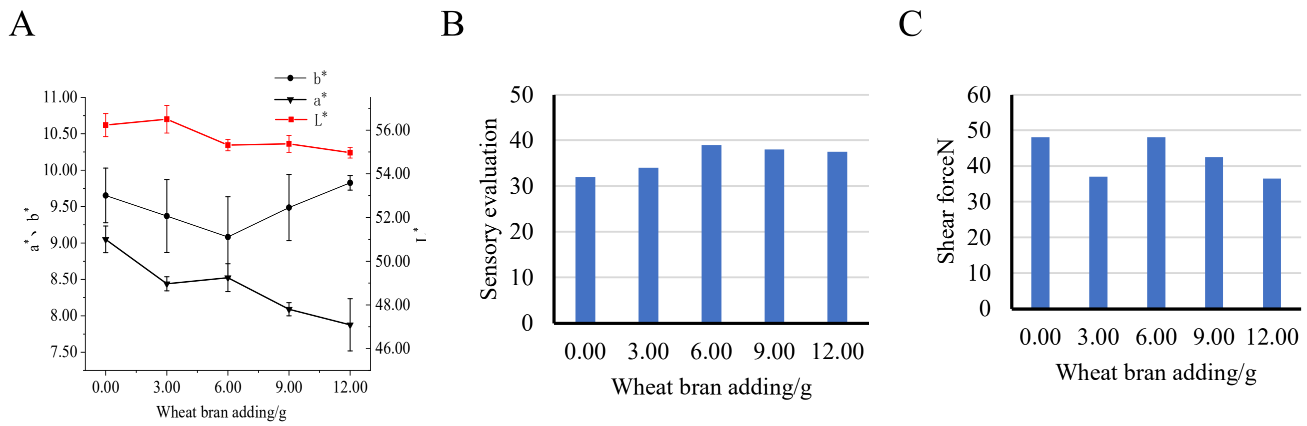


Figure 4.5 - Dependence of color indicators (A), sensory values (B) and cutting force (C) on different amounts of wheat bran in cooked sausages from different types of poultry meat

As can be seen from figure 4.5B, with the increase of bran addition, the sensory scores of sausages increased and then decreased. When the bran content was 6.00g, the total score reached the highest of 39.5 points, and then the score began to decrease, which may be related to the decline of color quality and taste of sausage.

As shown in figure 4.5C, the shearing force of sausages with bran added was all lower than that without bran added, indicating that the amount of bran added had a certain effect on the tenderness of sausages, and the shearing force of sausages with bran added showed a trend of first decreasing, then increasing and then decreasing. The shear force reached the maximum when the addition amount was 6.00g, and continued to decline after it exceeded 6.00g, which might be caused by the effect of the chamber structure system formed by bran and protein on the inside of the sausage, and then caused by the decline of its supporting effect after the effect was destroyed. Therefore, when excessive bran is added (9 g, 12 g), the internal system of sausage is easy to break down and the sausage is easy to produce loose taste. The quality evaluation process should be combined with the actual sense.

In conclusion, the quality of poultry sausage with taro paste was the best when the bran content was 1.2 %.

4.2.2 Determination of the effect of different amounts of phosphate complex on the spectral, structural-mechanical and sensory properties of cooked sausages from different types of poultry meat

For the formation of technological and functional properties - structure and better binding of the liquid fraction of the components of minced meat, it is suggested to use a complex of phosphates (sodium pyrophosphate 60%, sodium tripolyphosphate 39%, sodium hexametaphosphate 1%).

The work investigated the effectiveness of the interaction of phosphates in the recipe of boiled sausages with poultry meat and taro paste. The amount of phosphates added to the formulation was 1.0 g, 1.5 g and 2.0 g by weight of raw materials (500 g). The control was a sample without phosphates - 0g.

As can be seen from Figure 4.6A, as the addition of complex phosphate increased, the L* index (brightness value) first increased and then tended to decrease. The a* (redness) indicator, on the contrary, first decreased, then increased, and with the exposure time, a decrease was observed. The b* indicator (yellowness) decreased, but increased over time. By regulating pH of sausage system and chelating metal ions, composite phosphate can delay the oxidation reaction of products and promote the hair color of products [239, 240]. The results showed that adding 1.50 g compound phosphate could significantly increase the redness value and decrease the yellowness value, while adding 1.00 g compound phosphate could improve the brightness, redness value and in general quality of sausage.

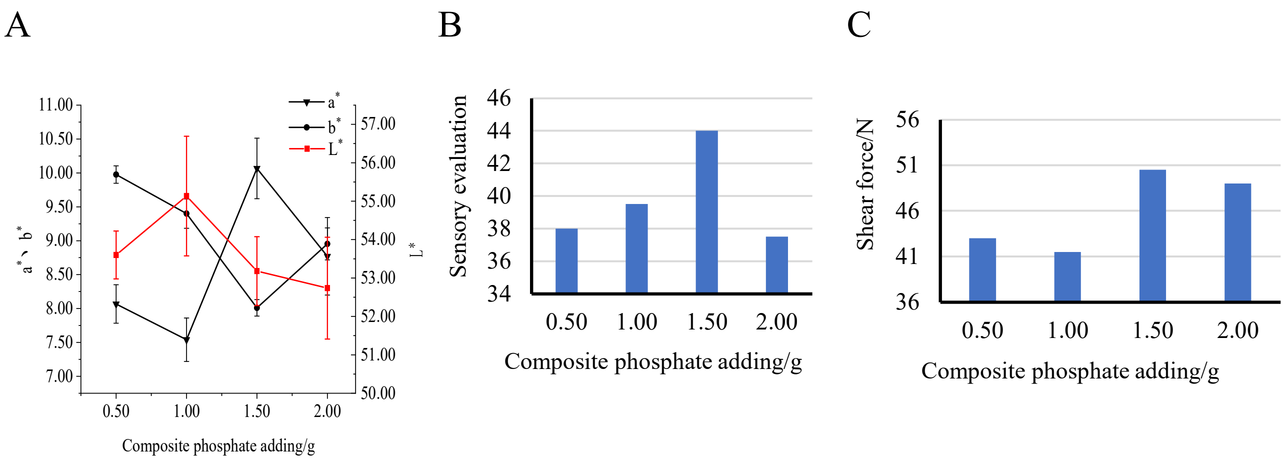


Figure 4.6 - Dependence of color indicators (A), sensory indicators (B) and cutting force (B) on different amounts of phosphates in cooked sausages from different types of poultry meat

As can be seen from figure 4.6B, with the increase of compound phosphate supplemental level, the sensory score of sausage showed an upward trend (1g, 1.5g) and then a downward trend (2 g). The highest total score was 43.7 when the composite phosphate was 1.50 g, and then the score began to decrease. The saponification reaction between the compound phosphate, in the amount of 2 g, and the excess oil in the product and the enhanced water retention effect made the sausage soft and astringent, which resulted in the decrease of sensory effect.

As shown in figure 4.6C, the shear force of sausage decreases first and then increases with the increase of compound phosphate addition, among which the shear force of sausage with the addition of 1g is the least. The reason may be that the alkaline neutralization of complex phosphate improves the pH and negative charge repulsion of sausage system, destroys the distribution of muscle fibers in tissues, promotes the dissociation of actomyosin into actin and myosinт [241], improves the water retention of sausage, and thus enhances the tenderness of sausage shear force.

In conclusion, the quality of poultry sausage with taro paste was the best when the compound phosphate content was 0.3 %.

4.2.3 Determination of rational quantities of ingredients in the recipe composition of cooked sausages from different types of poultry meat by orthogonal analysis

The cooking loss rate is an important indicator that affects the quality and sensory quality of sausages. It can reflect the water holding capacity of meat. The smaller the loss, the stronger the water holding capacity. When the cooking loss rate is high, it is easy to increase the loss of nutrients and pigments in sausages. Therefore, exploring the cooking loss rate is of greater significance for the quality changes of sausages during preservation. The results of orthogonal experiment 9 (3^3) are shown in table 4.6.

Table 4.6 - Analysis of orthogonal test results

Serial Number	A (Amount of bran added) /g	B (Amount of taro paste added) /g	C (Compound phosphate addition amount) /g	Sensory score	Shear force /N	Cooking loss rate, %
1	1 (4.50)	1（75.00）	1（1.25）	32.70	146.50	2.60
2	1	2（80.00）	2（1.50）	40.20	119.97	5.99
3	1	3（85.00）	3（1.75）	36.80	180.43	4.04
4	2 (6.00)	1	2	35.40	156.12	8.44
5	2	2	3	42.00	154.90	5.89

6	2	3	1	35.00	176.86	9.54
7	3（7.50）	1	3	37.70	116.91	6.22
8	3	2	1	41.20	131.50	4.88
9	3	3	2	37.40	105.85	6.15
K_1	109.70	105.80	108.90			
K_2	112.40	123.40	113.00			
K_3	116.30	109.20	116.50			
Range R	6.60	17.60	7.60			
Factor priority	B＞C＞A					
Optimization	$A_3B_2C_3$					
K_1	446.90	419.53	454.86			
K_2	487.88	406.37	381.94			
K_3	354.26	463.14	452.24			
Range R	133.62	56.77	72.92			
Factor priority	A＞C＞B					
Optimization	$A_3B_2C_2$					
K_1	12.63	17.26	17.02			
K_2	23.87	16.76	20.58			
K_3	17.25	19.73	16.15			
Range R	4.04	4.99	4.19			
Factor priority	B＞C＞A					
Optimization	$A_1B_1C_2$					

The larger the range R value, the greater the importance of the influence of this factor. Therefore, the impact of various factors on sensory scores was B>C>A. The impact on shear force was A>C>B, and the impact on cooking loss rate was B>C>A. Due to the comprehensive balance analysis, a comprehensive optimization combination could be obtained.

The equilibration was as follows:

1. Factor A: good for sensory score A3, good for shear force A3, good for cooking loss rate A1, while factor A in cooking loss rate was at the end, so select A3.

2. Factor B: B2 was good for sensory evaluation, B2 was good for shear force, and B1 was good for cooking loss rate. According to the comprehensive balance method, the two indicators in B2 were the best. Although B1was the main factor in cooking loss, adhering to the principle of maximizing the amount of taro paste added to sausages, B2 was chosen.

3. Factor C: C3 was good for sensory evaluation, C2 was good for shear force, and C2 was good for cooking loss rate. According to the comprehensive balance method, C2 had the best two indicators, and A was the second most influential factor in the sensory quality of C3, so C2 was chosen. The result of the optimal formula for the combination of components is A3B2C2.

According to the results of the orthogonal analysis, the presence of rational quantities of ingredients was established: taro paste - 16 kg, wheat bran - 1.5 kg, phosphate complex - 0.3 kg per 100 kg of raw meat. The determined norms allow to obtain a finished product with the following maximum indicators: sensory evaluation - 45 units , cutting force - 148.46 N, losses during cooking - 4.96%.

4.3 Study of the effect of antioxidants on the quality characteristics of cooked sausages from different types of poultry meat

Sausage products with a high fat content are prone to oxidation during processing and storage. Oxidation reduces the quality of sausages, promotes rancidity, affects smell, color change, loss of nutrients and formation of toxic substancesт [242, 243]. Consumption of such sausages threatens the health and even life of consumers [244, 245]. Therefore, protective ingredients such as antioxidants are added to prevent these defects. Nowadays, a special emphasis in the food industry is placed on natural ingredients.

Ginger juice is a unique substance that is a powerful antioxidant. Contains a significant amount of essential oils, essential amino acids, carbohydrates, vitamins - B3, B6, B2, B5, B9, C and minerals - iron, potassium, magnesium, phosphorus and zinc. One of the most important active substances in the composition of ginger juice is the compound gingerol (1-3%), which determines the smell and taste of the fresh root, and most importantly - prevents the creation of free radicals. The effect of heat treatment transforms gingerol through a reverse aldol reaction into zingerone, which is less pungent and has a spicy-sweet aroma. The daily dosage of the extract is no more than 4 g (4000 mg). The safety of ginger has been clinically confirmed in vitro and in vivo [246].

Onion juice contains: proteins - 1.1 g, fats - 0.1 g, carbohydrates - 9.3 g (sugar - 4.2 g), vitamins (pantothenic acid, riboflavin, thiamin, A, beta-carotene, betaine, B6, C, E, K, choline, folate, niacin), minerals (selenium, sodium, calcium, magnesium, manganese, copper, fluorine, iron, phosphorus, potassium, zinc). The main component of the juice is the antioxidant compound - quercetin. Quercetin - a natural biochemical substance of the group of flavonoids (vitamin of group P) has antioxidant and membrane-stabilizing ability, that is, it neutralizes the oxidation process - it leads to a decrease in the influence of free radicals. The daily dose of juice is 20-50 ml [247].

Sodium isoscorbate (sodium erythorbate, sodium isoscorbinate) is an antioxidant, with preservative properties, heat stable. Officially approved as a food additive by FAO/WHO. Sodium erythorbate is produced from starch by fermentation of microorganisms or synthetically. It is widely used in the food industry. Helps preserve color and increase shelf life, without any side effects. The recommended application rates for meat products are up to 50 g/100 kg of raw meat [248, 249, 250].

In order to inhibit oxidation processes in the technology of making cooked sausages from different types of poultry, it was proposed to use natural ginger and onion juice (3:2) and sodium erythorbate, and their synergistic effect on the quality properties of the finished product was investigated.

To determine the effective interaction of antioxidants with meat raw materials, it is suggested to add ginger juice in the amount of 3.0% (in experimental samples T2, T4) and 0.2% sodium isoscorbinate (in experimental samples T3, T4) to the mass of raw materials. The control (T1) was a sample without adding the indicated antioxidants (table 4.7).

Table 4.7 — Recipe of boiled poultry sausages with antioxidants

Ingredients, (kg)	Sample			
	T1 (Control)	T2	T3	T4
Duck meat	56	56	56	56
Chicken breast	40	40	40	40
Pork fat	4	4	4	4
Taro paste	16	16	16	16
Wheat bran	1.5	1.5	1.5	1.5
Complex phosphate	0.3	0.3	0.3	0.3
Rice wine	4.0	4.0	4.0	4.0
Onion Juice	2.0	2.0	2.0	2.0
Ice water	16.0	14.0	16.0	14.0
Salt	1.4	1.4	1.4	1.4
Pepper	0.4	0.4	0.4	0.4
Sodium d-isoascorbate	0	0	0.2	0.2
Ginger Juice	0	3.0	0	3.0

The effectiveness of antioxidants was determined by measuring the accelerated oxidation test (method of Yang Yifang et al.[251]) after 0 h, 3 h, 6 h, 9 h, 12 h, 15 h, 18 h. at a temperature of 37 ºC, according to indicators: acid number, TBARS, DPPH, structure, color, mass fraction of moisture and fat.

The results of cooking loss were shown in table 4.8.

Table 4.8.—Total weight loss during cooking during accelerated oxidation of poultry sausage

Sample	Cooking loss						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	0.24± 0.02^{c}	0.16± 0.02^{c}	0.11± 0.00^{c}	0.08± 0.02^{d}	0.07± 0.02^{b}	0.05± 0.02^{a}	0.04± 0.02^{a}
T2	0.66± 0.00^{a}	0.61± 0.02^{a}	0.54± 0.03^{a}	0.47± 0.01^{a}	0.14± 0.03^{a}	0.07± 0.01^{a}	0.04± 0.01^{a}
T3	0.18± 0.02^{d}	0.15± 0.02^{c}	0.13± 0.02^{c}	0.12± 0.02^{c}	0.08± 0.02^{b}	0.07± 0.02^{a}	0.04± 0.02^{a}
T4	0.53± 0.02^{b}	0.42± 0.02^{b}	0.41± 0.02^{b}	0.37± 0.03^{b}	0.12± 0.02^{a}	0.07± 0.01^{a}	0.05± 0.01^{a}

The results showed that after 0 hours of exposure, compared to the control (T1), the cooking losses of sausages in the samples (T2 and T4) were significantly increased ($P<0.05$), while the cooking losses of the sausages in the sample (T3) were significantly decreased ($P<0.05$). The cooking loss of sausages in T1 and T3 showed a gentle downward trend as a whole, while the cooking loss of sausages in T2 and T4 decreased sharply at 12 h, suggesting that the addition of D-isoascorbate sodium could reduce the cooking loss of sausages, while the addition of ginger juice could increase the cooking loss of sausages.

Changes in the emulsifying stability of poultry meat sausage are shown in Table 4.9 and Table 4.10. After 0 hours, compared to the control (T1), the loss of mass fraction of moisture in the sausage samples (T2 and T4) was increased, while the T3 sample had the lowest values ($P<0.05$). There was no significant difference in fat loss in groups - T2 and T3 after 0 hours ($P<0.05$). These results indicate that the addition of sodium D-isoascorbate can improve the water and fat loss performance of the sausage, as well as improve the emulsification stability of the sausage.

Table 4.9 — Changes in moisture loss during accelerated oxidation of poultry meat sausage

Sample	Moisture loss						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	0.17± 0.00^{c}	0.10± 0.02^{c}	0.08± 0.02^{c}	0.06± 0.00^{c}	0.05± 0.02^{b}	0.04± 0.02^{a}	0.03± 0.00^{a}
T2	0.56± 0.02^{a}	0.54± 0.00^{a}	0.48± 0.02^{a}	0.42± 0.03^{a}	0.10± 0.02^{a}	0.05± 0.01^{a}	0.03± 0.01^{a}
T3	0.14± 0.00^{d}	0.11± 0.03^{c}	0.10± 0.02^{c}	0.09± 0.03^{c}	0.05± 0.02^{b}	0.06± 0.00^{a}	0.03± 0.00^{a}
T4	0.47± 0.02^{b}	0.37± 0.03^{b}	0.37± 0.00^{b}	0.33± 0.02^{b}	0.10± 0.02^{a}	0.05± 0.01^{a}	0.04± 0.01^{a}

Table 4.10 — Changes in fat loss during accelerated oxidation of poultry meat sausage

Sample	Fat loss						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	0.07± 0.02^{ab}	0.06± 0.00^{a}	0.04± 0.02^{a}	0.02± 0.02^{a}	0.02± 0.02^{a}	0.01± 0.02^{a}	0.01± 0.02^{a}
T2	0.10± 0.02^{a}	0.07± 0.02^{a}	0.07± 0.02^{a}	0.05± 0.01^{a}	0.04± 0.02^{a}	0.02± 0.02^{a}	0.01± 0.01^{a}
T3	0.04± 0.02^{b}	0.04± 0.02^{a}	0.04± 0.02^{a}	0.04± 0.02^{a}	0.03± 0.00^{a}	0.01± 0.02^{a}	0.01± 0.02^{a}
T4	0.07± 0.02^{ab}	0.05± 0.02^{a}	0.04± 0.02^{a}	0.04± 0.02^{a}	0.02± 0.02^{a}	0.02± 0.02^{a}	0.01± 0.02^{a}

In conclusion, the addition of D-isoascorbate sodium can improve the water retention, oil retention and emulsification stability of poultry meat sausage, and improve the quality characteristics of sausage.

The color value can measure the quality of meat products. The changes of the color value of sausage (*L**, *a**, *b**) were shown in table 4.11, 4.12, 4.13.

Table 4.11 — Changes of *L** in accelerated oxidation of poultry meat sausage

Sample	*Brightness value* (L^*)						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	64.70± 0.63^b	64.56± 0.37^a	64.01± 0.13^b	62.90± 0.30^a	61.55± 2.37^a	59.28± 0.66^b	56.44± 1.14^b
T2	66.01± 0.29^a	64.03± 0.17^b	64.70± 0.16^a	62.14± 0.16^b	61.71± 0.10^a	60.64± 0.81^a	58.50± 0.50^a
T3	63.47± 0.12^c	63.43± 0.12^c	61.23± 0.10^d	63.18± 0.18^a	62.91± 0.21^a	60.06± 0.64^{ab}	59.32± 0.48^a
T4	63.54± 0.10^c	62.46± 0.18^d	62.38± 0.24^c	62.95± 0.15^a	62.11± 0.37^a	60.42± 0.64^a	58.97± 0.28^a

*L** represents the brightness value of the product. The larger the L* value, the brighter the sausage; the smaller the L* value, the darker the sausage. As can be seen from table 4.11, *L** values of the four groups of sausages showed an overall downward trend, indicating that the oxidation degree of sausages became more serious with the extension of accelerated oxidation time. Compared with the control group, sausage added with D-isoascorbate sodium (T3) had the least change in *L**, followed by the sausage added with ginger juice combined with D-isoascorbate sodium (T4), indicating that the addition of D-isoascorbate sodium can better maintain the brightness of the sausage.

*a** represents the redness value of the product. The larger the value is, the sausage is red; otherwise, it is green. As can be seen from table 4.12, the *a** value of sausages in group T3 was higher than that in group T1 in the whole accelerated oxidation process. In the accelerated oxidation process, *a** of each group showed a decreasing trend. At 0 h, the levels of T3 sample were significantly higher than those of the other three samples ($P<0.05$), which indicated that the addition of D-isoascorbic acid could maintain the color of sausage. Samples T2 had the lowest *a**, which may be due to the ginger color of the ginger juice itself affecting the color of the sausage.

Table 4.12 — Changes of *a** in accelerated oxidation of poultry meat sausage

Sample	*Redness value* (a^*)						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1(Control)	9.20± 0.28[c]	9.76± 0.12[c]	8.79± 0.16[b]	8.06± 0.28[c]	7.96± 0.10[c]	7.13± 0.04[c]	7.70± 0.18[a]
T2	7.31± 0.09[d]	7.28± 0.15[d]	8.07± 0.07[c]	8.08± 0.13[c]	8.35± 0.15[c]	6.88± 0.10[c]	6.80± 0.73[b]
T3	12.00± 0.34[a]	10.76± 0.11[a]	10.83± 0.29[a]	10.18± 0.10[a]	9.12± 0.24[b]	9.06± 0.16[a]	8.15± 0.42[a]
T4	11.45± 0.33[b]	10.32± 0.24[b]	10.79± 0.11[a]	9.73± 0.17[b]	9.92± 0.41[a]	8.14± 0.43[b]	7.86± 0.34[a]

*b** represents the yellowness value of the product. The higher the value is, the more yellow the sausage is; otherwise, the bluer the sausage is. It can be seen from table 4.13 that the *b** value of sausages in the four groups fluctuated between 11 and 14. At 18 h, there was no significant difference in the *b** value of sausages in each group, among which the *b** value of sample T3 was the lowest, while the *b** value of sample T2 was higher than that of the other three groups, which may be due to the ginger color of ginger juice, thus affecting the yellowness of sausages. The results showed that sodium D-isoascorbate could delay the oxidation and keep the good color of sausage during the accelerated oxidation process.

Table 4.13 — Changes of b^* in accelerated oxidation of poultry meat sausage

Sample	*Yellowness value* (b^*)						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	12.16± 0.12[ab]	12.70± 0.07[a]	12.33± 0.39[a]	12.57± 0.16[ab]	12.99± 0.52[a]	13.05± 0.16[b]	12.25± 1.06[a]
T2	12.51± 0.10[a]	12.36± 0.22[a]	12.63± 0.16[a]	12.72± 0.19[a]	12.75± 0.06[a]	13.67± 0.27[a]	13.04± 0.28[a]
T3	11.95± 0.07[b]	12.38± 0.07[a]	11.75± 0.32[b]	12.40± 0.48[ab]	12.08± 0.39[a]	12.57± 0.11[b]	11.74± 1.59[a]
T4	11.77± 0.37[b]	10.65± 0.38[b]	12.45± 0.03[a]	12.10± 0.27[b]	12.65± 1.02[a]	12.62± 0.49[b]	12.86± 0.65[a]

Texture is an important index to evaluate the quality of meat products. Table 4.14 and table 4.15 respectively showed the changes of hardness and elasticity of sausages in each group during accelerated oxidation. As shown in the table, compared with control T1, adding antioxidant substances can significantly reduce the hardness and elasticity of sausage ($P<0.05$), and the value of sausage in T3 is closer to that in T1, followed by sample T2.

It can be seen from table 4.14. that with the extension of accelerated oxidation time, the hardness of sausages in each group presents an increasing trend, which may be due to the water loss of sausages caused by accelerated oxidation treatment at 72 °C, which leads to the gradual increase in the hardness of meat products. Throughout the oxidation process, compared to the control T1, the hardness of the sausage in samples T2 and T4 was significantly reduced ($P<0.05$). The hardness index of the sausage in the T3 was significantly different from the T1 sample, in the interval from 0 to 6 hours, compared to the control. At 18 hours of exposure, sample T3 exceeded the control by 1.02 times according to the specified indicator.

Table 4.14 — Change in hardness index during accelerated oxidation of poultry meat sausage

Sample	Hardness, *N*						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	115.7±3.54[a]	140.2 0.59	157.1 ±6.11[a]	164.9±7.11[a]	179.2±8.48[a]	248.3±11.26[a]	272.6±0.73[a]
T2	80.6±1.40[c]	122.6 ± 7.12[b]	130.5 ±2.79[b]	137.7±13.14[b]	140.7±6.56[b]	166.8±20.70[b]	186.7±220.0[b]
T3	91.2±1.61[b]	128.7 ± 2.29[b]	135.6 ±4.33[b]	151.2±10.26[ab]	177.1±24.01[a]	230.16 ±6.50[a]	278.7±18.73[a]
T4	58.7±2.57[d]	71.6±0.82[c]	80.5 ±4.22[c]	109.5±6.35[c]	120.3±4.78[b]	165.3±15.29[b]	158.9±6.07[c]

As can be seen from Table 4.15, after 0 h, the index of elasticity of sausages in samples T2 and T4 decreased ($P<0.05$), compared to the control (T1). No particular changes were detected in sample T3, according to the indicated indicator. These facts indicate that sodium D-isoascorbate affects the elasticity of sausages, depending on the dosage. There was no significant difference in the elasticity of sausages between all groups after 3–12 h ($P>0.05$). After 18 h, the elasticity of the sausage in sample T3 was the lowest. The reason is the loose internal structure of the sausage, due to the loss of water, which leads to a decrease in the elasticity of the sausages.

Table 4.15 — Change in elasticity index during accelerated oxidation of poultry meat sausage

Sample	Elasticity						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	0.85±0.03[a]	0.80±0.01[ab]	0.79±0.02[a]	0.77±0.02[a]	0.89±0.08[a]	0.85±0.01[a]	0.82±0.00[b]
T2	0.73±0.01[b]	0.75±0.03[b]	0.85±0.05[a]	0.80±0.11[a]	0.78±0.06[b]	0.86±0.02[a]	0.86±0.00[a]
T3	0.83±0.01[a]	0.82±0.04[a]	0.84±0.03[a]	0.80±0.03[a]	0.83±0.03[ab]	0.81±0.01[b]	0.79±0.01[c]
T4	0.68±0.07[b]	0.77±0.02[ab]	0.77±0.04[a]	0.79±0.03[a]	0.78±0.03[b]	0.82±0.01[b]	0.82±0.01[b]

The results of the acid number change in the process of accelerated oxidation of duck sausage are shown in Table 4.16. In the process of accelerated oxidation, the acid number of sausages in each group showed a tendency of gradual increase, indicating that the oxidation process of sausages has an increasing tendency, and the fat is constantly decomposed with the formation and accumulation of fatty acids. The results showed that at the initial stage, there were no differences in the acid number values of the samples. As the oxidation time increased, the treatment group increased, when 18 hours, the acid number of the sausage had a significant difference ($P<0.05$), that is, the acid number of the sausage of sample T3 was one of the lowest in the whole oxidation process, secondly, it is sample T2, suggesting that sodium D - different ascorbic acid and ginger can effectively inhibit the production of free fatty acids to delay the oxidation of sausage. However, after combining these two technological components, the antioxidant effect decreased, which may indicate an incorrect proportion of their combination. The acid value of sodium isascorbate was the best among the three treatment sample (T3).

Table 4.16 — Change of acid value during accelerated oxidation of poultry meat sausage

Sample	Acid value, mg/kg						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	1.79± 0.11^{a}	1.83± 0.13^{a}	1.95± 0.07^{a}	2.05± 0.12^{a}	2.23± 0.05^{a}	2.92± 0.09^{a}	3.50± 0.13^{a}
T2	1.77± 0.09^{a}	1.81± 0.09^{a}	1.85± 0.06^{ab}	1.99± 0.09^{ab}	2.02± 0.11^{b}	2.28± 0.14^{bc}	2.79± 0.11^{c}
T3	1.62± 0.06^{a}	1.66± 0.09^{a}	1.74± 0.06^{b}	1.85± 0.06^{b}	1.96± 0.06^{b}	2.13± 0.11^{c}	2.43± 0.06^{d}
T4	1.68± 0.11^{a}	1.69± 0.09^{a}	1.76± 0.06^{b}	1.96± 0.06^{ab}	2.09± 0.09^{ab}	2.48± 0.09^{b}	3.01± 0.11^{b}

Table 4.17 shows the results of studies of the TBARS indicator. The TBARS values of the sausages in the four samples show a gradual increasing trend, and the TBARS values of the sausages in the three treatment groups are significantly lower than those in the T1 control throughout the oxidation process ($P<0.05$). After 0 hours, TBARS values for sausages in samples T2 and T3 significantly decreased compared to the control group ($P<0.05$). The values of the T4 sample, according to the TBARS indicator, had a slight difference, compared to the T1 sample. This fact indicates that ginger juice and sodium D-isoascorbate can inhibit lipid oxidation in sausage products, but the combination of these two substances reduces the antioxidant capacity of sausage products. There was no significant difference between the treatment groups at 3–12 h ($P>0.05$), but there was a significant difference between the treatment groups and the control group at T1 ($P<0.05$). At 18 h, the *TBARS* value of sausage in T3 sample was significantly lower than that in control T1, treatment samples T2 and T4 ($P<0.05$). Compared with the TBARS values of the four groups, the sausages in T3 sample have better antioxidant capacity, that was, D-isoascorbate sodium can effectively inhibit the lipid oxidation of sausages and prolong the storage time of sausages.

Table 4.17 — Change of *TBARS* value during accelerated oxidation of poultry meat sausage

Sample	*TBARS*, mg/100 g						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	0.49 ± 0.00^{a}	0.58 ± 0.00^{a}	0.60 ± 0.02^{a}	0.64 ± 0.00^{a}	0.68 ± 0.00^{a}	0.71 ± 0.02^{a}	0.85 ± 0.02^{a}
T2	0.40 ± 0.02^{c}	0.45 ± 0.00^{b}	0.48 ± 0.01^{b}	0.52 ± 0.01^{b}	0.56 ± 0.00^{b}	0.58 ± 0.00^{c}	0.68 ± 0.01^{c}
T3	0.39 ± 0.00^{c}	0.46 ± 0.00^{b}	0.47 ± 0.00^{b}	0.51 ± 0.01^{b}	0.54 ± 0.00^{c}	0.57 ± 0.00^{c}	0.64 ± 0.01^{d}
T4	0.46 ± 0.01^{b}	0.46 ± 0.02^{b}	0.48 ± 0.00^{b}	0.52 ± 0.01^{b}	0.55 ± 0.01^{bc}	0.63 ± 0.01^{b}	0.76 ± 0.00^{b}

Table 4.18 shows the results of the free radical scavenging ability (DPPH) of antioxidants added to poultry sausages. In the process of oxidation, the DPPH index in four samples of cooked sausages tended to decrease.

Table 4.18 — Changes in DPPH index during accelerated oxidation of poultry meat sausage

Sample	*DPPH*, %						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	93.29± 0.12[ab]	90.58± 0.98[a]	92.50± 0.40[b]	92.72± 0.12[a]	85.94± 1.68[b]	84.21± 0.49[b]	73.61± 0.78[c]
T2	93.69± 0.28[a]	90.54± 2.02[a]	92.69± 0.15[b]	92.24± 0.24[b]	92.34± 0.18[a]	89.04± 0.41[a]	88.96± 0.49[a]
T3	93.57± 0.61[a]	91.77± 0.54[a]	92.83± 0.13[ab]	90.81± 0.03[c]	91.37± 0.07[a]	89.48± 0.32[a]	85.78± 0.14[b]
T4	92.65± 0.28[b]	91.61± 0.32[a]	93.17± 0.13[a]	89.50± 0.27[d]	92.28± 0.08[a]	89.30± 0.76[a]	88.40± 0.83[a]

The clearance rate in samples T2 and T3 had no difference in DPPH values compared to control T1 after 0–6 hours ($P>0.05$). Then it was significantly different from the T1 control ($P<0.05$). However, there was no significant difference between samples T1 and T2 after 0 and 3 hours of exposure. Significant differences in the DPPH index between the T3 and T4 samples were found after 0 hours and 3 hours of exposure. After 18 hours of exposure, the absorption rate of free radicals in the three experimental groups was higher than that of the control group, and the absorption rate of sample T3 was slightly lower than that of samples T2 and T4. These results showed that individual use (ginger juice, sodium D-isoascorbate) and combined use (ginger juice + sodium D-isoascorbate) can well inhibit the initial stages of lipid oxidation in sausages. A gradual decrease in the values of the antioxidant effect in the sausages of the experimental three groups was observed at the later stages, compared to the control - T1 ($P<0.05$).

In theory, ginger juice can not only remove the fishy smell of poultry meat and improve the taste of sausage, but also have antioxidant effects. However, the antioxidant capacity of erythorbic acid + ginger juice (T4) did not particularly affect the TBARS value.

Table 4.19 — Changes in the total of microflora during accelerated oxidation in cooked poultry sausages

Sample	Total colony(cfu/g)						
	0 h	3 h	6 h	9 h	12 h	15 h	18 h
T1 (Control)	1200	1800	3600	5400	7000	8000	8900
T2	800	1700	2800	4300	6400	7800	8600
T3	1060	1800	3400	5600	6600	7300	9200
T4	900	1600	3700	4800	5400	6700	7800

As can be seen from Table 4.19, with the extension of the holding time at 37 °C, the total number of microbial colonies in the sausage increased 7-10 times after 18 hours. The total number of colonies in 1 g of sample reached approximately 8,000-9,000, but did not exceed food safety requirements - 10,000. According to 37°C, 24h shelf life is 7-10 days to calculate, the product can be stored at 4°C for 5-7 days.

4.4 Justification of the use of oil-gelatin emulsion for the production of cooked sausages from different types of poultry meat

Gelatin is a type of high-protein gel without cholesterol and fat. This is a food thickener with a great prospect of application. Gelatin is widely used in meat jellies, preserves, candies, vermicelli, instant noodles, ice cream and other food products. Gelatin is a protective colloid. To study the influence of gelatin on the structural characteristics of cooked sausages from different types of poultry meat, it is necessary to analyze its properties.

4.4.1 Preparation and characteristics of oil- gelatin emulsion parameters

The process of preparing the oil-gelatin emulsion was carried out in several stages. At the first stage, gelatin was dissolved in water (300 ml of water - 100 g of gelatin granules) and heated to a temperature of 95±0°C until complete dissolution.

At the second stage, 400 ml of a mixture of vegetable oils was added to the gelatin solution and subjected to homogenization under the following conditions: rotation speed - 10,000 rpm, duration - 3 minutes. The properties of the emulsion are given in Table 4.20.

Table 4.20 - Characteristics of oil-gelatin emulsion

Test parameter	Test result
Gelatinization temperature/ °C	95±0°C
Peak viscosity/ Pa.s	1155.67±116.09
Valley viscosity/ Pa.s	566.33±46.32
Final viscosity/ Pa.s	1161±87.62
Disintegration value/ Pa.s	540.33±32.04
Retrogradation value/ Pa.s	596±42.04
Brightness value L*	92.24±0.28
Redness value a*	2.95±0.05
Yellowness value b*	9.52±0.2
Whiteness value	87.37±0.26
Moisture content/%	35.56±2.93%

Linen is the main indicator of the quality assessment of oil-gelatin emulsion, which reflects color and quality. The whiteness index, which is closely related to the protein composition, protein denaturation, aggregation, degree of crosslinking, optical properties of the surface, etc., directly depends on the change in the internal structure of the oil-gelatin emulsion. Table 4.20 shows that the oil-gelatin emulsion has the following characteristics: whiteness - 87.37 units, mass fraction of moisture - 35.56 units, viscosity -1161 units. Color indicators have high values of brightness L - 92.24 units, and brightness b - 9.52 units. and slight redness a - 2.95 units, which significantly increases and saturates the value of whiteness.

4.4.2 Determination of the amount of oil-gelatin emulsion for cooked sausages from different types of poultry meat

To improve the structural-mechanical and physico-chemical characteristics of cooked sausages from different types of poultry meat, the addition of an oil-gelatin emulsion (developed in section 4.4.1) as a substitute for animal fat is proposed. The oil-gelatin emulsion was added to the scad of the recipe in the amount of 0 kg, 5 kg, 10 kg, 15 kg, 20 kg, 25 kg, the control was a sample without the addition of emulsion - 0 kg.

Table 4.21 - Recipe of cooked sausages from different types of poultry meat using oil-gelatin emulsion

Ingredients, (kg)	Sample					
	T1 (Control)	T2	T3	T4	T5	T6
Duck meat	56	56	56	56	56	56
Chicken meat	40	40	40	40	40	40
Pork fat	4	4	4	4	4	4
Taro paste	16	16	16	16	16	16
Wheat bran	1.5	1.5	1.5	1.5	1.5	1.5
Rice wine	4	4	4	4	4	4
Onion-Ginger Juice	5	5	5	5	5	5
Ice water	14	14	14	14	14	14
Pepper	0.2	0.2	0.2	0.2	0.2	0.2
Salt	1.4	1.4	1.4	1.4	1.4	1.4
Complex phosphate	0.3	0.3	0.3	0.3	0.3	0.3
Oil-gelatin emulsion	0	1	2	3	4	5

The effectiveness of the effects of different amounts of oil-gelatin emulsion on the quality of cooked sausages of poultry meat was studied according to: moisture content, pH value, cooking losses and emulsification stability (table 4.22).

Table 4.22 - Physico-chemical indicators of cooked sausages of poultry meat with oil-gelatin emulsion

Sample	Moisture content, %	pH	Cooking loss, %	Moisture loss, %	Fat loss, %
T1 (Control)	64.63 ± 0.79^{d}	6.5 ± 0.03^{a}	0.42 ± 0.01^{d}	0.39 ± 0.02^{d}	0.03 ± 0.01^{a}
T2	66.69 ± 1.2^{b}	6.36 ± 0.03^{c}	0.59 ± 0.01^{bc}	0.57 ± 0.01^{b}	0.02 ± 0.01^{b}
T3	67.86 ± 1.49^{a}	6.38 ± 0.04^{bc}	0.49 ± 0.01^{cd}	0.46 ± 0.01^{c}	0.03 ± 0.01^{a}
T4	67.67 ± 0.53^{ab}	6.41 ± 0.01^{b}	0.27 ± 0.01^{e}	0.25 ± 0.01^{e}	0.02 ± 0^{b}
T5	67.07 ± 0.41^{ab}	6.36 ± 0.04^{bc}	0.6 ± 0.01^{b}	0.57 ± 0.02^{b}	0.03 ± 0^{a}
T6	66.76 ± 0.59^{bc}	6.33 ± 0.11^{d}	0.8 ± 0.02^{a}	0.77 ± 0.02^{a}	0.03 ± 0.01^{a}

According to the data in Table 4.22, compared to the control group T1, the added amount of oil-gelatin emulsion had a significant effect on the water content, pH, cooking loss and emulsification stability of poultry meat sausage ($P<0.05$). Adding larger doses of oil-gelatin emulsion decreased the water-holding capacity of the sausage. The water content in the sausage also first increased and then decreased. A similar trend was observed with the pH value. According to the amount of added oil-gelatin emulsion - 3 kg (T4), the pH value of the sausage was the highest (6.41). It was established that the addition of oil-gelatin emulsion in larger quantities contributed to losses during cooking, and the indicators of the mass fraction of moisture and fat first decreased and then increased. For 3 kg of oil-gelatin emulsion (T4), the weight loss of the sausage during cooking was the smallest, and the indicators of the mass fraction of fat and moisture were higher than in other samples. Thus, the optimal addition of oil-gelatin emulsion to the recipe of cooked sausages from different types of poultry meat was 3 kg.

Table 4.23 and Figure 4.7 show that compared to the control (T1), the change in color characteristics in the samples with the addition of emulsion (T2-T6) with an increase in its amount, the value of L* increased by 1-1.1 times, and the value a* and b* did not differ (P>0.05). Chen Yichun et al. [236] found in their study that compared to solid animal fat after cutting and mixing, the emulsified vegetable oil pre-emulsion had smaller oil droplets and a larger tension surface, which increased the brightness value of the sausage, making it brighter. Therefore, the addition of oil-gelatin emulsion improves the color of sausages, due to saturated brightness, as evidenced by organoleptic evaluation data (Figure 4.7).

Table 4.23 - Color characteristics of cooked sausages of poultry meat with oil-gelatin emulsion

Sample	Brightness value (L*)	Redness value (a*)	Yellowness value (b*)
T1 (Control)	54.4 ± 1.23^{e}	8.84 ± 0.57^{d}	13.76 ± 0.53^{a}
T2	55.24 ± 1.85^{d}	8.8 ± 0.35^{d}	12.51 ± 0.99^{d}
T3	56.66 ± 1.84^{c}	9.08 ± 0.66^{c}	12.96 ± 0.05^{c}
T4	57.11 ± 2.29^{bc}	8.56 ± 0.33^{e}	11.85 ± 0.6^{e}
T5	57.25 ± 0.47^{b}	9.23 ± 0.43^{b}	11.6 ± 0.61^{f}
T6	59.8 ± 0.21^{a}	9.25 ± 0.16^{a}	13.46 ± 0.26^{b}

Figure 4.7- Photo of cuts of cooked sausages of poultry meat with oil-gelatin emulsion

In the research of Chen Yichun et al. [236], the addition of vegetable oil pre emulsion had a greater impact on the hardness, chewiness and resilience of sausage, while elasticity and cohesion had increased but no significant difference. This was because during the heating process of vegetable oil pre emulsion, the molecular structure of myofibril protein was stretched, exposing its active groups. During the pre emulsion process, the introduced protein participates in the network structure formed by the meat gel, and PPPH closely combined with the protein in the matrix, thus improving the hardness of the sausage. OCA also formed a stable molecular structure in the meat matrix by inducing PPPH polypeptide molecular cross-linking, so that sausage had a stable gel property. Table 4.24 shows the structural and mechanical parameters of cooked sausages.

Table 4.24 shows that, compared to the control T1, the structural and mechanical parameters of the sausage gradually decreased with increasing doses of the oil-gelatin emulsion: hardness by 1.5-2.5 times, elasticity by 1-1.3 times, cohesion by 1-1.3 times, stickiness by 1.2-3.15 times, chewing ability by 1.2-3.3 times and elasticity by 1.1-1.7 times, respectively.

Table 4.24 - Structural and mechanical characteristics of cooked sausages of poultry meat with oil-gelatin emulsion

Sample	Gummi ness(N)	Cohesive ness	Hard ness(N)	Resili- ence	Springi ness	Chewi ness(N)
T 1 (Control)	1584.16±233.47^{a}	0.43±0.01^{a}	3704.31±441.28^{a}	0.17±0^{a}	0.79±0^{a}	1253.34±181.81^{a}
T 2	1342.23±69.87^{b}	0.4±0.03^{b}	2493.96±222.7^{b}	0.16±0.01^{b}	0.75±0.02^{b}	1027.37±98.82^{b}
T 3	1285.33±190.49^{c}	0.36±0.01^{c}	2447.46±83.81^{c}	0.15±0.01^{c}	0.7±0.04^{c}	818.43±31.19^{c}
T 4	1077.81±81.32^{d}	0.35±0.01^{d}	1692.43±171.7^{d}	0.13±0.01^{d}	0.66±0.01^{d}	610.33±70.76^{d}
T 5	580.9±48.43^{e}	0.34±0^{e}	1650±142.37^{e}	0.12±0^{e}	0.64±0.05^{e}	408.2±14.71^{e}
T 6	502.7±62.17^{f}	0.33±0^{f}	1458.59±204.29^{f}	0.1±0^{f}	0.61±0.02^{f}	386.32±115.6^{f}

The limit amount of addition of oil-gelatin emulsion is 3 kg. In this study, gelatin was added on the basis of vegetable oil, but the coagulation ability of food gelatin is weaker than that of agar, and it does not solidify if the concentration is below 5%. Thus, with an increase in the dose of oil-gelatin emulsion added to the sausage recipe, the coagulation ability, hardness, elasticity, cohesiveness, stickiness and other properties of the consistency of the products decrease.

Shear strength is the main indicator for evaluating the tenderness of meat and meat products. The lower the shear force, the better the tenderness of the meat and products. It can be seen from Table 4.25 that the addition of a larger amount of oil-gelatin emulsion affected the shear strength index of cooked poultry sausages. The value of the indicator first decreased, then increased, compared to the control ($P<0.05$).

Table 4.25-Change in the shear force index from the added amount of oil-gelatin emulsion to cooked sausages of poultry meat

Sample	Shear force
T1 (Control)	50.64 ± 7.04^{a}
T2	25.82 ± 7.54^{c}
T3	17.03 ± 2.54^{d}
T4	15.81 ± 5.58^{f}
T5	15.91 ± 9.16^{e}
T6	29.03 ± 4.25^{b}

It showed that in the T3-T5 range (2-4 kg) the addition of oil-gelatin emulsion improved the softness of cooked sausages of poultry meat by 2.9-3.2 times, compared to the control. If you exceed this range, the tenderness of the sausage will decrease. The results showed that sample T4 with the addition of 3 kg of oil-gelatin emulsion had a 3.2-fold lower shear force index and a softer consistency compared to the control and other samples.

4.4.3 Dynamics of moisture distribution inside cooked sausages from different types of poultry meat with oil-gelatin emulsion

From figure 4.8, it could be seen that on the basis of relaxation time, the fitted distribution of T2 had three peaks, which represented bound water (T2b), non-flowing water (T21), and free water (T22), respectively.

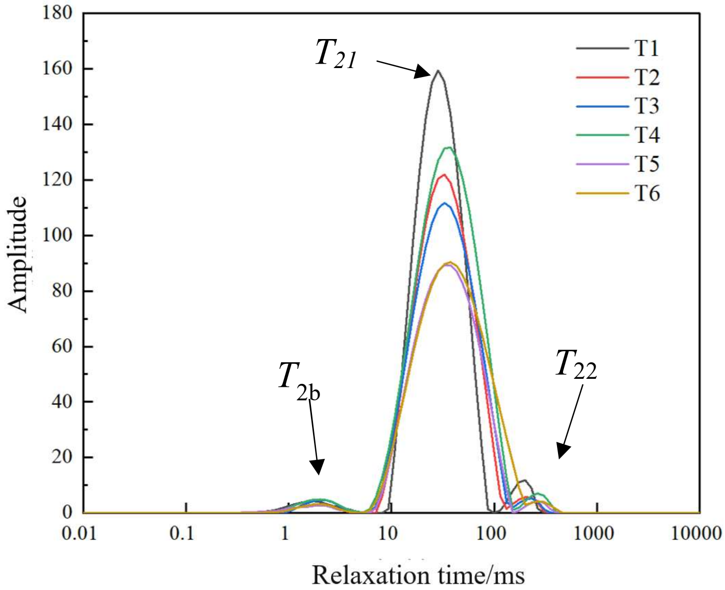


Figure 4.8- Dependence of the relaxation time on the dynamic distribution of water in cooked sausages of poultry meat.

The results showed that the addition of oil-gelatin emulsion changed the water distribution in sausages, and the relaxation time of sausages with the addition of oil-gelatin emulsion was significantly shortened ($P<0.05$). According to the analysis of the peak of non-flowing water, compared to the control group, the presence of non-flowing water in the sausage of the experimental group was less. As the amount of oil-gelatin emulsion increased, the peak area first decreased, then increased, and then decreased, indicating that the increase in the amount of oil-gelatin emulsion decreased the non-flowing water content, and the presence of non-flowing water would also change with the increase of the amount of oil-gelatin emulsion. This showed that with the increase of the addition of oil-gelatin emulsion, the original non flowing water in sausage was more and more closely combined with the meat protein, and the free water was also more and more.

The results showed that in the T4 group, the peak area of bound water was the largest and the peak volume of fixed water was the largest.

Miklos et al. [252] showed that in the microstructure of sausage, the content and size of fat would have an impact on the change of relaxation time. Compared with chopped animal fat, there were smaller emulsion droplets in the microporous structure of the gel network. Because water molecules were restricted by the network structure and were not easy to flow, it accelerated the spin exchange with water molecules in the environment, thereby reduced the spin-spin relaxation time.

4.4.4 The effect of adding different amounts of oil-gelatin emulsion on the sensory evaluation of cooked sausages from different types of poultry meat

According to the results of the organoleptic evaluation of cooked sausages with different amounts of oil-gelatin emulsion, it was established that the addition of oil-gelatin emulsion neutralized the smell of poultry meat (Table 4.26).

Table 4.26 - Organoleptic assessment of cooked sausages of poultry meat with oil-gelatin emulsion

Sample	Flavour	Texture	Appearance	Color	Overall acceptability
T 1 (Control)	7.23 ± 1.36^{e}	7.75 ± 1.38^{c}	7.41 ± 1.19^{de}	6.31 ± 1.45^{cd}	7.73 ± 1.27^{f}
T 2	8.03 ± 1.56^{cd}	7.96 ± 0.77^{ab}	7.83 ± 1.41^{d}	6.83 ± 1.13^{c}	7.75 ± 1.09^{c}
T 3	8.26 ± 1^{b}	7.99 ± 0.54^{ab}	8.61 ± 1.31^{b}	7.08 ± 1.55^{bc}	8.49 ± 0.96^{b}
T 4	8.86 ± 0.97^{a}	8.11 ± 1.03^{a}	8.61 ± 0.97^{a}	7.59 ± 1.56^{a}	8.71 ± 1.45^{a}
T 5	8.11 ± 1.02^{c}	7.98 ± 0.88^{ab}	8.29 ± 0.71^{c}	7.13 ± 1.74^{b}	7.49 ± 1.12^{d}
T 6	7.75 ± 1.07^{d}	7.65 ± 1.21^{d}	7.52 ± 0.83^{e}	6.4 ± 1.44^{d}	7.27 ± 1.35^{e}

Sample (T4) with the addition of oil-gelatin emulsion in the amount of 3 kg had the highest score - 8.71, felt pronounced meaty taste, with sufficient elasticity and a uniform structured cut surface. With a smaller amount of emulsion introduction (1-2 kg), the taste in the sausages was not pronounced, the color was lighter, and the products had a too dense consistency. With a larger amount of emulsion (4-5 kg), the taste of oil was felt too much, the product had a pale color and too soft consistency - loose structure and large pores.

4.5 Selection of food dyes for cooked sausages of poultry meat

The color of the product, both on the outside and on the cut, is important and the main criteria for assessing its quality. Technological methods with the addition of dyes, related to color formation and color stabilization of meat raw materials and should not cause deviations in organoleptic characteristics or lead to product spoilage. The main undesirable fact of poultry meat, namely broiler chickens, is the characteristic pale pink color of muscle tissue. This especially applies to the pectoral muscles, due to the low level of the heme pigment - myoglobin. Also, the use of oil-fat emulsion, which has a light color, prompted the introduction of dyes into the formulation.

To compare the effectiveness of coloring samples, two natural vegetable dyes were chosen - red beetroot powder and fermented rice.

Red beetroot powder contains natural pigments anthocyanin and betaxanthin, which are obtained from red beetroot. It has a color from red-purple to dark purple. Obtained by extraction, separation, concentration and drying.

Fermented rice is a natural dye that does not have an "E" index. It is obtained by fermentation of rice or rice flour with molds of the genus Monascus. In the fermentation process, they form coloring pigments - from yellow to red, which makes it possible to get the desired shade of meat products. Fermented rice is an absolutely harmless supplement. It does not contain any synthetic components. Fermented rice is used to obtain a natural color of sausage products, to improve the appearance and cross-section of finished products (including those produced with a partial replacement of meat raw materials), as well as for coloring gels of animal and soy proteins, protein-fat emulsions. The recommended dosage of fermented rice is to add 50-150 g to 100 kg of minced meat.

The consumer attractiveness of finished products and the effectiveness of dosages were assessed by their color characteristics: brightness value (L*), redness value (a*), yellowness value (b*) and organoleptic indicators. The results of this part of the data were published in [239].

Dyes were added to the recipe in the following amounts: fermented rice - 0.3 kg, red beet powder - 0.2 kg and 0.4 kg per 100 kg of raw meat. The action of each dye and their combined action were tested separately. The control was a sample without the addition of dyes - 0 kg (Table 4.27).

Table 4.27 - Concentration of dyes in cooked sausages of poultry meat

Ingredient, (кg)	Control	T1	T2	T3	T4
Red rice powder	0.0	0.3	0.0	0.3	0.3
Beet red powder	0.0	0.0	0.2	0.2	0.4

The addition of red pigments allows you to improve the color of sausages and get a bright color. Table 4.28 shows the data and indicates that, compared to the control, the value of the redness index a* in raw minced meat and ready-made sausages with the use of dyes increased (P<0.05). Whereas, the values of L* and b* showed a tendency to decrease (P<0.05). Sample T2 (0.2 kg of red beet powder) had a redder color - 13.27 than sample T1 (0.3 kg of fermented rice) - 11.29. This proves that red beetroot powder has a higher amount of red pigment than fermented rice. The a* value of sample T3 was 1.5 times higher than that of T2. Test sample T4, with an increased amount of red beet powder (0.4 kg), had the highest values of a* - 4 times, compared to the control. And by 1.2-2 times, compared to samples with the use of dyes (T2-T3) and the saturated red color of the sausage, as evidenced by the organoleptic indicators of the quality of cooked sausages (Table 4.29).

Table 4.28 - Color characteristics of cooked sausages from different types of poultry meat with dyes [253]

Sample	Brightness value (L*)		Redness value (a*)		Yellowness value (b*)	
	Mashed meat	Sausage	Mashed meat	Sausage	Mashed meat	Sausage
Control	73.65± 1.15[a]	73.04± 0.89[b]	6.90± 0.45[d]	5.50± 0.48[d]	14.90± 1.04[a]	13.88± 0.18[a]
T1	71.12± 0.53[b]	69.57± 2.01[c]	12.27± 0.27[c]	11.29± 0.06[c]	14.76± 0.32[a]	13.34± 0.66[a]
T2	65.57± 0.29[c]	67.32± 1.32[c]	18.54± 1.12[b]	13.27± 0.23[c]	12.56± 0.98[bc]	12.06± 0.49[b]
T3	61.96± 1.48[d]	61.89± 2.87[d]	19.51± 1.70[b]	19.40± 2.58[b]	11.13± 1.03[b]	11.60± 0.84[c]
T4	59.37± 0.23[e]	63.59± 0.22[d]	24.21± 1.17[a]	22.30± 0.21[a]	8.95± 0.61[c]	11.39± 0.18[c]

According to the results presented in Table 4.29, it was determined that the color evaluation of samples with the addition of dyes was higher (6.30-7.20) than in the control group - 4.80.

Table 4.29 — Organoleptic assessment of cooked sausages from different types of poultry meat with dyes [253]

Sample	Texture	Color	Consistence	Flavor	Overall acceptability
Control	5.10±0.99[bc]	4.80±0.79[b]	6.00±1.76[a]	6.10±1.85[a]	7.30±1.06[ab]
T 1	6.50±1.08[a]	6.30±1.42[a]	7.00±1.56[a]	7.10±1.29[a]	6.50±1.43[b]
T 2	6.00±1.05[ab]	6.50±1.08[a]	5.90±1.52[a]	6.80±1.55[a]	7.30±1.20[ab]
T 3	6.50±1.35[a]	7.00±1.49[a]	6.60±1.51[a]	6.50±0.85[a]	7.90±0.88[a]
T 4	4.70±1.25[c]	7.20±1.48[a]	6.10±1.20[a]	6.20±1.55[a]	6.10±1.37[b]

The consistency indicators of samples T1 and T3 were 1.5 times higher than in the control group. The taste score of T1 (7.1) was the highest and slightly different from samples T2 and T3. However, sample T3 had the highest total score and was significantly different from the control group. In addition, the color and consistency score of the T3 sample was higher than that of the control group. According to the results of the sensory evaluation, the sausage of sample T3 had a uniform bright red color, a rich aroma, and an elastic and tender consistency [253].

This fact proves that the use of red beetroot powder in the amount of -0.2 кg and fermented rice 0.3 кg is an effective dose for making boiled poultry sausages.

Conclusions to Section 4

1. According to the results of the orthogonal analysis, it was established that there are rational quantities of ingredients: taro paste - 16 kg, wheat bran - 1.5 kg, phosphate complex - 0.3 kg per 100 kg of raw meat. The determined norms allow to obtain a finished product with the following maximum indicators: sensory evaluation - 45 units , cutting force - 148.46 N, losses during cooking - 4.96%.

2. The addition of ginger juice and sodium D-isoascorbate inhibited the oxidation processes in boiled poultry sausages: the acid value decreased by 1.1-1.4 times, TBARS - by 1.1-1.32 times and promoted the binding of free radicals (DPPH) - 1.1-1.2 times compared to the control.

3. Addition of sodium D-isoascorbate in the amount of 0.2 % to the mass of raw meat improves the indicators of redness and brightness by 1.05 times and the elasticity of the sausage, comparable to the control.

4. A complex combination of natural components - the addition of ginger and onion juice and sodium isoscorbinate reduced the number of microorganisms by 1.14-1.17 times, compared to samples T1-T3.

5. A highly stable oil-gelatin emulsion was obtained in a ratio of 1:1. It was established that the rational dose is 3 кg of such an emulsion. An increase in the emulsion content leads to a deterioration of the taste (pronounced taste of oil), discoloration and a violation of the structure (loose, with the presence of pores).

6. According to color and organoleptic indicators, a rational dosage of natural dyes was determined in the amount of 0.3 кg of fermented rice and 0.2 кg of red beet powder, which gave boiled poultry sausages a characteristic red color.

7. According to the research results, a recipe for cooked sausages from different types of poultry meat (duck and chicken) with technological additives was developed: ginger and onion juice, sodium isoscorbinate, red beet powder and oil-fat emulsion table 4.30:

Table 4.30- Recipe for cooked sausages from different types of poultry meat

Ingredients	Quantity, kg
Raw meat, kg, (calculated as 100kg)	
Duck meat	56
Chicken meat	40
Pork fat	4
Taro paste	16
Wheat bran	1.5
Onion and Ginger Sauce	5
Gelatin-oil emulsion	3
Ice water	14
Rice wine	4
Potato starch	0.7
Salt	1.4
Complex phosphate	0.3
Complex spices	0.8
Pepper	0.3
Sodium D-isoascorbate	0.2
Beet red powder	0.2
Red yeast rice	0.3

SECTION 5
DEVELOPMENT OF SAUSAGE PRODUCTION TECHNOLOGY USING VARIOUS RAW MATERIALS

5.1 Recipe of boiled sausages using vegetable ingredients

In previous studies, the possibility of joint use of meat raw materials (pork and poultry) and vegetable raw materials (taro paste and wheat bran) for the production of boiled sausages has been substantiated. The technological ingredients that are most acceptable in terms of sensory, physicochemical, organoleptic characteristics were analyzed and selected. The influence of prescription components (gelatin-oil emulsion, beet powder, D-sodium isoascorbate) on the intensification of manufacturing stages and reducing the degree of oxidative and hydrolytic changes in lipids was also established. So, according to preliminary studies, three new recipes were developed.

In the technology of manufacturing boiled sausages, the norms of prescription ingredients of novelty of work established as a result of research were used, in appropriate quantities (of the total amount of raw materials, %):

- Recipe 1 (boiled sausage with pork meat and taro paste): pork meat - 80%, taro paste - 8%, wheat bran – 1.2% and natural dyes – 0.2%.

- Recipe 2 (boiled sausage with pork and duck meat): pork meat – 50 %, duck meat - 40%, taro paste - 8%, wheat bran – 1.2%, natural dyes - 0.2%.

- Recipe 3 (boiled sausage with boned poultry meat (ducks and chicken), taro paste, antioxidants, gelatin-oil emulsion, natural dyes): duck meat - 56%, chicken meat - 40%, taro paste - 16%, wheat bran - 1.5%, emulsion (gelatin-oil) - 3%, antioxidants - 5.2% and natural dyes -0,5%.

The recipe composition of the main raw materials of the developed samples of boiled sausages is shown in Table 5.1.

To increase the economic efficiency of production, the share of pork meat in the formulations was reduced (table 5.1), which was replaced with poultry meat (duck or chicken), taro paste and wheat bran, protein stabilizer - gelatin-oil emulsion, antioxidant

- D-sodium isoascorbate, which is caused by the antioxidant effect, increased biological value and digestibility by the human body, lower cost of this type of raw material.

Table 5.1 - Recipes of cooked sausages with vegetable ingredients

Raw material, kg	Recipe № 1 (Pork-Taro paste-Bran sausage)	Recipe № 2 (Pork-Duck-Taro paste-Bran sausage)	Recipe № 3 (Poultry meat-Taro paste-Bran sausage)
Raw meat, kg, (calculated as 100kg)			
Lean pork	80.0	50.0	——
Duck meat	——	40.0	56.0
Chicken meat	——	——	40.0
Pig fat	20.0	10.0	4.0
Raw meat, kg, (calculated as 100kg)			
Wheat bran	1.2	1.2	1.5
Taro paste	8.0	8.0	16.0
Potato starch	0.7	0.7	0.7
Onion and Ginger Sauce	——	——	5.0
Sodium D-isoascorbate	——	——	0.2
Gelatin-oil emulsion	——	——	3.0
Salt	1.4	1.4	1.4
Complex phosphate	0.3	0.3	0.3
Complex spices	0.8	0.8	0.8
Pepper	0.3	0.3	0.3
Rice wine	4.0	4.0	4.0
Ice water	20.0	20.0	14.0
Red yeast rice	0.2	0.2	0.3
Beet red powder	——	——	0.2

5.2 Development of the technological scheme of boiled sausages with plant components

Based on the obtained experimental data, the development of the technology for the production of cooked sausages with taro paste was based. During the work, a technological scheme for the production of this meat product was developed. It was created on the basis of generally recognized (current technological instructions) stages of the technological process of manufacturing such products: cooking minced meat in a couter, forming sausages, precipitation, roasting, cooking. Also, the technological process consists of auxiliary (preparation of taro paste, vegetable-gelatin emulsion) stages (Fig. 5.1).

1. Acceptance of raw materials is carried out visually with an organoleptic evaluation.

Meat raw materials are checked for compliance with the accompanying documents: stamp and stamps, compliance with the category; absence of defects; thermal state; shelf life before delivery to the enterprise.

Food ingredients, additives, spices upon admission to production are checked for: production date, shelf life before entering production; the presence on the label of data on the composition, bookmark rates; absence of packaging defects.

Packaging materials and containers are monitored for compliance with accompanying documents and the possibility of use for contact with food.

It is forbidden to use raw materials in the absence of accompanying documents with an expired shelf life and do not meet the requirements of regulatory documentation. The water used to make boiled foods is used after cleaning.

2. Preparation of raw materials. Chilled meat raw materials (collapsed and veined) come to production with a temperature in the thickness of the muscles from 0°C - 4°C in multi-turn polymer boxes chilled from the cooling chamber. If necessary, meat raw materials are cleaned (removal of mechanical impurities, blood clots, prints of veterinary marks, removal of feathers and bristles). After stripping, raw meat, water and spices are weighed on scales.

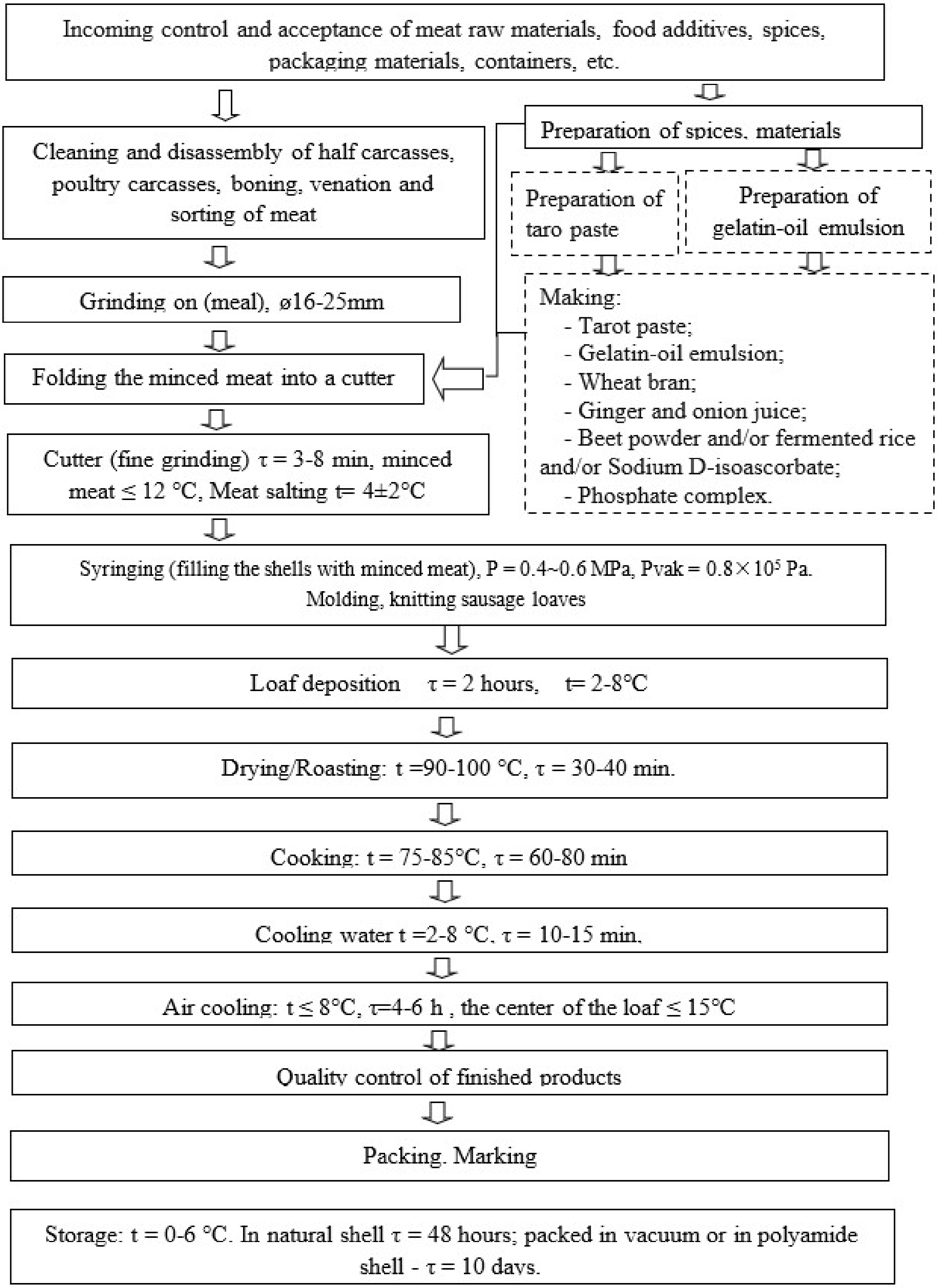


Fig.5.1 Technological scheme of production of boiled sausages with vegetable components

Frozen block meat is ground on a block cutter and sent for fine grinding onto a cutter.

Before grinding, fatty raw materials (fatty or semi-greasy pork) must be cooled to a temperature of from 0°C to 4°C, or freeze-fatty pork and fat, to a temperature of -3°C to -1°C).

The lard was cut on a lard machine, the size of the pieces is set according to the recommendations of the recipes.

The taro paste Processing technology. The root crop is cleaned of dirt and skin on a roller cleaning machine (MW2100 model, production capacity 0.5-2 t/h, Shandong Zhucheng Mingwei Food Machinery Co., LTD). The cleaned root crop is cut into slices 1 cm thick, on an industrial electric vegetable slicer (model: OP-6600, production capacity 300 kg/h). It is directed to be cooked in an autoclave (model RT 700-1200, production capacity 100 kg/h, Zhucheng Ritong Machinery Co., LTD) at a temperature of 110 ℃ for 20-30 minutes and cooled. The resulting mass is homogenized in a cutter for 3-5 minutes. The homogeneous mass is laid out on a baking sheet and sent for drying to an industrial drying cabinet at a temperature of 60 ºC to a humidity of 45-55%. They are packed in polymer bags and stored in cooling chambers at a temperature of 6-8°C.

The process of preparing the preliminary oil-gelatin emulsion. Add 3 liters of water to 1 kg of gelatin granules, dissolve them by heating, add 4 liters of vegetable oil mixture. Homogenize the resulting mixture at -10,000 rpm for 3 min.

Shell preparation. The natural shell was washed in water with a temperature of (15 -20)°C, then soaked in water with a temperature of (20 -25)°C. To add elasticity to the walls of the shell - wash with warm water (30-35)°C, checking the quality characteristics of factory processing. The shell was cut into segments, carefully cutting off the ends of the intestines.

Artificial sausage casings are cut into segments of the required length. Before use, artificial protein shells were washed in running water with a temperature of (15-20)°C for 25-30 minutes. Or soaked in a 10% solution of salt for 25-30 minutes. to strengthen the shell. After washing or soaking, the shells were shaken to remove excess moisture.

Polyamide, fibrous shells were pre-soaked in water with a temperature of (30-35) °C for 30-40 minutes. Shake off excess moisture before stuffing.

3. Cooking minced meat. Low-fat raw materials are loaded into the cutter, complex components containing phosphates were introduced. Make (mix) additives in the raw material for several revolutions of the cutter, then add half the moisture in the form of ice or ice water, salt. Cutter the minced meat for (1.5-2) minutes, then add fatty raw materials and gelatin-oil emulsion, taro paste, wheat bran, ginger and onion juice, sodium isoascorbinate, red beet powder, fermented rice, red wine, spices and some of the remaining moisture. Continue cuttering to minced meat temperature (10-12) °C.

4. The shells were filled with minced meat on a vacuum syringe (at a residual pressure P = 0.8×104 Pa). The ends of the loaves in the artificial shell were fixed with aluminum clips (brackets) with or without a loop with or without a pneumatic clipper. Provided that minced sausage was formed in a natural casing – sausages were tied with twine. The air that got into the minced meat during syringing was removed by piercing the shell (by puncturing). After knitting, the loaves were hung on frames at intervals to evenly roast the shell and prevent casts.

5. Sausages are deposited in the deposition chamber at a temperature not exceeding 8 °C and relative humidity of 80-85% - 2 hours.

6. Heat treatment of cooked products is carried out in a universal heat chamber under the following modes:

- Drying/roasting - carried out at a temperature of – 90-100°C, lasting from 30 to 40 minutes. Until the temperature reaches 45-50°C inside the loaf. They also visually determined the condition of the surface of the loaves by drying and redness of the surface. The gap between roasting and cooking should not exceed 30 minutes. To prevent the destruction of the structural protein framework of minced meat.

A characteristic feature of the proposed technology is the optimization of the cooking process for the developed recipe composition of sausages.

Steam cooking - was carried out at a temperature of - 75-85°C and a relative humidity of 95% until the temperature in the center of the product reaches 71°C (± 1) °C, after which exposure was carried out - for 10 minutes. The best effect in terms of rheological, physico-chemical, sensory, organoleptic indicators was achieved during the cooking time of the developed new cooked sausages, with a duration of 60-80 minutes. The specified parameters ensured the destruction of about 99% of vegetative forms of microorganisms, thanks to which the products became ready for use.

7. Cool sausages in the shower with cold tap water for 10-15 minutes. until the temperature in the center of the sausage loaf reaches 30-35°C.

After cooling in the shower, boiled sausages are sent to the cooling chamber by air, until the temperature in the center of the loaves reaches no higher than 15°C at a temperature in the chamber from 2-8°C and relative humidity from 90-95 %. The end of the technological process is considered the moment of reaching the temperature in the thickness of the product 15°C.

The hardware and technological scheme for the production of cooked sausage products with vegetable components is given in Appendix D.

8. Quality control of finished products is carried out in accordance with the requirements of regulatory documents. Sausages with manufacturing defects (deformed loaves, loaves with influxes of minced meat over the shell, broth-fat sagging, cracked shell, etc.) - do not allow for sale.

9. Packaging of cooked products is carried out of one name, one date of manufacture in polymer boxes or boxes.

10. Store cooked products in refrigerators at a temperature from 0°C to 6°C and relative humidity of 75-78 %. The shelf life of boiled sausages from the moment of completion of the technological process is no more than 48 hours. It is allowed to store products packed under vacuum -10 days, from the moment of completion of the process.

The listed stages of sausage production of the developed composition were the basis of the study carried out as part of this work. A characteristic feature of the proposed technology is the addition of tarot paste to the bowl in the process of grinding meat of tarot paste, wheat bran and the introduction of functional components into the minced meat – structure-forming and antioxidant action.

The introduction of a gelatin-oil emulsion into the recipe ensured the formation of not only the necessary consistency of the finished product, but also improved the biological characteristics of the product. A reduction in the amount of animal fat was achieved through the use of a gelatin-oil emulsion. This will reduce the amount of trans fats and cholesterol in the finished product. and will contribute to better digestion by the human body.

The stages of the technological process added to standard production procedures are indicated in Figure 5.1 by dashed lines.

The positive result of the production technology is achieved due to the introduction of natural ingredients. The introduction of taro paste and wheat bran into the recipe - a source of vegetable protein and valuable dietary fibers, which allowed to increase the amount of moisture retained by the mass and improve the nutritional value of the product due to the use of dietary fibers. Mixing taro paste and wheat bran contributed to their synergistic effect. This variation contributed to the realization of the structured form of the product with the specified functional and technological properties, the reduction of caloric content and the improvement of its appearance, juiciness, consistency, and stabilized the color of the product. An important prerequisite for high quality and guaranteed shelf life of sausages is the protection of their components from oxidation. To do this, instead of synthetic antioxidants, it was recommended to introduce natural antioxidants based on ginger juice and onions into minced meat. This allows you to preserve their taste properties and stabilize the color throughout the shelf life.

In view of the above, we believe that the formulations of the developed products and the technological scheme of its production allow us to obtain products enriched with natural protein and dietary fiber guaranteed shelf life with characteristic improved indicators of biological and nutritional value, improved functional and technological characteristics and reduced fat content.

The industrial approbation of the technology for the production of boiled sausages with taro paste was carried out at the institutions: FOP "Klymenko L.O." (Sumi) and FOP

"Filon A.M." (Sumy); Guangxi Zhifu Agricultural Development Co., Ltd, Guilin PLANT Biotechnology Co., Ltd (Guangxi Province, China) - (Appendices E1-E 8).

In total, from 2023, 180 kg of products were manufactured using the implemented technolog in Ukraine. Two companies in China's Guangxi Province have promoted and applied of 1.8 tons of poultry taro paste sausage, with an output value of approximately 10200 US dollars.

5.3 Evaluation of quality characteristics of finished products

The qualitative characteristics of the finished products examined in point 5.1 were evaluated according to generally accepted criteria: nutritional and biological value, sanitary-hygienic, structural-mechanical and organoleptic indicators.

The products differed: types of meat raw materials and vegetable components.

During the entire technological process, experimental products undergo physicochemical, biochemical, and microbiological transformations in raw materials.

In the process of research, the positive influence of the proposed prescription composition of raw materials on the complex of qualitative characteristics of sausages was revealed.

5.3.1 Physical and chemical characteristics of the product

To characterize the physicochemical changes in the samples, moisture, protein, fat and pH content were determined. Based on the obtained data, it was determined that cooked sausages with the addition of poultry meat, taro paste, wheat bran, emulsion (gelatin-oil) and natural dyes, antioxidants fully meet the requirements of regulatory documentation in terms of physico-chemical, organoleptic and other indicators (Table 5.2).

The chemical composition is one of the characteristics of the quality of the product, its nutritional and energy value, which depend on the quantitative ratio of moisture, fat, protein, minerals and indicate the stability of the product during storage (Table 5.2).

Table 5.2 - Organoleptic and physicochemical parameters of boiled sausages with herbal ingredients

Indicator name	Requirements for ND	Recipe № 1	Recipe № 2	Recipe № 3
Appearance	Loaves with a clean, dry surface, without damage to the shell, minced meat, slips, bouillon and fatty edema	Products with a clean, dry surface, without damaging the shell, there are minor broth edema.	Products with a clean, dry surface, without damaging the shell, the latter fits snugly to the minced meat, without broth edema.	Products with a clean, dry surface, without damaging the shell, the latter fits snugly to the minced meat, without broth edema.
Consistency	Elastic	Elasticity is reduced in the peripheral part.	The surface section is dense	On the lumbar section, the surface is dense without voids
Type of minced meat on the cut	Pink or light pink minced meat is evenly mixed without voids and gray spots	The minced meat is gray-pink, the color is heterogeneous, there are gray spots and relatively large cavities.	Pink minced meat is evenly mixed, without gray spots.	Light pink minced meat is evenly mixed, without gray spots.
Taste and smell	Peculiar to this type of product with a pronounced aroma of spices, moderately salty, without foreign taste and smell	Inherent in this product, but implicitly expressed, salinity is uneven, without foreign odors and tastes.	Inherent in this product, salinity is uniform, there are no foreign tastes and odors.	Inherent in this product, salinity is uniform, there are no foreign tastes and odors.
Mass fraction, %- protein, not less	10	15	16.5	17.1
- fat, not more	35	16	8	5.5
- moisture, not more	74	65	65	67
Energy value, kcal (kJ)/100 g	921-1298	780	580	558
pH	*	6.20	6.25	6.38
Cutting force, N	*	15	14	17
Hardness(N)	*	106	101	244
Chewiness(N)	*	76	22	81
Redness (a)	*	11.78	18.16	9.08
Lightness (L)	*	54.81	54.37	56.66
Yield, %	*	123.8	128.4	129.6
*	Not normalized			

Comparative analysis of the chemical composition and energy value of finished products did not reveal significant deviations between the samples of formulations. This confirms the high nutritional value of the new formulation ingredients with different meat components.

Structural-mechanical (rheological) properties of food products determine the behavior of products in various technological processes, characterize the state of aggregation, dispersion, structure, structure and type of interactions within the product. These properties also determine the taste and digestibility of food.

Consequently, structural and mechanical indicators characterize the depth of changes that occurred during the heat treatment of samples. It should be noted that the values of the indicators of cut force, hardness, chewiness, which characterize the consistency of the product were lower formulation № 1 and № 2 (without gelatin-oil emulsion), compared to the corresponding indicators of formulation № 3 using gelatin-oil emulsion (Table 5.2).

In the sample formulation № 3, lower weight loss of the product after heat treatment is observed, compared to samples of formulations № 1 and № 2, as evidenced by an increase in yield by 4,6%.

5.3.2 Organoleptic evaluation of experimental boiled sausages with different types of meat and herbal supplements

Organoleptic indicators are qualitative norms of the final product, based on the analysis of perception, which are perceived by the visual and sensory organs of a person.

The commission conducted a study of three prescription samples of cooked sausages with different types of meat and herbal supplements, evaluating each indicator on a 9-point scale using the weighting factor of each indicator.

The results of evaluation of the studied products are shown in Figure 5.2.

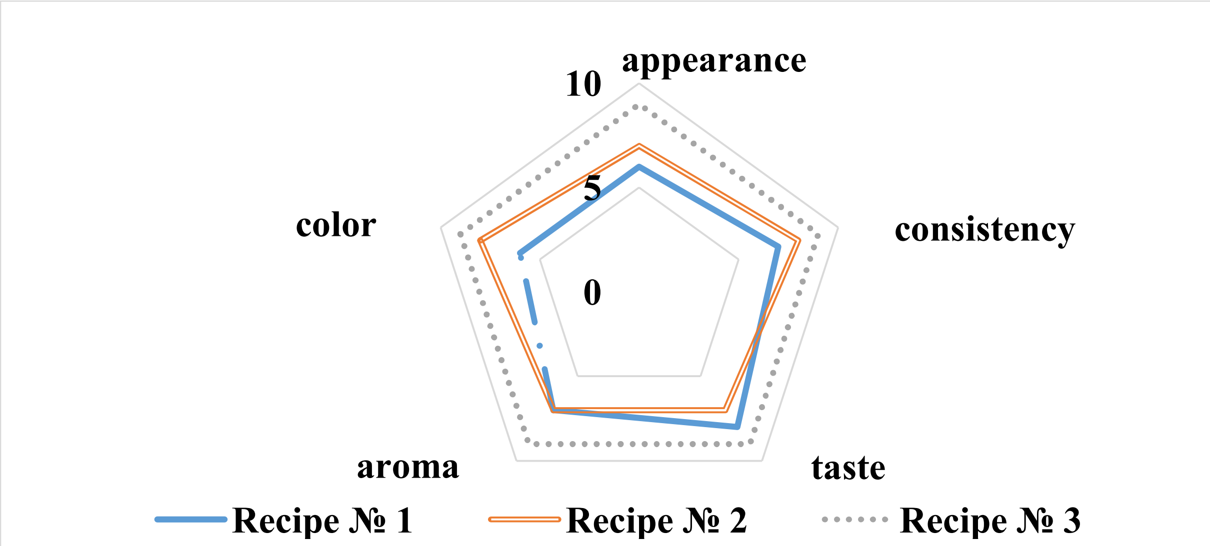


Figure 5.2 Diagram of studied cooked sausages with different types of meat and herbal supplements

From the data presented in fig. 5.2 it follows that organoleptic indicators: appearance, color, smell, taste, texture of boiled sausages with different types of meat and herbal supplements differ from each other. Prescription sample № 3 had a more expressive, saturated color - due to the addition of beet powder and fermented rice, elastic consistency - due to the addition of gelatin-oil emulsion, a pleasant taste - due to the arrangement of duck meat, chicken and taro paste, compared to the recipe sample № 1.

According to organoleptic indicators, among all variants of sausages, the sample of recipe № 3 had the highest rating of the tasting commission — 9,0.

The improvement of organoleptic quality indicators is associated with the introduction of taro paste and wheat bran into the recipe. The created carbohydrate framework contributed to the retention of natural moisture of raw meat and prevented the loss of added moisture, due to fiber fibers.

The presented materials prove the validity of the established rational amount of the prescription composition of products, namely, meat raw materials (pork, duck, chicken), taro paste, wheat bran, emulsion (gelatin-oil) and natural dyes, antioxidants, phosphate complex in the recipe of boiled sausages of various layouts.

5.3.3 Investigation of microbiological parameters of finished boiled products according to recipe samples

The sanitary and hygienic condition of the product is the last quality control indicator in the technological link during the manufacture of the product. The presence and amount of appropriate microflora in the product affects the duration of storage.

According to microbiological indicators, finished products should not exceed the norms established in the regulatory documentation Zrf regulates the total number of microorganisms, the permissible amount of which should not exceed 1.0×10^3 CFU in 1 g of product, bacteria of the E. coli group (coliform coli) and Staphylococcus aureus in 1 g, sulfite-reducing clostridium in 0.1 g, bacteria of the genus Salmonella and L. monocytogenes in 25 g of product.

During microbiological studies, no bacteria of the E. coli group, Staphylococcus aureus, sulfite-reducing clostridia and bacteria of the genus Salmonella were found in all samples of the developed formulations. The total number of bacteria of the group did not exceed the sanitary permissible level – and was at the level of $(2.1\text{-}5.4)\cdot10^2$ CFU/g The obtained results of determination of microbiological parameters in finished products are presented in Table 5.3.

Table 5.3 - Microbiological indicators of finished products according to recipe

Indicator name	Norm	Recipe № 1	Recipe № 2	Recipe№ 3
The total number of microorganisms, CFU in 1.0 g of product, not more than	1×10^3	$2{,}6\times10^2$	$2{,}1\times10^2$	$5{,}4\times10^2$
Bacteria of the E. coli group (coliforms), in 1.0 g of product	Not allowed	Not allowed	Not allowed	Not allowed
Sulfite-reducing clostridia, in 0.01 g of product	Not allowed	Not allowed	Not allowed	Not allowed
Bacteria of the genus Proteus, in 0.1 g of product	Not allowed	Not allowed	Not allowed	Not allowed
Staphylococcus aureus, in 1.0 g of product	Not allowed	Not allowed	Not allowed	Not allowed
Pathogenic microorganisms, in particular bacteria of the genus Salmonella, in 25 g of product	Not allowed	Not allowed	Not allowed	Not allowed
L. monocytogenes, in 25 g of product	Not allowed	Not allowed	Not allowed	Not allowed

The results of microbiological studies indicate the safe sanitary condition of all finished products.

Microbiological spoilage of the product may occur in case of contamination of raw materials, failure or incorrectly set temperature and humidity conditions, or in violation of packaging conditions.

In accordance with the requirements of regulatory documents – sausages are stored at the manufacturer and in the trading network at a temperature from 0ºC to 6°C and relative humidity from 75 % to 78 %. The shelf life of developed boiled sausages from the moment of completion of the technological process is no more than 48 hours.

Conclusions to section 5

1. Recipes of three types of cooked sausages with vegetable components have been developed, namely:

- Recipe 1 (boiled sausage with pork meat and taro paste): pork meat - 80%, taro paste - 8%, wheat bran – 1.2% and natural dyes – 0.2%.

- Recipe 2 (boiled sausage with pork and duck meat): pork meat – 50 %, duck meat - 40%, taro paste - 8%, wheat bran – 1.2%, natural dyes - 0.2%.

- Recipe 3 (boiled sausage with boned poultry meat (ducks and chicken), taro paste, antioxidants, gelatin-oil emulsion, natural dyes): duck meat - 56%, chicken meat - 40%, taro paste - 16%, wheat bran - 1.5%, emulsion (gelatin-oil) - 3%, antioxidants - 5.2% and natural dyes -0.5%.

2. Improved schematic technological scheme for the manufacture of boiled sausages, which includes the following stages: 1) quality control of meat raw materials obtained in chilled or frozen state, 2) defrosting of meat raw materials if there is such a need, 3) preparation of taro paste and gelatin-oil emulsion, 4) fine grinding of meat raw materials and additional ingredients in a cutter, 5) syringing minced meat into a shell, 6) precipitation of boiled sausages to obtain a dense structure, 7) heat treatment (drying/roasting) of sausage loaves until the temperature in the center reaches 45-50 °C, 8) cooking of sausages at a temperature in the chamber from 75-85°C and relative

humidity of 95% until the temperature in the center of the loaf reaches 71 °C (±1) ° C for 60-80 minutes, 9) two stage cooling of the finished product (water/air) to a temperature not exceeding 15°C and its transfer for storage / shipment from the enterprise.

3. Improvement of rheological, organoleptic, physicochemical and microbiological parameters of cooked meat products due to the introduction of selected components has been proven. The products produced according to the developed recipe No. 3 are characterized by increased color indices - redness (a) and lower lightness (L), texture (Hardness and cut force), the best indicator of emulsion stability, standard pH and moisture binding.

SECTION 6
SOCIO-ECONOMIC EFFECT IN IMPLEMENTATION OF NEW TECHNOLOGIES

In this section, the results of determining the socio-economic effect of the introduction of technologies using taro paste from the root vegetable "Areca taro" and products using it are given, the cost price is calculated, and general data on the approval of the research results are given. The economic feasibility of introducing developments into the practical activities of food industry enterprises has been proven.

The assessment of the socio-economic effect from the introduction of technology of taro vegetables (taro paste) was carried out taking into account the following provisions. In today's conditions, the formation of investment and current economic activity of restaurant industry institutions is based on the search for innovations that can be brought to the stage of production application. From these positions, the technology of products from the root of the taro (taro paste) is quite attractive. Firstly, this technology implements the main components of the innovative development strategy–marketing, technological, organizational, technical, and secondly, defined and justified during the study technological principles for obtaining taro paste products from root crops, allowing to expand the range of products, which, according to marketing forecasts, will be in demand by consumers.

The proposed technology provides for complex processing of root crops, which has not previously been used in the food industry due to the lack of industrial cultivation technologies. This approach to the processing of root crops allows to reduce the cost of production and make it affordable from an economic point of view for the general population of Ukraine, to increase the efficiency of production.

It is positive that the main raw material in the technological cycle of tarot paste production is used taro root crop purchased from agricultural enterprises in Nigeria, which to some extent increases the risks arising from the use of imported raw materials, namely, increased transportation and storage costs, non-compliance with delivery times, etc. The creation and implementation of such technologies is relevant in the conditions of the modern market economy of the state and is a priority direction of its development.

The technology of products from the root of the taro (taro paste) involves the use of natural raw materials of plant origin–the taro vegetable. Under these conditions, the creation of products with high nutritional and biological value is ensured, which contributes to ensuring the health of consumers and increasing their efficiency.

Direct quantitative assessment of the effectiveness of this technology is carried out by calculating the cost of new products in comparison with the cost of market analogues (tomato paste). To determine the cost of production at the first stage, the cost of raw materials and materials necessary for the production of 1000 kg of products from taro vegetables was calculated. The costs at each technological stage of production of products from taro vegetables (taro paste) and the necessary equipment for this are given in table. 6.1.

Table 6.1 - Scheme of cost modeling in the technology of products from taro vegetables (taro paste)

Stages of production	Items of expenditure	Necessary equipment/storage space
Purchase of taro vegetables and their storage before use in the technological process	Buying a taro vegetable	Vegetable composition
	Electricity	
	Workforce	
Washing and peeling	Water supply	Vegetable Cleaning Machine
	Electricity	
	Workforce	
Cooking	Water supply	Pressure Boiler Double Boiler
	Electricity	
	Workforce	
Grinding to a uniform consistency	Electricity	Industrial cutter, production table
	Workforce	
Cooking to a pasty consistency	Electricity	Pressure Boiler Double Boiler
	Workforce	
Packaging and labeling	Packaging materials	Polystyrene bags, vacuumizer, production table, label
	Electricity	
	Workforce	
Storage	Electricity	Refrigerating compartment
	Workforce	

Data table 6.1 make it possible to summarize the main items of expenditure in the production of products from taro vegetables (taro paste), which is necessary to determine the total cost of production.

For a better understanding of the process of manufacturing a product from the taro (taro paste), the cost of purchasing the necessary equipment to start production and the cost of its operation are calculated, according to the technical characteristics given in table 6.2.

Table 6.2 - The cost of fixed assets of production and their operation

Necessary equipment	Brand, size	Quantity per 1t of manufactured products, Piece.	Electricity consumption per 1t, kW Water	consumption per 1t, liters	Market value as of 2023, UAH
Vegetable Cleaning Machine	Vektor XH 30 1020×590×590	1	6	1500	40975
Pressure Boiler Double Boiler	JYGKJ-600/D 1300×1100×1400	2	80	1000	256000
Industrial cutter	YAZICILAR L100IV 1000×700×1350	1	75	-	527940
Production table	Chimneybud, 1800×700×850	2	-	-	38626
Vacuum izer	Vacuum Packaging Machine «Status SV-2000»\ 420×270×170	3	2,64	-	16350
Refrigerating compartment	Polair Standard KXC80 1660×3460×2200	1	-	-	95021
Medium-temperature monoblock	MXM MMN 112 1660×3460×2200	1	33,36	-	87216
Total					1062128

To calculate the total cost of production, we took into account the cost of all costs for the production and sale of manufactured products as of 2023 in Ukraine (Table 6.3).

Table 6.3 - Calculation of the cost of taro vegetable products (taro paste)

Cost items for the production and sale of products	Production factors per 1 ton of product	Based on 1000 kg of products as of 2023, UAH
Purchase of raw materials (75 UAH/kg)	1500 т	112500
Labor force (number of employees and average wage per day)	8 people/4 people per shift/12 hour working day/15 working days per month	58262,4
Transportation	Delivery of 1 ton of raw materials once a day	7500
Electricity	197 kWt	935,75
Water supply	2500 L	81,63
Rent of industrial premises 100m^2	1 night	700
Product labeling and packaging	1000 polystyrene bags (Vacuum bag PA/PE transparent food)	3200
Production cost	-	183179,78
Cost of equipment	1062128	-
The cost of preparation, equipment and development of production	3,5% cost of equipment	-
Depreciation of equipment taking into account the cost of starting production (based on 10 years)	1099302,48 UAH/year	305,36
The cost of unsold products during the shelf life	2.5% of production cost	4579,5
Costs due to technical defects	1% of production cost	1831,8
Corporate income tax Group 2 single tax payers 20% of the minimum wage (1340 UAH/month)	Based on the production of 30 tons of semi-finished products per month	44,7
UST of the enterprise 2nd group of single tax payers 22% of the minimum wage (1474 UAH/month)	Based on the production of 30 tons of semi-finished products per month	49,1
The minimum payment of personal income tax is 18% of the minimum wage (1206 UAH/month) for an employee	Based on the production of 30 tons of semi-finished products per month (8 employees)	321,6
The minimum payment of SSC is 22% of the minimum wage (1474 UAH/month) for an employee	Based on the production of 30 tons of semi-finished products per month (8 employees)	393,1
Cost per 1000 kg		190704,94
Profit of the enterprise (minimum 15% markup)		28605,74
Cost of 1000 kg		219310,68
VAT 20%		43862,14
Selling price 1000 kg		263172,82

The average rate of output from 1 ton of raw materials (taro crop) averages 700 kg. Since the calculations are based on 1 ton of finished products, it is established that its production will take 1 day. The lease of production premises of 100 m^2 was determined based on 1 working day with a total cost of 21000 UAH for 30 days of rent. Labor costs were calculated in accordance with the Law of Ukraine "On State Budget of Ukraine for 2023" dated 03.11.2022, No. 2710-IX. and amount to 40.46 UAH/hour with 12 hours of shift work schedule. According to the tariffs for 2023, presented separately for each region in Ukraine, the average cost of 1 kW of electricity for enterprises of voltage class 2 consuming more than 750 kW per month is UAH 4.75/kW. The cost of 1 m^3 of water on average in Ukraine and the tariff for centralized water supply and sewerage services in the amount of UAH 32.65 are taken into account. After analyzing the freight market in the sector up to 5 tons, the cost per 1 km, on average in Ukraine, is 15 UAH/km. The maximum distance of delivery of raw materials according to the maximum profitability of production is indicated no more than 500 km, which is taken as the basis for the calculations. The cost of preparation, equipment and development of production is 3.5% of the cost of equipment. The cost of unsold products during the shelf life is 2.5% of production costs. Costs due to technical defects amount to 1% of production costs.

Thus, the calculations made it possible to determine the selling price of 1000 kg of the developed product, which is UAH 263172.82.

It is determined that the introduction of product technology in food industry enterprises will allow an economic entity to receive a profit of 28.6 thousand UAH for each ton of products sold.

To determine the selling price for a product from taro vegetables (taro paste), the market price for an analogue, tomato paste, was taken into account, which averaged UAH 200/kg (the selling price for tomato paste is quite high, given the average price of fresh tomatoes, which is UAH 15/kg, which is 5 times higher than the price of taro, which is quite expensive to import from Nigeria) as of 2023. Therefore, given that the cost of taro paste is 190.70 UAH/ g, and the cost price is only 4.65% lower than the market price for an analogue, tomato paste, determining the margin in the range of 15% (minimum margin) and taking into account the VAT of 20%, taro paste will be sold 24% more expensive than its counterpart, tomato paste. The main reason for the high selling price compared to the analogue, tomato paste, is due to the fact that the main raw material, taro root vegetables, for the production of taro paste is 5 times more expensive than fresh tomatoes. In the market for the sale of plant concentrates, a strategy for the sale of products from a new type of raw material for Ukraine should be worked out, which will allow it to be adapted to the region's economy and create the most competitive taro paste products while maximizing profits.

The industrial approbation of the technology for the production of boiled sausages with taro paste was implemented at the enterprises of Ukraine and China (FOP "Klymenko L.O.", FOP "Filon A.M.", Guangxi Zhifu Agricultural Development Co., Ltd, Guilin PLANT Biotechnology Co., Ltd (Appendices E1-E 8).

Conclusions to Section 6

1. An assessment of the socio-economic effect of the development and implementation at food enterprises of the technology for making cooked sausages from different types of meat with the addition of taro paste was carried out. It is shown that the determined technological principles of the production of new products allow to ensure complex processing of taro root crops, which helps to reduce the cost of production, while simultaneously increasing the efficiency of the technological process.

2. A complex of organizational and technical measures for the introduction of new technologies was carried out at the food enterprises of FOP "Filon A.M.", FOP "Klimenko", Guangxi Zhifu Agricultural Development Co., Ltd, Guilin PLANT Biotechnology Co., Ltd.

3. The calculations made it possible to determine the selling price of 1000 kg of the developed product, which is UAH 263,172.82. It was determined that the introduction of technologies with the addition of taro paste at food industry enterprises will allow the business entity to receive a profit of UAH 28.6 thousand for each ton of sold products.

CONCLUSIONS

In the dissertation study, based on the analytical analysis of scientific and technical literature, the role of natural plant raw materials as sources of: protein, dietary fibers, dyes, antioxidants was formulated and proven, and the principles of their influence on the organization of the production of high-quality and safe sausage products were characterized. Traditional and modern technologies for the production of boiled sausages are analyzed.

1. On the basis of the conducted experimental studies, a rationalized technology for obtaining taro powder and taro paste was determined. The physico-chemical, biological, microbiological properties and aromatic compounds of taro paste prepared at different temperatures were analyzed and it was established that 110 °C is optimal. It was determined that taro paste with a moisture content of 64.4% should be used for the development of recipes for sausage products in order to preserve the natural taste and improve the quality of finished products. It has been proven that taro paste and wheat bran are raw materials with a high fiber content, the dietary fiber content is - 20.1 g/100 g and 31.4 g/100 g, respectively (in dry matter), which improves nutritional and structural-mechanical sausage characteristics. Regulatory and technical documentation for the production of products from the Areca taro root crop has been developed.

2. It has been proven that the optimal amount of taro paste is 8 kg in the recipe of pork sausages. The indicated amount ensures a minimum loss of weight and mass fraction of moisture of sausages during cooking by 37.2% and 11.36%, respectively, compared to the analogue. Contributes to the improvement of emulsion stability, increases water-binding capacity by 20%, protein content by 1.34 times and reduces the amount of animal fat in sausage by 1.6 times, compared to the analogue. With the addition of this amount of taro paste, the amount of potato starch is reduced by 60%.

3. It has been proven that the rational amount of replacing pork meat with duck meat is 40%. The set amount of duck meat gave the sausage product better elasticity and reduced the cut effort index by 1.26 times, compared to the control. The synergistic effect of plant additives (taro paste – 8 kg and wheat bran – 1.2 kg) on reducing the weight loss

of sausages during heat treatment and ensuring the structural stability of the protein framework has been scientifically substantiated and confirmed.

4. The study of the temperature-time parameters of heat treatment of cooked sausages with vegetable raw materials established that the rational cooking temperature is 75-85 ˚C with a duration of 60-80 minutes. Under these regimes, the loss of meat juice is reduced by 1.26 times (due to the binding of weakly bound moisture) and contributes to a greater output of the product by 1.15 times, compared to a cooking time of 40 minutes. With a longer duration of cooking (100 minutes), a significant loss of weight, mass fraction of moisture and deterioration of the consistency of the product was observed.

5. A recipe for cooked sausage made from poultry meat (duck, chicken - 3:2) was developed based on composition optimization criteria and rational amounts of technological ingredients were established: taro paste – 16 kg, wheat bran - 1.5 kg, phosphate complex - 0.3 kg for 100 kg of minced meat. The specified norms allow to obtain finished products with the following maximum indicators: sensory evaluation - 45 units, cutting force - 148.46 N, cooking losses - 4.96%.

6. It is scientifically proven and confirmed that the addition of ginger-onion juice (5%) and sodium D-isoascorbate (0.2%) inhibited oxidation processes in boiled poultry sausages: the acid number decreased by 1.1-1.4 times, TBARS - 1.1-1.32 times and promoted the binding of free radicals (DPPH) - 1.1-1.2 times, improved redness and brightness indicators by 1.05 times, compared to the control. To reduce the amount of animal fat in the recipes of cooked poultry sausages, it is suggested to use a highly stable oil-gelatin emulsion, in a ratio of 1:1, with a rational dose of 3 kg. Based on color and organoleptic indicators, a rational dosage of natural dyes has been determined in the amount of: 0.3 kg - fermented rice and 0.2 kg - red beet powder, which gave boiled poultry sausages a characteristic red color. Based on the results of the research, three new recipes for cooked sausages were developed.

7. Based on the obtained results, a technological scheme for the production of cooked sausages from various types of meat was developed, the difference of which is

the addition of taro paste, wheat bran, oil-gelatin emulsion, ginger-onion juice, sodium D-isoascorbate, red beets and fermented rice.

8. The effectiveness of the proposed technology is confirmed by socio-economic calculations. The technology was tested in production conditions and implemented at the FOP "Klymenko L.O.", FOP "Filon A.M." (city of Sumy), Guangxi Zhifu Agricultural Development Co., Ltd and Guilin PLANT Biotechnology Co., Ltd (Guangxi Province, China).

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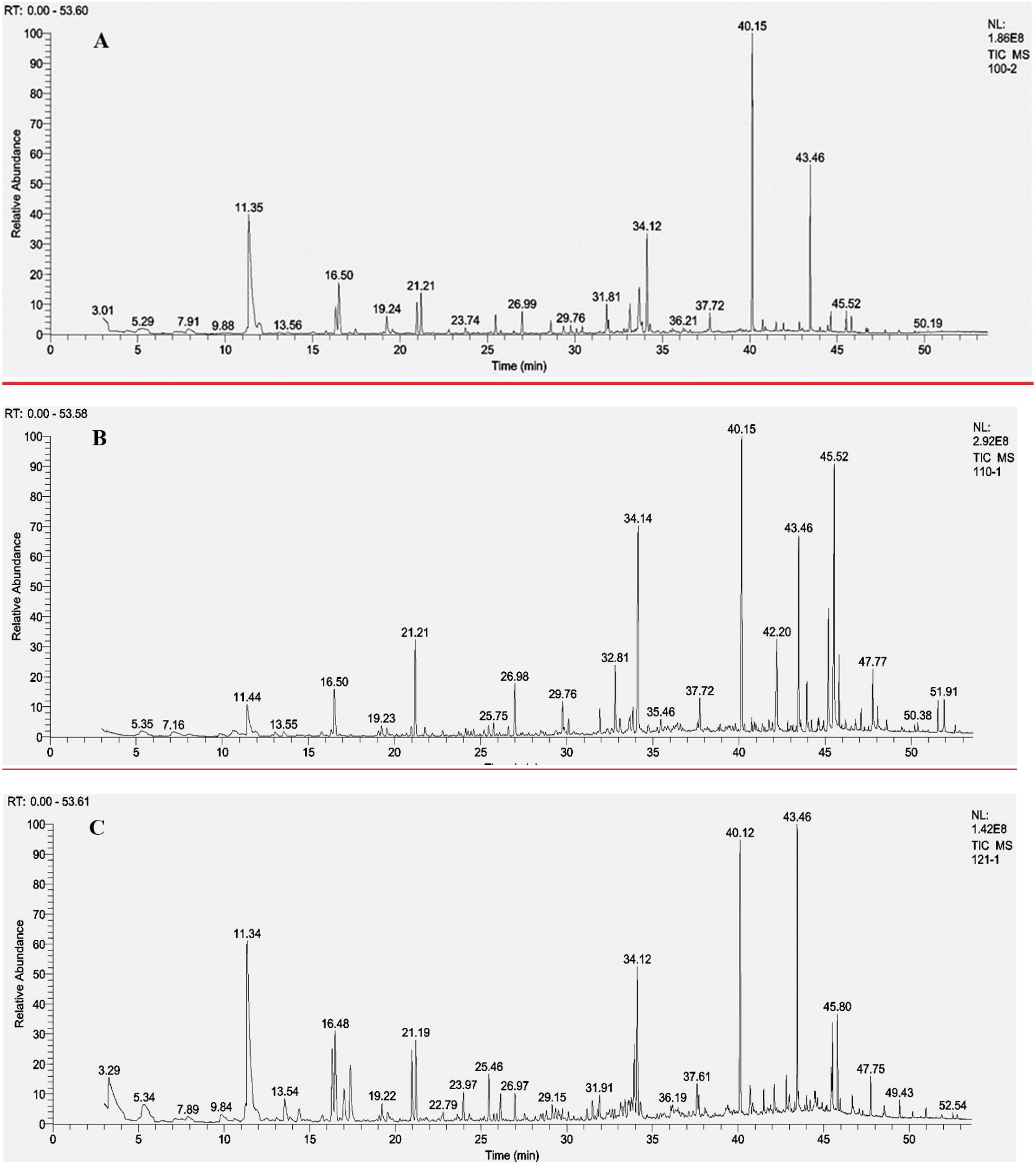
APPENDICES

APPENDIX A. GC-MS chromatogram of taro paste, A-100℃，B-110℃，C-121℃. (Note: Solid phase microextraction mass spectrometry of the aroma of taro puree cooked at 100℃, 110 ℃, 121℃)



APPENDIX B. Title sheet of technical conditions

ДКПП 10.3

ПОГОДЖУЮ

Директор

ФОП «Філон А.М.»

__________ А.М. Філон

«_02_» ___12___ 2022 р.

УКНД 67.080.20

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__________ В.І. Ладика

«_09_» ___12___ 2022 р.

ПРОДУКТИ ІЗ ТАРО КОНЦЕНТРОВАНІ ТА СУШЕНІ

Технічні умови

ТУ У 10.3-04718013-008:2022

Вперше

Дата надання чинності _22.12.2022_

Чинні до _22.12.2027_

РОЗРОБЛЕНО

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Appendix C. Main normative indicators and quality characteristics of taro products

Concentrated taro products (mashed potatoes, paste) are products that are made from whole or crushed, coarsely mashed or mashed taro vegetables or by reconstituting taro powder. Dried taro products (powder) is a product that is made from pre-prepared, dried and crushed to a given size taro crop particles.

According to organoleptic parameters, tarot products concentrated and dried must meet the requirements given in Table C1.

Table C 1- Sensory requirements

Name of indicators	Characteristic	
	concentrated puree, concentrated paste	Powder
1 Taste and smell	Clean, without foreign tastes and odors	
2 Color	From transparent to light cream color and from pink to light red, depending on the variety, yellow and orange shades are allowed	From white to light cream and from pink to light red, depending on the variety, yellow and orange shades are allowed
3 Consistency	Homogeneous gel without sediment	Powder without impurities

According to physical and chemical indicators, tarot products concentrated and dried must meet the requirements given in Table C 2.

Table B 2–Physical and chemical parameters of products from taro concentrated and dried

Name of indicators	Normalized values		Control methods
	Powder	Taro paste	
Mass fraction of moisture, %, not more than	15,0	65,0	DSTU 8004
Protein mass fraction, %, not less than	10,0	5,0	DSTU ISO 1871
Mass fraction of dietary fiber (fiber), %, not less than	40,0	15,0	DSTU ISO 5498
pH 10 % aqueous suspension	10-11		DSTU 4957

According to the content of toxic elements and mycotoxins, tarot products concentrated and dried must meet the requirements given in the Order of the Ministry of Health of Ukraine No. 368 of 13.05.2013 and indicated in Table B 3.

Table B 3- Limit requirements for harmful toxins in products

Name of toxic elements	Acceptable levels	Test methods
Toxic elements, mg/kg, not more than:		
Mercury	0,02	According to GOST 26927, DSTU ISO 6637
Arsenic	1,0	According to GOST 26930, DSTU ISO 6634
Copper	5,0	According to GOST 26931, DSTU ISO7952, GOST 30178
Lead	0,5	According to GOST 26932, DSTU ISO 6633, GOST 30178
Cadmium	0,03	According to GOST 26933, DSTU ISO 6561, GOST 30178
Mycotoxins, mg/kg, not more than:		
Aflatoxin B1	0,005	According to MU 4082 , MR 2273 , DSTU EN 12955
Mycotoxin patulin	0,05	DSTU 4947
Zearalenone	1,0	According to MR 2964

According to safety indicators (microbiological indicators), concentrated and dried taro products must meet the requirements given in the Order of the Ministry of Health of Ukraine No. 548 of 19.07.2012 and indicated in Table B 4.

Table B 4-Product hygiene requirements

Metrics name	Acceptable levels	Test methods
The number of mesophilic aerobic and facultative-anaerobic microorganisms, CFU in 1 g, not more than	$5 \cdot 10^4$	According to DSTU8446
Bacteria of the group of E. coli (coliforms) in 0.1 g	Not allowed	According to DSTU30518
Pathogenic microorganisms, in particular bacteria of the genus Salmonella, in 25 g	Not allowed	According to DSTUEN 12824
Mold fungi, CFU in 1 g, not more than	$1 \cdot 10^2$	According to DSTU8447
Yeast, CFU in 1 g, not more than	$1 \cdot 10^2$	According to DSTU8447

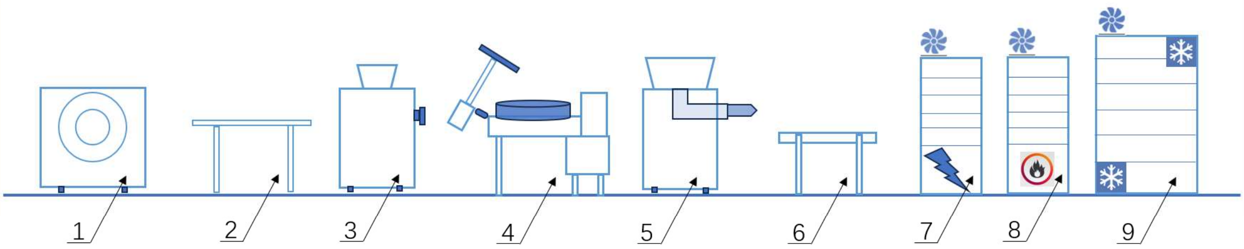
Store dried products from taro (powder) in clean, dry rooms, not infected with pests of grain stocks, well ventilated or equipped with supply and exhaust ventilation, protected from direct sunlight and heat sources, at a temperature of (20-30) °C and relative humidity not exceeding 75%. Shelf life - no more than 3 years. If the shelf life of the powder exceeds 1 year, then before use in food production, it is necessary to check it for compliance with organoleptic and microbiological standards.

Concentrated products (mashed potatoes, paste) are stored in clean, dry rooms, well ventilated or equipped with supply and exhaust ventilation, protected from direct sunlight and heat sources at a temperature of (0-8) °C and relative humidity not exceeding 80%. Shelf life not more than 1 year. If the shelf life exceeds 180 days, then before use in food production, it is necessary to check it for compliance with organoleptic and microbiological standards.

The shelf life of products concentrated and dried from taro (mashed potatoes, paste, powder) may be set by the manufacturer (depending on the quality of raw materials, the level of production technology, equipment characteristics, packaging conditions and properties of packaging materials) provided that the products meet the requirements of these specifications and agree these terms with the central executive authority on health care.

Appendix D. Poultry sausage production flow chart

Schematic diagram of sausage production line equipment



No.	*Device name*	*No.*	*Device name*
1	*Microwave defroster*	*6*	*workbench*
2	*Division table*	*7*	*digester*
3	*Meat mincer*	*8*	*bakery*
4	*Chopper mixer*	*9*	*Cold storage*
5	*Sausage stuffer*	*8*	

Poultry sausage production flow chart	
Design unit	SUMY NATIONAL AGRARIAN UNIVERSITY
Design time	May 10, 2023
Country/City	Ukraine /Sumy
Designer	Shang feifei, PhD

Appendix E. Documents confirming the industrial implementation of the developed technology

Appendix E 1

Application proof

Product name	Taro paste poultry sausage
Standard number	Q / ZFA-0001S-2022
Invention Institution	1 Hezhou University; 2 Sumy National Agrarian University
Product inventor	Shang Feifei， Kryzhska Tetyana
Application Company	Guangxi Zhifu Agricultural Development Co., Ltd
Mailing address	631, Group 20, Tianchang Village, Shatian Town, Pinggui County, Hezhou City, Guangxi

Since December 10, 2022, our company has adopted the product formula and processing technology of "Taro paste poultry sausage" provided by Shang Feifei. Taro poultry sausage has a special flavor of taro, good taste, balanced nutrition, and a stronger aroma after baking. It is suitable for sale in restaurants and supermarkets. The trial production of sausages was 1800kg, with an output value of approximately 10200 US dollars. After sales, the product was well received by customers and has good economic value, which meets our company's product needs.

Enterprise (official seal):

Head of enterprise:

Date: 2023. 3. 10

Appendix E 2

Application proof

Product name	Taro paste poultry sausage
Standard number	Q / PLD-004S-1
Invention Institution	1 Hezhou University; 2 Sumy National Agrarian University
Product inventor	Shang Feifei , Kryzhska Tetyana
Application Company	Guilin PLANT Biotechnology Co., Ltd.
Mailing address	No. 59 Yanxin Road, Gongcheng County, Guilin

Our company is a key agricultural product processing enterprise, with an annual production of 10,000 tons of taro paste. Since January 7th, 2023, our company has adopted the product formula and processing technology of "Taro paste poultry sausage" provided by Shang Feifei. Further processing and utilization of taro paste is the company's development goal. They are nutritious, protein-rich, with good nutritional value and economic value, and they are in line with our company's product needs.

Enterprise (official seal):

Head of enterprise: Xinfeng Yang

Date: June 24, 2023.

Appendix E 3

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ НАЦІОНАЛЬНИЙ АГРАРНИЙ УНІВЕРСИТЕТ

УЗГОДЖЕНО Проректор з наукової та міжнародної діяльності, доктор економічних наук, професор	ЗАТВЕРДЖУЮ Директор ФОП «Філон А.М.»
Ю.І. Данько (підпис) (ініціали, прізвище)	А.М. Філон (підпис) (ініціали, прізвище)
«06» 02 2023 рік (дата)	«30» січня 2023 рік (дата)

АКТ
ВПРОВАДЖЕННЯ НАУКОВО-ДОСЛІДНОЇ РОБОТИ

Замовник: ФОП «Філон А. М.»
(найменування організації)

директор Філон Андрій Михайлович
(посада, ПІБ керівника організації)

Цим актом підтверджується, впровадження результатів роботи виконаних у межах

	наукової держбюджетної тематики:	Розробка технічної документації на напівфабрикат з рослинної сировини для м'ясних фаршевих виробів подвійного призначення (найменування теми)
	Номер державної реєстрації:	0122U202024
	Держбюджетна тематика виконується на кафедрі:	Технологій та безпечності харчових продуктів
	Дата виконання держбюджетної тематики:	2022–2023 р.
	Результати роботи впроваджені на підприємстві:	ФОП «Філон А.М.» (найменування підприємства, де здійснювалось впровадження)
1	**Вид впроваджених результатів**	технологія ковбасок зі свинини із використанням продуктів із таро концентрованих (експлуатація виробу, роботи, технології; виробництво виробу, роботи, технології, функціонування систем)
2	**Характеристика масштабу впровадження**	дослідно-промислова партія (унікальне, одиночне, партія, масове, серійне)
3	**Форма впровадження**	виробничий випуск
4	**Новизна результатів науково-дослідних робіт**	використана нова сировина, розроблено нову технологію, нові досліджені результати, продукція випускається вперше (піонерські, принципово нові, якісно нові, модифікація, модернізація старих розробок)
5	**Впроваджені на основі нормативно-технічної документації**	ТУ У 10.3-04718013-008:2022 (вказати номер і назву нормативно-технічної документації)

Continuation of the application E 3

6	**Впроваджені в промислове виробництво**	ФОП «Філон А.М.» (назва підприємства)
7	**Рентабельність продукції (Додаток 1)**	37 % (характеристика прибутковості господарської діяльності підприємства від реалізації дослідно-промислової партії)
8	**Соціальний і науково-технічний ефект (Додаток 2)**	розроблені ковбаски зі свинини рекомендовано використовувати як самостійний харчовий продукт, так і у складі кулінарної продукції в закладах ресторанного господарства та підприємствах харчової промисловості (холодні та гарячі закуски, салати, виробів із борошна), які значно розширять асортимент готової продукції збагаченої харчовими волокнами та рослинним білком і можуть бути реалізовані в оптовій та роздрібній торгівлі. (використання в харчовій промисловості та реалізація населенню)

9 Удосконалено виробництво та доведено економічний ефект від випуску та реалізації дослідно-промислової партія розміром 30 кг. До акту додається розрахунок економічного ефекту (Додаток 1)

10 До акту додається довідка про соціальний ефект від впровадження результатів науково-дослідної роботи (Додаток 2)

11 Співвласниками акту впровадження науково-дослідної роботи є Сумський національний аграрний університет та Університет Хечжоу, Китай (School of Food and Biological Engineering, Hezhou University, Hezhou, China)

ВІД ЗАКЛАДУ ОСВІТИ

Керівник роботи

(підпис) А.О. Геліх (ініціали, прізвище)

Аспірант

(підпис) Шань Фейфей (ініціали, прізвище)

Завідувач кафедрою

(підпис) М.М. Самілик (ініціали, прізвище)

ВІД ПІДПРИЄМСТВА

Директор

ФОП «Філон А.М.»

(підпис) А.М. Філон (ініціали, прізвище)

Appendix E 4

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ НАЦІОНАЛЬНИЙ АГРАРНИЙ УНІВЕРСИТЕТ

УЗГОДЖЕНО Проректор з наукової та міжнародної діяльності, доктор економічних наук, професор	ЗАТВЕРДЖУЮ Директор ФОП «Філон А.М.»
Ю.І. Данько (підпис) (ініціали, прізвище)	А.М. Філон (підпис) (ініціали, прізвище)
«06» 02 2023 рік (дата)	«30» січня 2023 рік (дата)

АКТ
ВПРОВАДЖЕННЯ НАУКОВО-ДОСЛІДНОЇ РОБОТИ

Замовник: ФОП «Філон А. М.»
(найменування організації)

директор Філон Андрій Михайлович
(посада, ПІБ керівника організації)

Цим актом підтверджується, впровадження результатів роботи виконаних у межах

	наукової держбюджетної тематики:	Розробка технічної документації на напівфабрикат з рослинної сировини для м'ясних фаршевих виробів подвійного призначення (найменування теми)
	Номер державної реєстрації:	0122U202024
	Держбюджетна тематика виконується на кафедрі:	Технологій та безпечності харчових продуктів
	Дата виконання держбюджетної тематики:	2022–2023 р.
	Результати роботи впроваджені на підприємстві:	ФОП «Філон А.М.» (найменування підприємства, де здійснювалось впровадження)
1	**Вид впроваджених результатів**	технологія ковбасок курячих із використанням продуктів із таро концентрованих (експлуатація виробу, роботи, технології; виробництво виробу, роботи, технології, функціонування систем)
2	**Характеристика масштабу впровадження**	дослідно-промислова партія (унікальне, одиночне, партія, масове, серійне)
3	**Форма впровадження**	виробничий випуск
4	**Новизна результатів науково-дослідних робіт**	використана нова сировина, розроблено нову технологію, нові досліджені результати, продукція випускається вперше (піонерські, принципово нові, якісно нові, модифікація, модернізація старих розробок)
5	**Впроваджені на основі нормативно-технічної документації**	ТУ У 10.3-04718013-008:2022 (вказати номер і назву нормативно-технічної документації)

Continuation of the application E 4

6	**Впроваджені в промислове виробництво**	ФОП «Філон А.М.» (назва підприємства)
7	**Рентабельність продукції (Додаток 1)**	45 % (характеристика прибутковості господарської діяльності підприємства від реалізації дослідно-промислової партії)
8	**Соціальний і науково-технічний ефект (Додаток 2)**	розроблені ковбаски курячі рекомендовано використовувати як самостійний харчовий продукт, так і у складі кулінарної продукції в закладах ресторанного господарства та підприємствах харчової промисловості (холодні та гарячі закуски, салати, виробів із борошна), які значно розширять асортимент готової продукції збагаченої харчовими волокнами та рослинним білком і можуть бути реалізовані в оптовій та роздрібній торгівлі. (використання в харчовій промисловості та реалізація населенню)
9	Удосконалено виробництво та доведено економічний ефект від випуску та реалізації дослідно-промислової партія розміром 30 кг. До акту додається розрахунок економічного ефекту (Додаток 1)	
10	До акту додається довідка про соціальний ефект від впровадження результатів науково-дослідної роботи (Додаток 2)	
11	Співвласниками акту впровадження науково-дослідної роботи є Сумський національний аграрний університет та Університет Хечжоу, Китай (School of Food and Biological Engineering, Hezhou University, Hezhou, China)	

ВІД ЗАКЛАДУ ОСВІТИ

Керівник роботи

(підпис) А.О. Геліх (ініціали, прізвище)

Аспірант

Shang fei fei (підпис) Шань Фейфей (ініціали, прізвище)

Завідувач кафедрою

(підпис) М.М. Самілик (ініціали, прізвище)

ВІД ПІДПРИЄМСТВА

Директор

ФОП «Філон А.М.»

(підпис) А.М. Філон (ініціали, прізвище)

ФІЛОН Андрій Михайлович 3316908299 УКРАЇНА

Appendix E 5

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ НАЦІОНАЛЬНИЙ АГРАРНИЙ УНІВЕРСИТЕТ

УЗГОДЖЕНО Проректор з наукової та міжнародної діяльності доктор економічних наук, професор	ЗАТВЕРДЖУЮ Директор ФОП «Філон А.М.»
_______ (підпис) Ю.І. Данько (ініціали, прізвище)	_______ (підпис) А.М. Філон (ініціали, прізвище)
«06» 02 (дата) 2023 рік	«30» січня (дата) 2023 рік

АКТ
ВПРОВАДЖЕННЯ НАУКОВО-ДОСЛІДНОЇ РОБОТИ

Замовник: ФОП «Філон А. М.»
(найменування організації)

директор Філон Андрій Михайлович
(посада, ПІБ керівника організації)

Цим актом підтверджується, впровадження результатів роботи виконаних у межах

	наукової держбюджетної тематики:	Розробка технічної документації на напівфабрикат з рослинної сировини для м’ясних фаршевих виробів подвійного призначення (найменування теми)
	Номер державної реєстрації:	0122U202024
	Держбюджетна тематика виконується на кафедрі:	Технологій та безпечності харчових продуктів
	Дата виконання держбюджетної тематики:	2022–2023 р.
	Результати роботи впроваджені на підприємстві:	ФОП «Філон А.М.» (найменування підприємства, де здійснювалось впровадження)
1	**Вид впроваджених результатів**	технологія ковбасок з м’яса качки із використанням продуктів із таро концентрованих (експлуатація виробу, роботи, технології; виробництво виробу, роботи, технології, функціонування систем)
2	**Характеристика масштабу впровадження**	дослідно-промислова партія (унікальне, одиночне, партія, масове, серійне)
3	**Форма впровадження**	виробничий випуск
4	**Новизна результатів науково-дослідних робіт**	використана нова сировина, розроблено нову технологію, нові досліджені результати, продукція випускається вперше (піонерські, принципово нові, якісно нові, модифікація, модернізація старих розробок)
5	**Впроваджені на основі нормативно-технічної документації**	ТУ У 10.3-04718013-008:2022 (вказати номер і назву нормативно-технічної документації)

Continuation of the application E 5

6	**Впроваджені в промислове виробництво**	ФОП «Філон А.М.» (назва підприємства)
7	**Рентабельність продукції (Додаток 1)**	21 % (характеристика прибутковості господарської діяльності підприємства від реалізації дослідно-промислової партії)
8	**Соціальний і науково-технічний ефект (Додаток 2)**	розроблені ковбаски з м'яса качки рекомендовано використовувати як самостійний харчовий продукт, так і у складі кулінарної продукції в закладах ресторанного господарства та підприємствах харчової промисловості (холодні та гарячі закуски, салати, виробів із борошна), які значно розширять асортимент готової продукції збагаченої харчовими волокнами та рослинним білком і можуть бути реалізовані в оптовій та роздрібній торгівлі. (використання в харчовій промисловості та реалізація населенню)

9 Удосконалено виробництво та доведено економічний ефект від випуску та реалізації дослідно-промислової партія розміром 30 кг. До акту додається розрахунок економічного ефекту (Додаток 1)

10 До акту додається довідка про соціальний ефект від впровадження результатів науково-дослідної роботи (Додаток 2)

11 Співвласниками акту впровадження науково-дослідної роботи є Сумський національний аграрний університет та Університет Хечжоу, Китай (School of Food and Biological Engineering, Hezhou University, Hezhou, China)

ВІД ЗАКЛАДУ ОСВІТИ

Керівник роботи

(підпис) А.О. Геліх (ініціали, прізвище)

Аспірант

(підпис) Шань Фейфей (ініціали, прізвище)

Завідувач кафедрою

(підпис) М.М. Самілик (ініціали, прізвище)

ВІД ПІДПРИЄМСТВА

Директор

ФОП «Філон А.М.»

(підпис) А.М. Філон (ініціали, прізвище)

Фізична особа-підприємець Філон Андрій Михайлович 3316908299 Україна

Appendix E 6

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ НАЦІОНАЛЬНИЙ АГРАРНИЙ УНІВЕРСИТЕТ

УЗГОДЖЕНО Проректор з наукової та міжнародної діяльності, доктор економічних наук, професор	ЗАТВЕРДЖУЮ Директор ФОП «Клименко Л.О.»
____ Ю.І. Данько (підпис) (ініціали, прізвище)	____ Л.О. Клименко (підпис) (ініціали, прізвище)
«08» лютого 2023 рік (дата)	«06» 02 2023 рік (дата)

АКТ
ВПРОВАДЖЕННЯ НАУКОВО-ДОСЛІДНОЇ РОБОТИ

Замовник: ФОП «Клименко Л.О.»
(найменування організації)

директор Людмила Олександрівна Клименко
(посада, ПІБ керівника організації)

Цим актом підтверджується, впровадження результатів роботи виконаних у межах

	наукової держбюджетної тематики:	Розробка технічної документації на напівфабрикат з рослинної сировини для м'ясних фаршевих виробів подвійного призначення (найменування теми)
	Номер державної реєстрації:	0 1 2 2 U 2 0 2 0 2 4
	Держбюджетна тематика виконується на кафедрі:	Технологій та безпечності харчових продуктів
	Дата виконання держбюджетної тематики:	2022–2023 р.
	Результати роботи впроваджені на підприємстві:	ФОП «Клименко Л.О.» (найменування підприємства, де здійснювалось впровадження)
1	**Вид впроваджених результатів**	технологія ковбасок зі свинини із використанням продуктів із таро концентрованих (експлуатація виробу, роботи, технології; виробництво виробу, роботи, технології, функціонування систем)
2	**Характеристика масштабу впровадження**	дослідно-промислова партія (унікальне, одиночне, партія, масове, серійне)
3	**Форма впровадження**	виробничий випуск
4	**Новизна результатів науково-дослідних робіт**	використана нова сировина, розроблено нову технологію, нові досліджені результати, продукція випускається вперше (піонерські, принципово нові, якісно нові, модифікація, модернізація старих розробок)
5	**Впроваджені на основі нормативно-технічної документації**	ТУ У 10.3-04718013-008:2022 (вказати номер і назву нормативно-технічної документації)

Continuation of the application E 6

6	**Впроваджені в промислове виробництво**	ФОП «Клименко Л.О.» (назва підприємства)
7	**Рентабельність продукції (Додаток 1)**	40 % (характеристика прибутковості господарської діяльності підприємства від реалізації дослідно-промислової партії)
8	**Соціальний і науково-технічний ефект (Додаток 2)**	розроблені ковбаски зі свинини рекомендовано використовувати як самостійний харчовий продукт, так і у складі кулінарної продукції в закладах ресторанного господарства та підприємствах харчової промисловості (холодні та гарячі закуски, салати, виробів із борошна), які значно розширять асортимент готової продукції збагаченої харчовими волокнами та рослинним білком і можуть бути реалізовані в оптовій та роздрібній торгівлі. (використання в харчовій промисловості та реалізація населенню)
9	Удосконалено виробництво та доведено економічний ефект від випуску та реалізації дослідно-промислової партія розміром 30 кг. До акту додається розрахунок економічного ефекту (Додаток 1)	
10	До акту додається довідка про соціальний ефект від впровадження результатів науково-дослідної роботи (Додаток 2)	
11	Співвласниками акту впровадження науково-дослідної роботи є Сумський національний аграрний університет та Університет Хечжоу, Китай (School of Food and Biological Engineering, Hezhou University, Hezhou, China)	

ВІД ЗАКЛАДУ ОСВІТИ

Керівник роботи

_______ (підпис) А.О. Геліх (ініціали, прізвище)

Аспірант

_______ (підпис) Шань Фейфей (ініціали, прізвище)

Завідувач кафедрою

_______ (підпис) М.М. Самілик (ініціали, прізвище)

ВІД ПІДПРИЄМСТВА

Директор

ФОП «Клименко Л.О.»

_______ (підпис) Л.О. Клименко (ініціали, прізвище)

Печатка: Клименко Людмила Олександрівна, Ідентифікаційний номер 2185611609, Україна м. Суми

Appendix E 7

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ НАЦІОНАЛЬНИЙ АГРАРНИЙ УНІВЕРСИТЕТ

УЗГОДЖЕНО Проректор з наукової та міжнародної діяльності, доктор економічних наук, професор _______ Ю.І. Данько (підпис) (ініціали, прізвище) «08» травня 2023 рік (дата)	ЗАТВЕРДЖУЮ Директор ФОП «Клименко Л.О.» _______ Л.О. Клименко (підпис) (ініціали, прізвище) «06» 02 2023 рік (дата)

АКТ
ВПРОВАДЖЕННЯ НАУКОВО-ДОСЛІДНОЇ РОБОТИ

Замовник: ФОП «Клименко Л.О.»
(найменування організації)

директор Людмила Олександрівна Клименко
(посада, ПІБ керівника організації)

Цим актом підтверджується, впровадження результатів роботи виконаних у межах

наукової держбюджетної тематики: Розробка технічної документації на напівфабрикат з рослинної сировини для м'ясних фаршевих виробів подвійного призначення
(найменування теми)

Номер державної реєстрації:

0	1	2	2	U	2	0	2	0	2	4

Держбюджетна тематика виконується на кафедрі: Технологій та безпечності харчових продуктів

Дата виконання держбюджетної тематики: 2022–2023 р.

Результати роботи впроваджені на підприємстві: ФОП «Клименко Л.О.»
(найменування підприємства, де здійснювалось впровадження)

1	**Вид впроваджених результатів**	технологія ковбасок курячих із використанням продуктів із таро концентрованих (експлуатація виробу, роботи, технології; виробництво виробу, роботи, технології, функціонування систем)
2	**Характеристика масштабу впровадження**	дослідно-промислова партія (унікальне, одиночне, партія, масове, серійне)
3	**Форма впровадження**	виробничий випуск
4	**Новизна результатів науково-дослідних робіт**	використана нова сировина, розроблено нову технологію, нові досліджені результати, продукція випускається вперше (піонерські, принципово нові, якісно нові, модифікація, модернізація старих розробок)
5	**Впроваджені на основі нормативно-технічної документації**	ТУ У 10.3-04718013-008:2022 (вказати номер і назву нормативно-технічної документації)

Continuation of the application E 7

6	**Впроваджені в промислове виробництво**	ФОП «Клименко Л.О.» (назва підприємства)
7	**Рентабельність продукції (Додаток 1)**	38 % (характеристика прибутковості господарської діяльності підприємства від реалізації дослідно-промислової партії)
8	**Соціальний і науково-технічний ефект (Додаток 2)**	розроблені ковбаски курячі рекомендовано використовувати як самостійний харчовий продукт, так і у складі кулінарної продукції в закладах ресторанного господарства та підприємствах харчової промисловості (холодні та гарячі закуски, салати, виробів із борошна), які значно розширять асортимент готової продукції збагаченої харчовими волокнами та рослинним білком і можуть бути реалізовані в оптовій та роздрібній торгівлі. (використання в харчовій промисловості та реалізація населенню)
9	Удосконалено виробництво та доведено економічний ефект від випуску та реалізації дослідно-промислової партія розміром 30 кг. До акту додається розрахунок економічного ефекту (Додаток 1)	
10	До акту додається довідка про соціальний ефект від впровадження результатів науково-дослідної роботи (Додаток 2)	
11	Співвласниками акту впровадження науково-дослідної роботи є Сумський національний аграрний університет та Університет Хечжоу, Китай (School of Food and Biological Engineering, Hezhou University, Hezhou, China)	

ВІД ЗАКЛАДУ ОСВІТИ

Керівник роботи

(підпис) А.О. Геліх (ініціали, прізвище)

Аспірант

(підпис) Шань Фейфей (ініціали, прізвище)

Завідувач кафедрою

(підпис) М.М. Самілик (ініціали, прізвище)

ВІД ПІДПРИЄМСТВА

Директор

ФОП «Клименко Л.О.»

(підпис) Л.О. Клименко (ініціали, прізвище)

Appendix E 8

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
СУМСЬКИЙ НАЦІОНАЛЬНИЙ АГРАРНИЙ УНІВЕРСИТЕТ

УЗГОДЖЕНО Проректор з наукової та міжнародної діяльності, доктор економічних наук, професор	ЗАТВЕРДЖУЮ Директор ФОП «Клименко Л.О.»
Ю.І. Данько (підпис) (ініціали, прізвище)	Л.О. Клименко (підпис) (ініціали, прізвище)
«08» лютого 2023 рік (дата)	«06» 02 2023 рік (дата)

АКТ
ВПРОВАДЖЕННЯ НАУКОВО-ДОСЛІДНОЇ РОБОТИ

Замовник: ФОП «Клименко Л.О.»
(найменування організації)

директор Людмила Олександрівна Клименко
(посада, ПІБ керівника організації)

Цим актом підтверджується, впровадження результатів роботи виконаних у межах

наукової держбюджетної тематики: Розробка технічної документації на напівфабрикат з рослинної сировини для м'ясних фаршевих виробів подвійного призначення
(найменування теми)

Номер державної реєстрації:	0	1	2	2	U	2	0	2	0	2	4

Держбюджетна тематика виконується на кафедрі: Технологій та безпечності харчових продуктів

Дата виконання держбюджетної тематики: 2022–2023 р.

Результати роботи впроваджені на підприємстві: ФОП «Клименко Л.О.»
(найменування підприємства, де здійснювалось впровадження)

1	**Вид впроваджених результатів**	технологія ковбасок з м'яса качки із використанням продуктів із таро концентрованих (експлуатація виробу, роботи, технології; виробництво виробу, роботи, технології, функціонування систем)
2	**Характеристика масштабу впровадження**	дослідно-промислова партія (унікальне, одиночне, партія, масове, серійне)
3	**Форма впровадження**	виробничий випуск
4	**Новизна результатів науково-дослідних робіт**	використана нова сировина, розроблено нову технологію, нові досліджені результати, продукція випускається вперше (піонерські, принципово нові, якісно нові, модифікація, модернізація старих розробок)
5	**Впроваджені на основі нормативно-технічної документації**	ТУ У 10.3-04718013-008:2022 (вказати номер і назву нормативно-технічної документації)

Continuation of the application E 8

6	**Впроваджені в промислове виробництво**	ФОП «Клименко Л.О.» (назва підприємства)
7	**Рентабельність продукції (Додаток 1)**	17 % (характеристика прибутковості господарської діяльності підприємства від реалізації дослідно-промислової партії)
8	**Соціальний і науково-технічний ефект (Додаток 2)**	розроблені ковбаски з м'яса качки рекомендовано використовувати як самостійний харчовий продукт, так і у складі кулінарної продукції в закладах ресторанного господарства та підприємствах харчової промисловості (холодні та гарячі закуски, салати, виробів із борошна), які значно розширять асортимент готової продукції збагаченої харчовими волокнами та рослинним білком і можуть бути реалізовані в оптовій та роздрібній торгівлі. (використання в харчовій промисловості та реалізація населенню)
9	Удосконалено виробництво та доведено економічний ефект від випуску та реалізації дослідно-промислової партія розміром 30 кг. До акту додається розрахунок економічного ефекту (Додаток 1)	
10	До акту додається довідка про соціальний ефект від впровадження результатів науково-дослідної роботи (Додаток 2)	
11	Співвласниками акту впровадження науково-дослідної роботи є Сумський національний аграрний університет та Університет Хечжоу, Китай (School of Food and Biological Engineering, Hezhou University, Hezhou, China)	

ВІД ЗАКЛАДУ ОСВІТИ

Керівник роботи

_______ (підпис) А.О. Геліх (ініціали, прізвище)

Аспірант

_______ (підпис) Шань Фейфей (ініціали, прізвище)

Завідувач кафедрою

_______ (підпис) М.М. Самілик (ініціали, прізвище)

ВІД ПІДПРИЄМСТВА

Директор

ФОП «Клименко Л.О.»

_______ (підпис) Л.О. Клименко (ініціали, прізвище)