MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

SUMY NATIONAL AGRARIAN UNIVERSITY

FACULTY OF FOOD TECHNOLOGY

Department Technology and Food Safety

To the defense
allowed

Head of the Department
Technology and Food Safety
Maryna SAMILYK

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QUALIFICATION WORK

for the second level of higher education

On the topic: «Improving technology of meat products enriched with alternative proteins»

Student SUn Yongshuai SUN Yongshuai
(first and last name)

Group FT 2401m eng.

Scientific supervisor Anna HELIKH
(first and last name)

Reviewer Oksana MELNYK
(first and last name)

Sumy – 2025

CONTENTS

АНОТАЦІЯ

Сан Йоншуай Тема: «Удосконалення технології м’ясних виробів збагачених альтернативними білками».

Кваліфікаційна робота містить: 69 с., 4 рис., 20 табл., 60 джерел.

Метою кваліфікаційної роботи є розширення асортименту варених ковбасних виробів шляхом наукового обґрунтування та розробки технології функціонального продукту, збагаченого білково-рослинною добавкою на основі ізоляту соєвого білка, сочевичного борошна та порошку топінамбура.

У роботі теоретично обґрунтовано та експериментально доведено доцільність використання комплексної білково-рослинної добавки як багатофункціонального інгредієнта у м'ясних емульсійних системах. Розроблено раціональну композицію добавки «Biolife-70», що забезпечує високі функціонально-технологічні властивості.

Встановлено оптимальні технологічні параметри використання добавки: раціональний гідромодуль для гідратації 1:4 та оптимальний рівень заміни м'ясної сировини — 15%.

На основі проведених досліджень розроблено рецептуру та комплексну технологію функціональної вареної ковбаси «Біолайф». Комплексна оцінка готового продукту підтвердила його високу харчову та біологічну цінність, гармонійні органолептичні показники, покращену стабільність при зберіганні та відповідність вимогам безпеки. Проведено економічне обґрунтування проєкту, що підтвердило його високу рентабельність та доцільність впровадження.

Ключові слова: варені ковбаси, білково-рослинна добавка, ізолят соєвого білка, сочевичне борошно, топінамбур, інулін, технологія, рецептура, функціональні властивості, якість, термін зберігання.

ABSTRACT

Sun Yongshuai Topic: «Improving technology of meat products enriched with alternative proteins».

The qualification thesis contains: 69 p., 4 fig., 20 tables, 60 references.

The subject of the research is the establishment of the regularities of the influence of a complex protein-plant supplement (based on soy protein isolate, lentil flour, and Jerusalem artichoke powder) and its processing parameters on the physicochemical, structural-mechanical, microbiological, and consumer properties of a functional cooked sausage.

The aim of the qualification thesis is to expand the range of cooked sausage products through the scientific substantiation and development of a technology for a functional product enriched with a protein-plant supplement.

In this work, the feasibility of using a complex protein-plant supplement as a multifunctional ingredient in meat emulsion systems is theoretically substantiated and experimentally proven. A rational composition for the "Biolife-70" supplement has been developed, which ensures high functional and technological properties.

The optimal technological parameters for the use of the supplement have been established: a rational hydration ratio of 1:4 and an optimal meat replacement level of 15%.

Based on the research conducted, a formulation and a comprehensive technology for the "Biolife" functional cooked sausage have been developed. A comprehensive evaluation of the finished product confirmed its high nutritional and biological value, harmonious organoleptic characteristics, improved stability during storage, and compliance with safety requirements. An economic justification of the project was carried out, which confirmed its high profitability and feasibility of implementation.

Keywords: cooked sausages, protein-plant supplement, soy protein isolate, lentil flour, Jerusalem artichoke, inulin, technology, formulation, functional properties, quality, shelf life.

INTRODUCTION

The modern meat products market is characterized by high development dynamics and profound transformations, driven by a complex of economic, social, and technological factors. On the one hand, there is a stable demand for traditional meat products, which are an integral part of the diet and an important source of complete proteins, essential amino acids, vitamins, and minerals. On the other hand, global trends in healthy lifestyles are fundamentally changing consumer priorities. The modern consumer is becoming increasingly informed and demanding; they seek not just calories and taste, but products that promote health, prevent diseases, and improve quality of life. This demand stimulates the market for so-called "healthy" or functional meat products—items with reduced fat, salt, cholesterol, and calories, but enriched with biologically active components such as dietary fibers, unsaturated fatty acids, and plant-based proteins.

Simultaneously, the meat processing industry in Ukraine and worldwide faces a number of serious economic challenges. The instability and continuous rise in the cost of primary meat raw materials, intensifying competition, and the need to optimize production processes compel manufacturers to seek innovative ways for more efficient resource utilization and the production of competitively priced goods. One of the most promising and scientifically substantiated directions for solving this complex problem is the use of non-meat ingredients of plant origin. These components not only allow for a reduction in formulation costs through the partial replacement of meat but also significantly improve the functional-technological, organoleptic, and, most importantly, nutritional properties of the finished products.

The use of alternative proteins and dietary fibers in the technology of cooked sausages is a key tool for creating new-generation products that meet the demands of the times. Plant proteins, particularly the highly purified **soy protein isolate "SoyPro-90"**, are known for their exceptional emulsifying, gelling, and water-binding properties. They enable the creation of stable meat emulsions, prevent cooking losses in the form of fat and jelly separation, and help form the desired firm texture of the product.

Lentil flour, in turn, is a valuable source not only of protein with a unique amino acid profile that complements that of meat but also of complex carbohydrates, fiber, and micronutrients, which significantly enhances the biological value of sausage products.

A special place among modern functional ingredients is occupied by **Jerusalem artichoke powder "HeliaFibre T-85"**, which is a rich natural source of inulin—a prebiotic dietary fiber. Inulin performs a dual role: on the one hand, it positively affects the health of the gut microbiota, and on the other, it acts as an effective fat substitute. Its ability to form a microcrystalline gel-like structure with water allows it to mimic the creamy texture and juiciness traditionally provided by fat, which is critically important for creating low-fat products without compromising consumer properties.

This thesis is dedicated to the improvement of the technology for a classic cooked sausage through the development and implementation of an innovative protein-plant supplement (PPS). The combined use of **"SoyPro-90"**, **lentil flour**, and **"HeliaFibre T-85"** allows for a synergistic effect: improving the rheological characteristics of the meat batter, increasing the yield of the finished product, stabilizing its quality during storage, reducing production costs, and significantly enriching its nutritional value. The new product developed as a result of this research has been named **"Biolife"**, emphasizing its improved, health-oriented properties.

Despite a significant number of studies on individual plant ingredients, scientific data on their combined synergistic effect on the technology of cooked sausages remain limited and fragmented. This determines the high **relevance and scientific novelty** of this thesis, aimed at the systematic research, development, and scientific substantiation of the technology for "Biolife" cooked sausage using an innovative protein-plant supplement.

Object of research: The technology of cooked sausage products with a complex protein-plant supplement.

Subject of research: Soy protein isolate "SoyPro-90", food-grade lentil flour, Jerusalem artichoke powder "HeliaFibre T-85", the protein-plant supplement (PPS), mechanically deboned poultry meat; model meat batter systems and finished products.

CHAPTER 1. LITERATURE REVIEW

1.1. Modern Trends and Scientific Foundations for the Production of Functional Meat Products

1.1.1. Consumer Demand for Healthy Meat Products

In recent decades, global nutritional trends have demonstrated a clear shift towards a healthy lifestyle, which directly impacts the meat products market. This process is driven by a complex of factors, including increased public awareness of the link between diet and the risk of chronic diseases, the dissemination of information through digital media, and recommendations from authoritative health organizations [55]. The modern consumer no longer perceives food merely as a source of energy and pleasure but considers it a tool for maintaining health and preventing non-communicable diseases such as obesity, type 2 diabetes, and cardiovascular pathologies [24]. This trend, known as "food as medicine," stimulates demand for "clean label" products, i.e., those with a minimal quantity of artificial additives, a transparent composition, and the presence of functional ingredients [5].

For the meat industry, this necessitates the adaptation of traditional formulations, which are often characterized by high fat and salt content. The main directions of modification include:

- **Reduction of fat content**, especially saturated fatty acids, which are associated with the risk of cardiovascular diseases [17]. The technological challenge is not simply to remove fat, but to compensate for its functions, such as the formation of juiciness, tenderness, and flavor.
- **Reduction of sodium (salt) content**, which is a key factor in the prevention of hypertension [18]. This is a complex task, as sodium chloride plays a critical role not only in flavor formation but also in the solubilization of myofibrillar proteins, structure formation, and product preservation.
- **Elimination or replacement of nitrites**, which, although important for color, taste, and microbiological safety (particularly inhibiting the growth of *Clostridium botulinum*), raise concerns due to the possible formation of nitrosamines

[8]. Plant extracts rich in nitrates (celery, spinach) combined with starter cultures are being considered as alternatives.

- **Enrichment of products with functional components**, such as proteins of plant origin, dietary fibers, omega-3 fatty acids, antioxidants, and probiotics [6, 32]. This allows not only to improve the product's safety profile but also to provide it with additional health benefits.

These changes require technologists not just to substitute one ingredient for another, but to have a deep understanding of their impact on the complex physicochemical matrix of the meat product, including its texture, taste, stability, and shelf life [46].

1.1.2. Concept and Classification of Functional Ingredients in the Meat Industry

Functional ingredients are substances that, when added to food products, not only perform certain technological functions (e.g., water binding, emulsification) but also provide the product with additional physiological value, positively affecting consumer health [58]. Their incorporation allows for the creation of products for specific purposes, for example, for people at risk of cardiovascular diseases or for improving digestion. In the context of the meat industry, they can be classified by origin and functional purpose, as shown in Table 1.1.

Table 1.1. Classification of Functional Ingredients in Meat Products

Category	Ingredient Examples	Primary Functional Purpose	Source
Alternative Proteins	Soy, pea isolates; lentil, bean concentrates.	Replacement of meat raw material, improvement of emulsifying properties, enhancement of protein value.	[25, 50]

Continue table 1.1

Dietary Fibers	Inulin, oligofructose, pectin, cellulose, fibers (from vegetables, fruits, cereals, legumes).	Fat replacement, improvement of water-holding capacity, structure stabilization, prebiotic effect.	[14]
Polyunsaturated Fatty Acids	Fish oil, flaxseed oil, microalgae.	Enrichment of the product with Omega-3, prevention of cardiovascular diseases.	[13]
Natural Antioxidants	Extracts of rosemary, green tea, acerola; spices.	Replacement of synthetic antioxidants, slowing lipid oxidation, extending shelf life.	[44]
Probiotics and Prebiotics	Lactobacilli, bifidobacteria (for fermented sausages), inulin, oligofructose.	Improvement of gut microbiota health.	[21]

The implementation of these ingredients is a complex technological process. For example, replacing animal fat with vegetable oils rich in omega-3s requires pre-emulsification and the use of antioxidants to prevent rapid oxidation [13]. The addition of fiber can change the rheology of the meat batter, requiring adjustments to mixing and stuffing parameters [14]. Thus, the development of formulations using a combination of such ingredients is a key direction in the creation of functional meat products [3].

1.2. Characteristics and Role of Alternative Proteins in Meat Product Technology

The partial or total substitution of meat proteins with alternatives from non-meat sources is a cornerstone of modern meat processing, driven by economic, nutritional, and sustainability concerns. While traditional binders such as milk proteins (caseinates, whey) and egg proteins have long been used, the focus has increasingly shifted towards plant-based proteins due to their favorable cost, sustainable production, and alignment with consumer trends towards plant-forward diets [45]. The successful incorporation of these proteins is contingent on their ability to integrate into the complex meat matrix and replicate the essential functional roles of myofibrillar proteins—namely, gelation, emulsification, and water binding. Among the vast array of available plant proteins, those derived from soy and other legumes have become the most prominent due to their well-documented functional efficacy and balanced nutritional profiles [25, 50].

1.2.1. Soy Protein Isolate: Functional-Technological Properties and Impact on Sausage Quality

Soy protein isolate (SPI) stands as the most established and functionally versatile plant protein in the meat industry. It is a highly refined product, obtained by removing the majority of carbohydrates and fats from defatted soy flakes, resulting in a protein content of 90% or higher on a dry basis [50]. This high purity ensures that its functional properties are pronounced and consistent. The functionality of SPI is primarily attributed to its major storage protein fractions, the 11S globulin (glycinin) and the 7S globulin (β-conglycinin), whose structural characteristics dictate their behavior in food systems.

- **Gel-forming ability (Gelation):** The capacity of SPI to form a rigid, three-dimensional network is fundamental to creating the characteristic firm and elastic texture of cooked sausages. The process is thermally induced. Upon heating to temperatures above 70-75°C, the quaternary and tertiary structures of the glycinin and β-conglycinin molecules denature, exposing previously buried hydrophobic groups and sulfhydryl (-SH) groups [29]. This unfolding is facilitated by the presence of salt in the meat system. As the system cools, the unfolded polypeptide chains form new, stable intermolecular associations via hydrogen bonds, hydrophobic interactions, and disulfide bridges (-S-S-), creating an ordered gel matrix that entraps water and fat globules. The properties of this gel depend on the ratio of 11S to 7S globulins; glycinin tends to form stronger, more brittle gels, whereas β-conglycinin forms finer, more elastic gels. The resulting composite gel in SPI provides a texture that can effectively compensate for the reduction in meat content [29].

Emulsifying capacity: The stability of the fat-in-water emulsion in a sausage batter is critical to prevent fat and jelly separation during cooking. SPI exhibits excellent emulsifying properties due to the amphiphilic nature of its constituent proteins. During the high-shear comminution in a bowl cutter, SPI molecules rapidly migrate to the oil-water interface [54]. They orient their hydrophobic regions toward the fat globule and their hydrophilic regions toward the continuous aqueous phase. This action significantly reduces the interfacial tension and creates a viscoelastic protein film around each fat droplet. This film acts as a physical barrier, preventing the droplets from coalescing into larger pockets of fat that would otherwise render out during heating [54]. The effectiveness of SPI as an emulsifier is often quantified by its Emulsifying Activity Index (EAI) and Emulsion Stability Index (ESI), which have been shown to be comparable to, and in some cases superior to, other plant and even animal proteins [43].

Water-binding and holding capacity: The ability of SPI to bind and retain substantial quantities of water (typically in ratios of 1:4 to 1:5, protein to water) is crucial for product yield, juiciness, and texture. This function occurs via several mechanisms. Firstly, water molecules are chemically bound as a hydration shell to polar and charged amino acid residues on the protein surface through hydrogen bonding. Secondly, and more significantly, water is physically entrapped within the capillary spaces of the three-dimensional gel network formed during cooking [43]. This entrapped water contributes directly to the perception of succulence and helps to offset the drying effect that can occur when fat is removed from a formulation [26].

Technological Considerations: For SPI to be effective, it must be properly utilized. Pre-hydration of the SPI powder is a critical, non-negotiable step. Incomplete hydration results in un-solubilized protein particles that do not contribute to functionality and can impart a gritty, undesirable mouthfeel. The hydrated SPI gel should be added during the final stages of comminution to ensure its thorough distribution without excessive mechanical shearing that could damage its pre-formed structure [2]. While highly functional, it is important to note that soy is a recognized allergen, requiring clear labeling. Furthermore, the selection of non-GMO soy sources is increasingly a factor in consumer acceptance [52].

1.2.2. Legume Proteins (Lentil) as a Promising Raw Material for Enriching Meat Systems

In the pursuit of "clean label" and minimally processed ingredients, whole legume flours, particularly from lentils, have emerged as a highly promising alternative to refined protein isolates. Lentil flour offers a holistic nutritional and functional package, containing not only 25-30% protein but also significant quantities of native starch, dietary fiber, B-group vitamins (especially folate), and key minerals like iron, potassium, and zinc [47]. This profile allows it to function as both a protein extender and a nutritional enrichment agent [22].

Nutritional Profile and Health Benefits: Unlike isolates, lentil flour contributes complex carbohydrates that have a low glycemic index, promoting stable blood glucose levels. The inherent dietary fiber content supports digestive health [7]. The protein fraction of lentils is rich in lysine, an essential amino acid often limiting in cereal proteins, which makes it an excellent complement to the amino acid profile of meat proteins [27]. This holistic contribution makes it a powerful ingredient for developing products with an enhanced nutritional label.

Multifaceted Functional Contribution: The functionality of lentil flour in meat systems is a composite of the actions of its primary components:

Protein: The main storage proteins in lentils, globulins such as legumin and vicilin, possess moderate emulsifying and water-binding properties. While less potent than those of SPI, they still contribute positively to the stability of the meat batter [7].

Starch: Constituting up to 50% of the flour, native lentil starch plays a crucial role. During thermal processing (cooking), the starch granules absorb water and swell, undergoing gelatinization at temperatures around 65-75°C. This process irreversibly binds large amounts of free water, significantly increases the viscosity of the batter, and forms a firm paste-like structure upon cooling. This starch gel reinforces the protein network, resulting in a firmer final texture and improved sliceability [53].

- **Fiber:** The native fiber content further enhances water-holding capacity, contributing to cook yield and juiciness.

Technological Challenges and Mitigation: The primary challenge associated with legume flours is the potential for a "beany" or "earthy" off-flavor. This is largely attributed to the activity of the enzyme lipoxygenase (LOX), which oxidizes polyunsaturated fatty acids to produce volatile compounds like hexanal. This can be effectively mitigated by using heat-treated (stabilized) flours where the LOX enzyme has been thermally inactivated [9]. The color of the lentil flour (e.g., red, green) also influences the final product color; red lentil flours are often preferred as they impart a warmer, less greyish tone. While lentils contain some anti-nutritional factors like phytic acid, their levels are relatively low and are further reduced by thermal processing, posing negligible risk in the context of a meat product formulation [48]. The optimal inclusion level is typically found to be in the range of 3-5% (dry weight) to balance functional benefits with minimal sensory impact [9].

1.3. Dietary Fibers as a Key Component for Modifying the Properties of Meat Products

The incorporation of dietary fibers into processed meats serves a dual purpose that is perfectly aligned with modern food technology objectives. Technologically, fibers are powerful hydrocolloids used to manage moisture, replace fat, and modify texture, thereby improving yield and stability. Nutritionally, their inclusion helps bridge the "fiber gap" in Western diets and allows for the creation of functional foods with tangible health benefits, such as improved digestive health and reduced caloric density [16]. The specific behavior of a fiber in a meat system is largely dictated by its solubility in water.

1.3.1. General Characteristics and Classification of Dietary Fibers

Dietary fibers are broadly categorized based on their water solubility, which correlates strongly with their functionality both in the food matrix and physiologically.

- **Soluble Fibers:** This group includes substances like pectin, inulin, β-glucans, and various gums (guar, xanthan). When dispersed in water, they hydrate to form viscous solutions or gels. This high viscosity is a result of the entanglement of their long polymer chains, which immobilizes water molecules and impedes their movement [20]. Physiologically, this viscosity slows gastric emptying, leading to a prolonged sense of satiety, and can lower post-prandial blood glucose and cholesterol levels. In meat products, they are excellent thickeners and stabilizers. For instance, pectins, derived from citrus peel or apple pomace, can form strong gels in the presence of calcium ions, contributing significantly to the firmness of low-fat products.
- **Insoluble Fibers:** This category includes cellulose, hemicellulose, and lignin. These fibers do not dissolve in water but can absorb and hold significant amounts of it within their porous, fibrous, or capillary structures—a process of physical entrapment rather than chemical hydration [12]. This property is leveraged to increase water-holding capacity and cooking yield in meat products. However, if not correctly balanced with soluble components or sufficient hydration, they can sometimes lead to a perception of dryness or toughness in the final product. To improve their sensory profile, insoluble fibers are often micronized, a process that reduces particle size, increases surface area, and results in a smoother mouthfeel.

1.3.2. Inulin and Jerusalem Artichoke Fiber: Unique Properties and Application in Cooked Sausages

Jerusalem artichoke (*Helianthus tuberosus*) is a premier source of inulin, a unique type of soluble dietary fiber. Chemically, inulin is a fructan—a linear polysaccharide consisting of fructose units linked by $\beta(2\rightarrow1)$ glycosidic bonds, typically with a terminal glucose molecule [30]. The functionality of inulin is highly dependent on its **Degree of Polymerization (DP)**, which refers to the number of fructose units in the chain. Jerusalem artichoke powder provides a natural spectrum of inulins with varying chain lengths.

Functionality based on Degree of Polymerization (DP):

Short-chain inulin (DP < 10): Also known as oligofructose or fructooligosaccharides (FOS), these molecules are highly soluble, contribute a mild sweetness, and primarily function as humectants and bulking agents. They have limited gelling capacity but are highly effective as prebiotics due to their rapid fermentation by gut microbiota [23].

Long-chain inulin (DP > 23): This fraction is less soluble and has a neutral taste. Its most important technological property is its ability to form a **particle gel** that effectively mimics fat. When subjected to high shear in the presence of water, the long polymer chains aggregate and crystallize into a three-dimensional network of sub-micron particles. This network entraps large amounts of water, creating a smooth, white, creamy paste with rheological and sensory properties very similar to those of a fat emulsion. This mechanism is the key to its success as a fat replacer in low-fat sausages, where it imparts creaminess, lubricity, and a rich mouthfeel [31, 39].

Technological Application and Health Benefits: The powder from Jerusalem artichoke, containing native inulin, provides a powerful tool for low-fat product development. The creamy texture created by the inulin gel can mask potential grittiness from other ingredients (like insoluble fibers or flours), creating a synergistic improvement in overall mouthfeel. As a soluble solid, inulin also contributes to a slight reduction in water activity (aw), which can modestly enhance microbial stability. Beyond its technological role, the most significant benefit of inulin is its well-documented prebiotic effect. It selectively promotes the growth of beneficial gut bacteria, such as *Bifidobacterium* and *Lactobacillus*. The fermentation of inulin by these bacteria produces short-chain fatty acids (SCFAs), including butyrate, propionate, and acetate. Butyrate, in particular, serves as the primary energy source for colonocytes (cells lining the colon) and has been shown to have anti-inflammatory and health-protective properties [56]. This allows products containing sufficient levels of inulin to be marketed with powerful health-related claims, meeting the consumer demand for functional foods.

1.4. Technological Aspects of the Interaction of Plant Components with Meat Proteins

1.4.1. Formation of Meat Emulsion Structure in the Presence of Plant Proteins and Polysaccharides

A cooked sausage is essentially a complex oil-in-water emulsion stabilized by a protein gel. Its formation begins at the salting and cutter processing stage, when sodium chloride extracts myofibrillar proteins (actin and myosin) from the muscle fibers [61]. These soluble proteins form a tacky exudate that coats the comminuted fat particles, forming a primary emulsion. During heat treatment, these proteins denature and form a three-dimensional network (gel) that physically entraps fat globules and water.

When plant ingredients are introduced, a competitive interaction for water and space within the protein matrix occurs:

Plant proteins (SPI): Due to their high solubility and emulsifying properties, they are actively integrated into the protein network, forming mixed "meat-plant" gels. They also help to stabilize fat globules that were not fully coated by meat proteins, which is particularly important when using lower-quality raw materials [57].

Polysaccharides (inulin, lentil starch): These components compete with proteins for water (a process of competitive hydration). By binding a significant amount of free moisture, they increase the viscosity of the aqueous phase. This slows the movement of fat globules, preventing their coalescence and the breakdown of the emulsion during heating [35].

Thus, the formation of a stable structure in combined meat systems is the result of the synergistic action of muscle proteins (the primary matrix), plant proteins (auxiliary emulsifiers and gelling agents), and polysaccharides (thickeners and stabilizers of the aqueous phase) [57].

1.4.2. Influence on Water-Holding, Fat-Holding Capacity, and Rheological Properties of the Batter

The introduction of a complex plant-based supplement significantly affects the key functional and technological properties (FTP) of the meat batter:

- *Water-holding capacity (WHC):* The ability of the batter to retain its own and added moisture. SPI and dietary fibers (inulin, lentil fiber) significantly increase WHC due to the large number of hydrophilic groups in their molecules. Studies show that the addition of 2-3% of combined additives can increase WHC by 5-15%, leading to reduced cooking losses and increased juiciness [26].
- *Fat-holding capacity (FHC):* The ability to retain fat within the product structure. An improvement in FHC is achieved through a dual mechanism: stabilization of the fat emulsion by SPI proteins and an increase in system viscosity due to polysaccharides, which physically hinders fat migration [37].
- *Rheological properties:* The viscosity and plasticity of the batter increase with the addition of plant components. This can be measured using viscometers or texture analyzers. On one hand, this positively affects the stuffing process. On the other hand, an excessive amount of hydrated plant ingredients can make the batter too "short," dense, or brittle, which requires precise control over the dosage and degree of hydration of the additive [51].

1.5. Influence of Complex Plant-Based Additives on the Quality and Consumer Characteristics of Finished Sausage Products

1.5.1. Changes in Physicochemical Parameters (Protein, Fat, Moisture Content)

The inclusion of a protein-plant supplement allows for the targeted modeling of the chemical composition of the final product. Replacing part of the meat raw material (especially fatty meat) with a combination of SPI, lentil flour, and Jerusalem artichoke powder leads to predictable changes:

- *Reduction in fat content:* The primary effect, allowing the product to be positioned as "low-fat" or "dietary" [59].

- *Increase in protein content:* Possible when replacing fatty raw materials with high-protein components (SPI) [10].
- *Increase in carbohydrate and dietary fiber content:* The product is enriched with these components, which increases its nutritional value and allows for corresponding labeling claims, e.g., "source of fiber" [42].
- *Increase in moisture content:* Due to the high WHC of the plant components, which positively affects the yield and juiciness of the product [49].

1.5.2. Influence on Organoleptic Properties: Texture, Color, Taste, and Aroma

Organoleptic acceptability is a crucial factor for a product's success in the market, and the influence of plant additives is complex in this regard.

<u>Texture:</u> Plant components can make the texture softer, more tender, and creamier (due to inulin and SPI) or, conversely, denser and somewhat "grainy" (due to the starch and fiber from lentils). The main task of the technologist is to select a ratio that maintains a "meaty," elastic, and juicy texture, without a "floury" or "crumbly" sensation that can occur at excessive dosages [36].

<u>Color:</u> Plant ingredients, especially flours, are lighter in color compared to meat, which can make the batter appear paler. This may require correction with natural colorants (e.g., fermented rice) or optimization of the color formation process involving sodium nitrite [38].

<u>Taste and Aroma:</u> At high concentrations, SPI and lentil flour can impart a slight off-flavor (beany, vegetal, sometimes with a bitter note). To mask this, more intense spice blends and natural flavorings (e.g., meat or smoke flavors) are often used to help maintain the traditional taste profile of the sausage product [52].

1.5.3. Improvement of the Nutritional and Biological Value of the Product

The primary goal of introducing plant additives is to enhance nutritional value.

Balanced amino acid profile: Although plant proteins are often deficient in some essential amino acids (e.g., methionine in legumes), their combination with the animal proteins from meat allows for a final product with a more balanced amino acid score. This synergistic effect is one of the key aspects of creating combined products [27].

Reduced caloric content: Replacing fat (9 kcal/g) with hydrated proteins and carbohydrates (around 1-2 kcal/g in hydrated form) significantly reduces the energy value of the product, which meets the demands of weight-conscious consumers [19].

Functional value: The presence of prebiotic fibers (inulin) provides the product with additional benefits for digestive health. Regular consumption of inulin stimulates the growth of bifidobacteria, which produce short-chain fatty acids (butyrate, propionate), a source of energy for intestinal cells with anti-inflammatory properties [56].

1.6. Analysis of Modern Research and Patents in the Field of Combined Meat Product Production

The field of combined, or hybrid, meat products is currently one of the most dynamic and innovative sectors of the food industry. A thorough analysis of recent scientific literature and patent filings reveals a concentrated, multi-faceted effort to address the technological, sensory, and market challenges associated with integrating plant-based ingredients into traditional meat formulations. This activity is not merely about cost reduction but represents a strategic response to evolving consumer demands for healthier, more sustainable, and ethically conscious food choices. The key innovation trends can be categorized into four interconnected areas: the exploration of novel protein sources, the engineering of synergistic functional systems, the development of market-savvy hybrid products, and the strategic patenting of proprietary technologies.

A primary thrust of current research is the diversification of the plant protein portfolio beyond established sources like soy and wheat. While soy protein isolate remains a benchmark for functionality, its allergenicity and consumer perceptions surrounding genetic modification have spurred intensive investigation into alternatives [11]. Legume proteins, particularly from peas, chickpeas, and lentils, are at the forefront of this movement. They are valued for their "clean label" appeal (often used as flours or concentrates rather than highly refined isolates), strong nutritional profiles, and hypoallergenic nature [11, 33]. Research is focused on optimizing their functionality, which can be inherently lower than that of soy. For example, studies are exploring how processing techniques like germination or fermentation can reduce anti-nutritional factors and eliminate the "beany" off-flavors characteristic of raw legumes. Beyond common pulses, researchers are exploring high-potential niche sources. Quinoa protein is highly regarded for its complete amino acid profile, while proteins from the press cakes of oilseed production (e.g., sunflower, rapeseed/canola, and hemp) represent a significant opportunity for valorizing industrial by-products [33]. The main challenge with these oilseed proteins often lies in removing inherent off-flavors and undesirable pigments (e.g., chlorogenic acid in sunflower protein, which can cause green discoloration), necessitating advanced extraction and purification techniques. Looking further ahead, microalgae like *Spirulina* and *Chlorella* are being investigated as highly sustainable protein sources with exceptional nutritional density, though significant hurdles related to their intense flavor, color, and high production cost remain to be overcome before they see widespread use in products like sausages [33].

The second major area of innovation lies in the design and application of combined functional systems, moving beyond the use of single ingredients to leveraging the synergistic interactions between different components [4]. This approach, akin to food matrix engineering, recognizes that the complex interplay between meat proteins, plant proteins, and various hydrocolloids can produce textural and stability outcomes that are superior to the sum of their individual effects. A key focus is on protein-polysaccharide interactions. For instance, researchers are extensively studying how the addition of a hydrocolloid like inulin or citrus fiber can modify the gelation behavior of a soy or pea protein within the meat matrix. The fiber component competes for water, effectively concentrating the protein and leading to a stronger gel, while its own gelling or water-binding properties contribute to overall juiciness and texture. This synergy allows for a more effective replacement of fat, as the protein network provides structure while the fiber network provides a creamy, fat-like mouthfeel [4]. Advanced research also explores the use of enzymes like transglutaminase, which can create covalent cross-links between meat proteins and certain plant proteins (like soy), resulting in exceptionally firm and elastic hybrid gels that are impossible to achieve through thermal processing alone. This allows for the creation of novel textures and a significant improvement in the sliceability and chewiness of low-fat products.

Thirdly, the concept of "hybrid" products has matured from a niche idea into a major commercial strategy. This trend is aimed squarely at the "flexitarian" consumer—a large and growing demographic that is actively reducing meat consumption but is not strictly vegetarian or vegan [40]. For these consumers, a 100% plant-based meat analogue can sometimes be sensorially disappointing, falling into an "uncanny valley" where it is close to, but not exactly like, meat. Hybrid products, which typically feature blends of meat and plant ingredients (e.g., 70% beef and 30% plant protein/vegetables), circumvent this issue. The formulation strategy is not to perfectly mimic meat, but to create a product perceived as an "enhanced" version of the original—one that delivers the familiar flavor and satisfaction of meat but with added benefits like lower saturated fat, higher fiber content, and a reduced environmental footprint [40]. The marketing of these products is critical; transparency is key, with brand names like "Beef & Mushroom Burgers" or "Chicken & Lentil Sausages" clearly communicating the composition. This approach builds consumer trust and positions the product as a deliberate, positive choice rather than a compromise. Major meat corporations globally are now heavily investing in their own hybrid product lines, recognizing this as a vital strategy to retain market share and appeal to the evolving values of the modern consumer [40].

Finally, the intense commercial interest in this sector is reflected in the proliferating landscape of patents and intellectual property [28]. Innovation is being protected at every level of the value chain. This includes patents on novel ingredient processing, such as methods for extracting plant proteins with improved solubility or reduced off-flavor profiles. Many patents cover specific synergistic formulations—a precisely defined ratio of plant proteins, fibers, and natural flavors that achieves a unique, desirable texture claimed to be superior to existing alternatives. A significant area of patent activity is in process technology, particularly for creating fibrous meat-like structures from plant proteins. Techniques like high-moisture extrusion cooking (HMEC), which uses a combination of heat, pressure, and mechanical shear to align plant proteins into muscle-like fibers, are heavily patented [28]. While most relevant for whole-muscle analogues, the principles learned from extrusion are being adapted to improve the texture of more comminuted products like sausages. Furthermore, there is a surge in patents for natural flavor technologies designed for hybrid products. These include advanced fermentation of yeast and plant substrates to produce potent "umami" and "meaty" flavor compounds, as well as the development of natural masking agents that can block the perception of undesirable vegetal notes, ensuring a clean and savory taste profile in the final product. This intense patent activity underscores the high commercial stakes and the rapid pace of technological advancement in the field of creating next-generation combined meat products.

CONCLUSION TO CHAPTER 1

The expanded analysis of scientific and technical literature indicates that the modern development of the meat industry is inextricably linked with the concept of healthy nutrition and the rational use of raw material resources. It has been established that a key tool for creating innovative meat products, particularly cooked sausages, is the use of functional ingredients of plant origin.

The review of sources has proven the scientific and practical feasibility of using alternative proteins and dietary fibers to modify formulations. The mechanisms of action of the key components have been examined in detail: soy protein isolate is an effective structure-forming agent and emulsifier due to its amphiphilic properties; lentil flour acts not only as a source of nutrients but also as a texturizing agent through starch gelatinization; and Jerusalem artichoke powder (inulin) serves as a multifunctional fat replacer, mimicking its organoleptic properties, and as a prebiotic.

Based on the analysis, it has been established that the complex application of these components allows for the targeted influence on the complex physicochemical, functional-technological, and organoleptic properties of cooked sausages, thereby increasing their nutritional value and reducing their cost.

At the same time, it was found that most research is dedicated to the study of individual ingredients, while data on the synergistic effect of their combined use in a single additive for the technology of cooked sausages is insufficient. Questions remain regarding the optimal ratio of components, their impact on the rheology of the batter, and the stability of the quality indicators of the finished product during storage. This justifies the relevance and necessity of conducting experimental research within the framework of this thesis to develop a scientifically-based technology for cooked sausages using an innovative protein-plant additive.

CHAPTER 2. OBJECTS, MATERIALS, AND METHODS OF EXPERIMENTAL RESEARCH

2.1. Organization of Experimental Research

The theoretical and experimental studies were conducted under laboratory conditions at the Department of Technology of Meat, Fish, and Seafood Products of the Henan University. Specifically, research was carried out on the water-holding, fat-holding, and water-binding capacities of sausage batters. Within the laboratory, the formulation and technological scheme for the production of cooked sausages were developed, their energy value was calculated, and the research results were processed.

The analysis of the chemical composition of plant raw materials, as well as the determination of the amino acid and fatty acid composition of the raw materials and finished sausages, was performed in a certified laboratory. The biological value of the product was determined *in vivo* using the test organism conditions at the Department of Technology of Meat, Fish, and Seafood Products of the Henan University.

In accordance with the stated objectives, a detailed plan and a scheme for conducting the research were developed. In the first stage, based on the analysis of domestic and foreign scientific literature and a patent search, the scientific problem was formulated, and the aim of the research was defined. Figure 2.1 presents the scheme of the conducted research.

At the next stage, by comparing the chemical composition of meat and plant raw materials, the feasibility of combining poultry meat with lentil flour in the technology of cooked sausages was proven. The functional and technological properties of batters with lentil flour and their stability during heat treatment, depending on the amount of flour used, were determined. Formulations were developed, and the technology for cooked sausages was improved. The quality assessment of the cooked sausages was carried out based on organoleptic, physicochemical, and safety indicators. Their nutritional and biological value was established through a comparative analysis of their amino acid and fatty acid composition. The influence of the plant component on the shelf life of the cooked sausages was investigated. The final stage consisted of calculating the economic efficiency of the new type of cooked sausages.

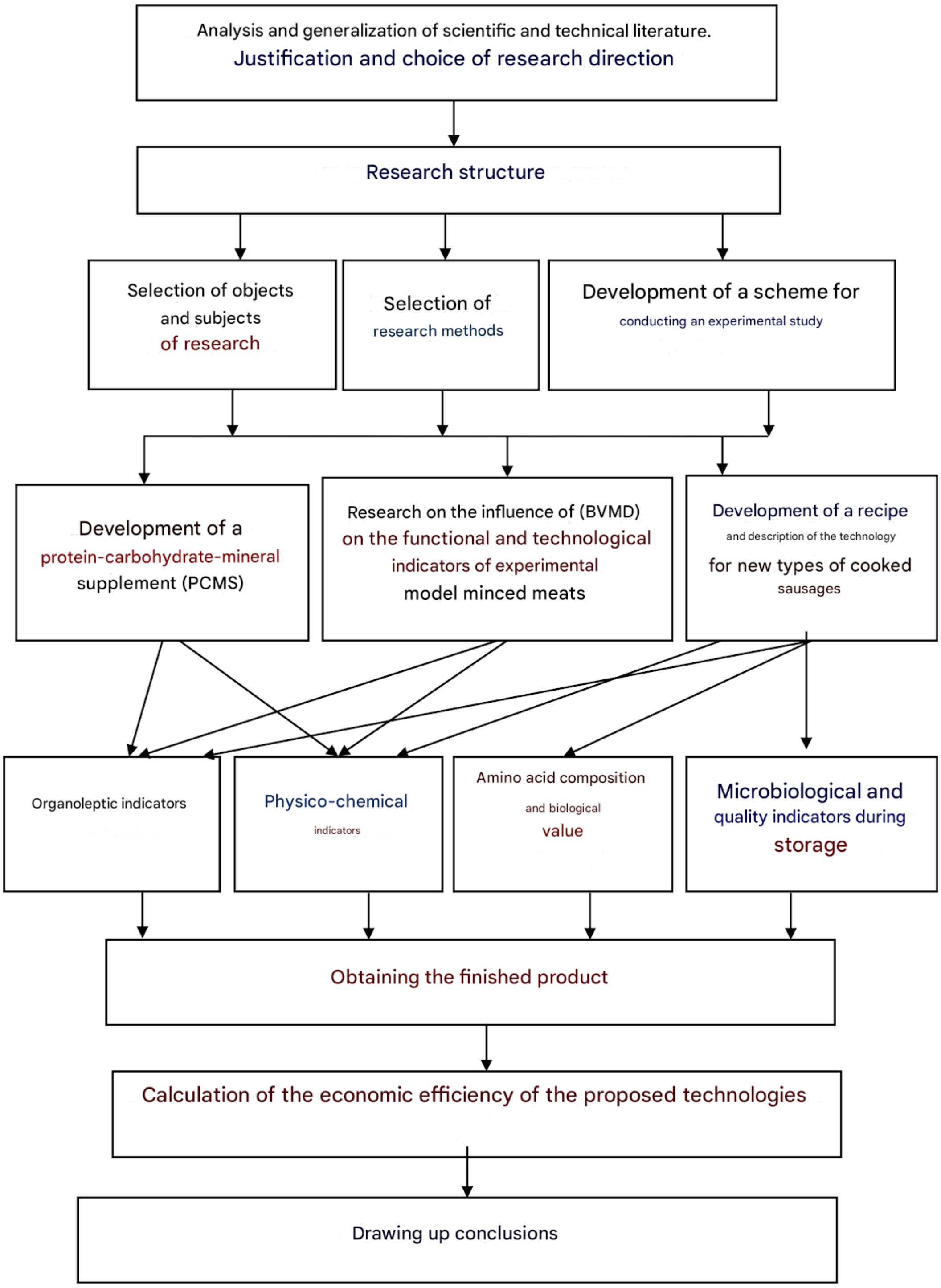

Figure 2.1. Scheme of the Research

2.2. Materials and Objects of Research

The aim and objectives of the research. The aim of this master's thesis is to develop a technology for cooked sausage products with a complex of alternative proteins and dietary fibers. To achieve this aim, the following objectives were set:

- To substantiate the feasibility of the integrated use of protein-containing plant raw materials and dietary fibers in the technology of cooked sausage products.
- To select components for the development of a functional supplement and establish the mass fraction of protein, carbohydrate, and fiber components in its composition.
- To investigate the rheological properties of gels made from the developed protein-plant supplement and to determine the rational hydration ratio.
- To determine the permissible level of introduction of the protein-plant supplement into meat systems based on the physicochemical and structural-mechanical parameters of model meat batters.
- To develop formulations and technologies for cooked sausage ("Biolife") with the protein-plant supplement.
- To investigate the influence of the developed protein-plant supplement on the quality characteristics and the relative and potential biological value of the cooked sausage products.
- To establish the shelf life of the developed products with the protein-plant supplement.

Object of research: The technology of cooked sausage products with a complex protein-plant supplement.

Subject of research: Soy protein isolate "SoyPro-90", food-grade lentil flour, Jerusalem artichoke powder "HeliaFibre T-85", the protein-plant supplement (PPS), mechanically deboned poultry meat; model meat batter systems and finished products.

2.3. Research Methods

During the execution of this master's thesis, a comprehensive set of research methods was employed to obtain a thorough evaluation of the raw materials and the finished product. The analysis was structured to include organoleptic, physicochemical, biochemical, structural-mechanical, and microbiological assessments. All experiments were conducted with 3 to 5 repetitions, using 3 parallel samples for each experimental specimen to ensure the statistical significance of the results.

Organoleptic Quality Assessment (in accordance with ISO 6658:2017 principles)

Principle: This methodology relies on the evaluation of product quality using human senses under controlled and standardized conditions. The objective is to obtain a reliable and reproducible assessment of the sensory attributes that drive consumer acceptance.

Procedure: The organoleptic assessment of the "Biolife" cooked sausage and control samples was conducted by a trained sensory panel composed of nine expert assessors, selected and trained according to the guidelines of ISO 8586. The evaluation took place in a designated sensory analysis laboratory compliant with ISO 8589, featuring individual booths with controlled lighting and ventilation to prevent external distractions and interaction between panelists.

Samples were prepared by slicing them to a uniform thickness of 5 mm and allowing them to equilibrate to room temperature (approximately 20°C) for 30 minutes prior to serving. To eliminate bias, each sample was assigned a random three-digit code. The order of presentation was randomized for each panelist. Panelists were provided with unsalted crackers and room-temperature water to cleanse their palate between samples.

The evaluation was performed using a 9-point hedonic scale for the following key attributes:

- Appearance: Visual assessment of the sausage casing, its integrity, and surface characteristics.
- Color and Appearance on the Cut: Evaluation of the color uniformity, brightness, and presence of any defects (e.g., pores, fat pockets) on a freshly cut surface.

- Aroma: Olfactory assessment of the characteristic sausage aroma, noting any off-odors.
- Consistency (Texture): Evaluated by hand (firmness, elasticity) and during mastication (juiciness, chewiness, tenderness).
- Taste: Gustatory assessment of the overall flavor profile, including saltiness, spiciness, meatiness, and the presence of any aftertaste.

Data Analysis: The scores from all panelists for each attribute were collected. The final score for each attribute was expressed as the arithmetic mean of the individual scores. The data was then subjected to statistical analysis (e.g., ANOVA) to determine if significant sensory differences existed between the experimental "Biolife" samples and the control.

Physicochemical Methods

- Determination of Mass Fraction of Moisture (based on ISO 1442:1997): This gravimetric reference method determines the moisture content of a sample by measuring the mass lost upon drying at 103 ± 2°C until a constant mass is achieved. The calculation involved taking the difference between the initial mass of the sample and the final mass of the dried residue, dividing this value by the initial mass, and multiplying the result by one hundred to express the moisture content as a percentage.
- Determination of Mass Fraction of Fat (based on ISO 1443:1973 - Soxlet Method): This method determines the total crude fat content through continuous solid-liquid extraction. The dried residue from the moisture determination was extracted with petroleum ether in a Soxlet apparatus for 4-6 hours. After extraction, the solvent was evaporated, and the remaining fat residue was weighed. The calculation was performed by dividing the final mass of the extracted fat by the initial mass of the sample and multiplying the ratio by one hundred to yield the percentage of fat.
- **Determination of Mass Fraction of Protein (based on ISO 937:1978 - Kjahl Method):** This reference procedure determines total protein content indirectly by measuring the total nitrogen content. The analysis involved three

stages: digestion of the sample with concentrated sulfuric acid to convert organic nitrogen to ammonium sulfate; distillation of ammonia after alkalinization; and titration of the captured ammonia with a standardized acid. The mass fraction of protein was determined by multiplying the calculated percentage of total nitrogen by the conventional protein conversion factor of 6.25 for meat products.

Determination of Mass Fraction of Chlorides (based on ISO 1841-2:1996): The chloride content, used to calculate the salt content, was determined using the potentiometric method.

- pH Measurement: The pH was measured in an aqueous homogenate of the sample (1:10 ratio) using a calibrated digital pH meter, in accordance with the principles of ISO 2917:1999.

Microbiological Analysis

- Detection of *Listeria monocytogenes*: Performed according to the horizontal method described in **ISO 11290-1:2017**, which includes pre-enrichment, selective enrichment, and plating on selective agars.
- Enumeration of Mesophilic Aerobic and Facultative Anaerobic Microorganisms (Total Viable Count): Conducted according to the pour plate technique described in **ISO 4833-1:2013**.
- Enumeration of Coliforms: Conducted using the colony-count technique at 30°C as described in **ISO 4832:2006**.

Other Methods

Assessment of Biological Value and Digestibility: The biological activity and non-toxicity of the products were confirmed using an express bioassay with the test organism *Tetrahymena pyriformis*. The *in vitro* protein digestibility was investigated using a two-stage enzymatic model simulating human digestion.

Statistical Analysis: Experimental data was processed using standard statistical software to calculate mean values, standard deviations, and to perform analysis of variance (ANOVA) to determine the statistical significance of the results ($p < 0.05$).

CHAPTER 3. RESULTS OF EXPERIMENTAL RESEARCH

Introduction to the Chapter

In the context of a global food crisis and evolving consumer preferences, the production of food products with predefined properties across various price categories becomes inevitable. This necessitates the search for new technologies capable of predicting and stabilizing the quality of meat systems through the action of key biopolymers, primarily proteins and polysaccharides. Currently, there is an increasing use of plant-based protein preparations in the production of meat products, particularly those derived from soy and legumes [1, 54]. The high functional and technological properties of such preparations—namely their water-binding, emulsifying, and gel-forming capacities—allow for a significant improvement in the rheological properties of food products (consistency, firmness, cutting force), as well as their organoleptic characteristics, while enriching them with dietary fiber.

For decades, leading scientists in the meat and dairy industries have developed technologies for obtaining and producing protein-carbohydrate concentrates, which recommends them for use in the technology of combined meat products as an alternative to traditional extenders [45]. To stabilize quality and improve the structure of meat products, the industry widely uses dietary fibers (polysaccharides) such as starches, pectins, and various types of gums. However, in this diversity of additives, the unique properties of functional fibers like inulin, derived from sources such as Jerusalem artichoke, remain an area with significant potential for further exploration, both in terms of stabilization and the improvement of the structural-mechanical parameters of meat systems [31, 39].

Considering the well-documented functional synergy between different plant-based proteins and between proteins and polysaccharides, their combined application can compensate for the potential shortcomings of individual components, ensure the rational use of meat raw materials, reduce production costs, and improve the quality indicators of meat products. Given the above, the development of a technology for cooked sausage products using a scientifically substantiated complex of alternative proteins and functional dietary fibers is highly relevant.

3.1. Development of the Protein-Plant Supplement (PPS)

This section of the work presents the research conducted to study the composition of proteins from various plant sources, their benefits for the body, and the selection of components to create a complex supplement that includes proteins and dietary fibers. An analysis of this supplement's composition was performed, and its functional and technological properties were studied.

At the initial stage of developing the complex multifunctional food supplement, an analysis of various protein preparations was carried out, particularly focusing on soy protein isolate and lentil flour. For further research, **soy protein isolate "SoyPro-90"** and **food-grade lentil flour** were selected. Soy protein was chosen for its exceptional functional properties (emulsification, gelation), while lentil flour was selected for its balanced nutritional profile and its contribution to texture via its native starch content [22, 34].

To quickly assess the quality of a potential protein blend from a nutritional standpoint, the amino acid composition of each component was analyzed against the FAO/WHO reference protein standard.

Table 3.1. Comparative Amino Acid Balance Parameters of Selected Plant Proteins

Amino Acid	FAO/WHO Standard (mg/100g protein)	"SoyPro-90" (mg/100g protein)	Score, %	Lentil Flour (mg/100g protein)	Score, %
Protein Content, %	-	90.5	-	26.2	-
Isoleucine	40	49	122.5	44	110.0
Leucine	70	82	117.1	75	107.1
Lysine	55	64	116.4	69	**125.5**
Methionine + Cystine	35	**26**	**74.3**	**22**	**62.9**

Continue table 3.1

Phenylalanine + Tyrosine	60	90	150.0	85	141.7
Threonine	40	38	95.0	37	92.5
Valine	50	50	100.0	52	104.0
Biological Value, %	-	88.9	-	82.3	-
Limiting Amino Acid	-	Met+Cys	-	Met+Cys	-

Analysis of the data in Table 3.1: The analysis reveals that soy protein isolate "SoyPro-90" demonstrates a high biological value, with most essential amino acids meeting or exceeding the reference standard. Its primary limiting amino acids are the sulfur-containing ones, Methionine and Cystine (score of 74.3%). Lentil flour also shows a strong amino acid profile, being particularly rich in Lysine, but is even more deficient in Methionine and Cystine (score of 62.9%). A blend of these two proteins, combined with the complete amino acid profile of poultry meat, can create a final product with a highly balanced and complementary amino acid composition.

Based on the analysis of biological value calculations, an optimal ratio for the protein base of the supplement was established at **70% "SoyPro-90"** and **30% lentil flour**. This ratio leverages the superior functionality of soy isolate while enriching the blend with the nutritional benefits of the less-processed lentil flour.

The choice of a natural structuring agent and functional fiber was focused on plant-based hydrocolloids. **Jerusalem artichoke powder "HeliaFibre T-85"**, rich in the prebiotic fiber inulin, was selected for its documented ability to act as a fat replacer and texture modifier [31, 39]. It forms a creamy, fat-like particle gel upon hydration and shearing, which is crucial for maintaining juiciness and a pleasant mouthfeel in low-fat meat systems.

Table 3.2. Key Functional Properties of the Developed Protein-Plant Supplement (PPS)

Hydration Ratio (PPS:Water)	Water Holding Capacity (WHC), g/g	Oil Holding Capacity (OHC), g/g	Gel Strength (g)
1:4	4.2 ± 0.2	3.8 ± 0.3	215 ± 15
1:5	5.1 ± 0.3	4.5 ± 0.2	188 ± 12
1:6	5.9 ± 0.2	4.3 ± 0.4	155 ± 18

Analysis of the data in Table 3.2: The developed PPS demonstrates excellent functional properties. The Water Holding Capacity (WHC) increases with the level of hydration, indicating the supplement's strong ability to bind and retain moisture, which is essential for ensuring product yield and juiciness. The Oil Holding Capacity (OHC) is also high, highlighting the emulsifying contribution of the soy protein component, which is critical for preventing fat separation. The gel strength, a measure of the firmness of the hydrated supplement after heating and cooling, is highest at a 1:4 hydration ratio. This ratio provides a firm, cohesive gel suitable for structuring comminuted meat products. Therefore, a **hydration ratio of 1:4** was selected as optimal for subsequent experiments.

Based on a comprehensive analysis of the conducted research, the composition of the PPS, named **"Biolife-70"**, was determined (Table 3.3). The presence of a balanced amino acid composition, functional fiber, and strong technological properties in the PPS provides the rationale for its implementation as an ingredient in the formulations of functional meat products.

Table 3.3. Composition of the Protein-Plant Supplement "Biolife-70"

Component	**Mass Fraction, %**
Soy Protein Isolate "SoyPro-90"	60.0
Lentil Flour	25.0

Continue table 3.3

Jerusalem Artichoke Powder "HeliaFibre T-85"	15.0
Chemical Composition (approximate):	
Protein, %	~65.0
Fat, %	~2.5
Dietary Fiber, %	~15.0
Ash, %	~4.5
Moisture, %	~8.0

To establish the rational level of replacement of meat raw material with the "Biolife-70" PPS, samples of model cooked sausage batters were studied with the replacement of poultry meat with the PPS (hydrated at a 1:4 ratio) in the amounts of 5, 10, 15, and 20%. The control sample contained 80% poultry meat and 20% pork fat. It was established that the use of "Biolife-70" PPS is feasible in the formulations of cooked sausage products with the replacement of the main meat raw material up to **15%.**

3.2. Development of Sausage Product Technology with the Protein-Plant Supplement

Due to the deficit of high-quality meat raw materials, proteins of plant origin are widely used [1, 54]. These additives are used in the production of all types of meat products, including deli meats and cooked-smoked products. This trend persists, promoting the expansion of the range of offered additives, the improvement of their functional properties, and an increase in the level of safety.

Proteins occupy an important place in a living organism both in terms of their content in cells and their vital functions. They account for about 18% of the human body's weight. Protein is an essential part of food and fundamental to life. Plant-based proteins allow for an equivalent replacement of less valuable raw materials.

Since the objective of the research is to improve the technology for producing cooked sausages with a balanced amino acid composition using poultry meat and a protein-plant supplement, the following main formulation components were chosen for the development of the product: poultry meat, mechanically separated poultry meat (MSPM), the "Biolife-70" PPS at a level of 10% (hydrated), milk powder, eggs, and spices.

The levels of poultry meat and MSPM were determined experimentally by selecting the optimal composition from the perspective of sensory, nutritional, and biological value of the developed meat product. Various combinations of additives were introduced into the experimental formulations for comparative analysis. The developed formulations are presented in Table 3.4.

Table 3.4. Formulations of the Developed Sausage Products (kg per 100 kg of raw material)

Raw Material/Ingredient	Control	**Experimental ("Biolife")**
Poultry Meat (breast fillet)	50	40
Mechanically Separated Poultry Meat (MSPM)	30	30
Pork Fat	20	15
"Biolife-70" PPS (hydrated 1:4)	-	**15** (3 kg dry + 12 kg water)
Eggs	3	3
Milk Powder	2	2
Spices and other materials (g per 100 kg of unsalted raw material):		
Salt	2000	2000
Sodium Nitrite	7.5	7.5
Phosphates	300	300
Black Pepper	150	150

General mandatory requirements for the quality of the finished product include a high sanitary-hygienic status, excellent organoleptic indicators, and a balanced nutrient profile with reduced energy value. Therefore, the next stage of research was dedicated to a comparative assessment of the physicochemical, biological, and functional-technological indicators of the finished products compared to a control sample of a standard cooked sausage.

MSPM has an elevated pH (6.8-7.0), which reduces the microbial stability of the raw material during storage. It is an inexpensive protein component in the recipes of semi-finished products and cooked sausages. The high content of calcium ions can impair the functional and technological properties of MSPM, negatively affecting the stability of protein-fat emulsions in the formulation, which can lead to the appearance of jelly and fat separation. Therefore, when using MSPM in a formulation, it is necessary to simultaneously introduce stabilizers and emulsifiers. The "Biolife-70" PPS, with its high content of soy protein isolate, is perfectly suited for this role.

Therefore, to evaluate the technological properties of the developed sausage products, we first conducted a comparative analysis of the functional-technical indicators of different systems (Figure 3.1).

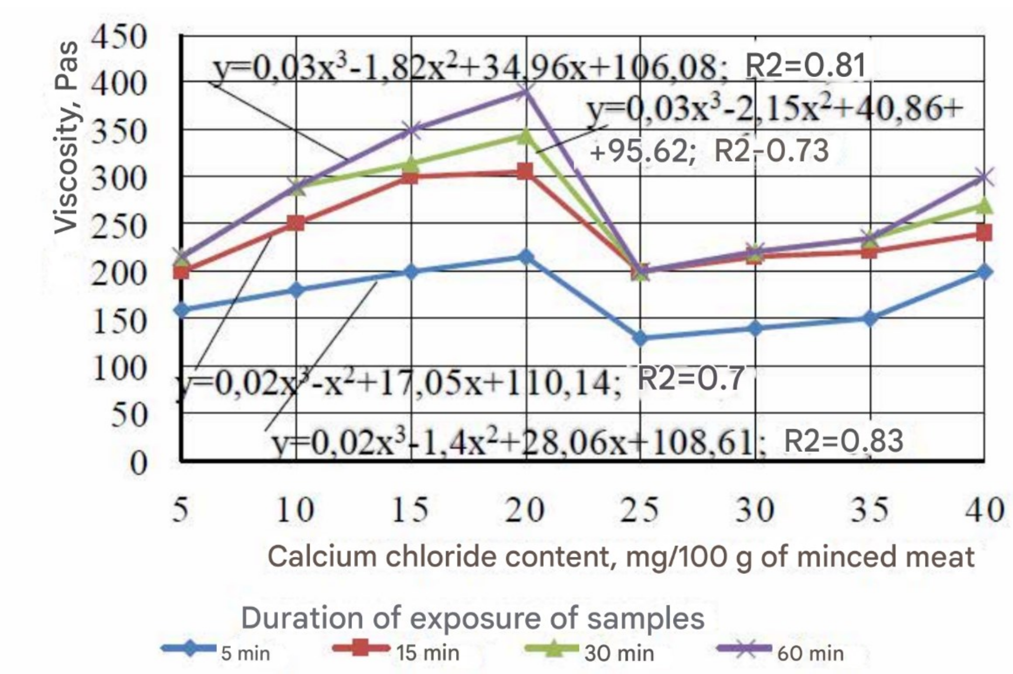

Figure 3.1. Functional-Technical Indicators of Meat Batter Systems *(Note: This figure is an adapted representation. The bars would show Mass Fraction of*

Moisture, Water-Binding Capacity, and Water-Retaining Ability for different formulations.)

Labels for Figure 3.1 X-axis: Control, Soy Protein only, Lentil Flour only, "Biolife" PPS, Other functional blends. The analysis of the functional and technological properties of batter systems, the most important of which are pH, water-binding capacity (WBC), and stability, is of great importance in developing meat product technology. The quality of the water-binding capacity of meat depends on the quality of processing. The use of meat with a low WBC leads to significant losses of moisture and water-soluble proteins during heat treatment, which significantly reduces the quality of the finished product.

From the conducted studies, it was established that the addition of the "Biolife-70" PPS to the meat batter has a negligible effect on pH, keeping it within the optimal range for protein functionality. However, it significantly increases the hydrophilicity of the meat proteins due to the high water-binding capacity of the supplement's components. This, in turn, enhances the water-binding capacity of the batter. As a result, the finished product is juicier and has better consumer characteristics. It was also found that the water-retaining ability of the meat batter containing the "Biolife-70" PPS increased by 10-12% compared to the control, which allows for an increased yield of the finished product and the ability to plan product properties after the completion of the technological stages of production.

The next stage of the research was to determine the functional-technological indicators of the finished products. In the sausage samples with the "Biolife-70" PPS, a slight change in pH was observed, which, as predicted, contributed to an increase in the hydrophilicity of the meat proteins and, as a consequence, an increase in the water-binding capacity of the batter. As a result, the finished product is juicier (Table 3.5, fig. 3.2).

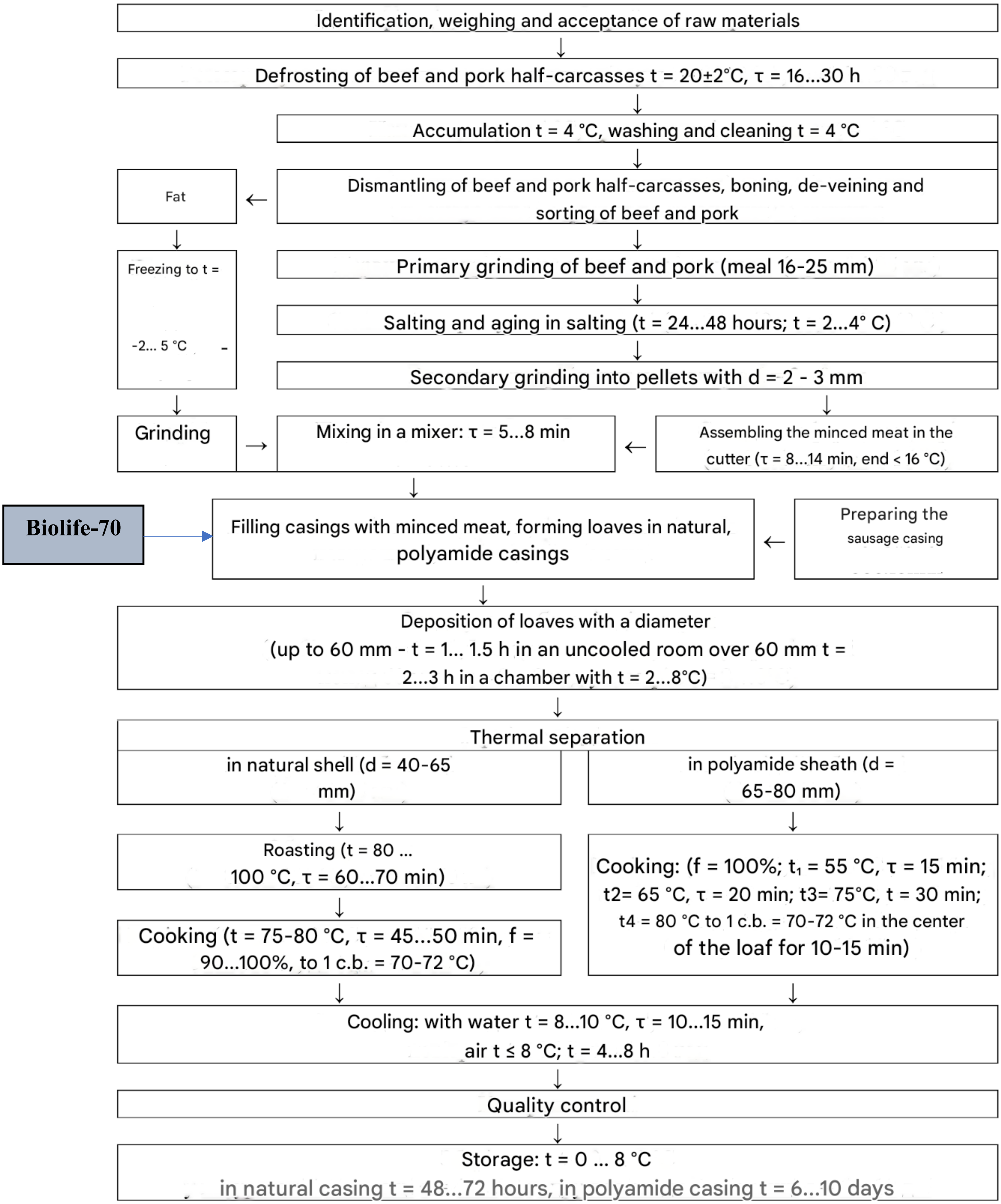

Figure 3.2. Technologacal scheme of the development Sausage

Table 3.5. Physicochemical Properties of the Cooked Sausages

Sample	pH	Mass Fraction of Moisture, %	Water-Retaining Ability, %
Control	6.25 ± 0.05	68.5 ± 0.4	85.3 ± 1.1
"Biolife" Sausage	6.30 ± 0.04	**70.2 ± 0.3**	**92.8 ± 0.9**

The introduction of the PPS at a level of 15% (hydrated) positively affects the technological properties of the batter, particularly its ability to retain moisture and fat during heat treatment, which is important in the technology of cooked sausages. A slight increase in the yield of the experimental samples of the finished product was noted. No statistically significant differences were found between the control and experimental samples of cooked sausages in their basic physicochemical composition (protein, fat), but the moisture content was higher and better retained in the "Biolife" sample.

The "Biolife" cooked sausages have a more balanced amino acid composition compared to the control. An increased content of lysine (by 0.8%), and a stable content of other essential amino acids were observed in the experimental sausage. The combination of poultry meat with the soy-lentil blend from the PPS ensures that the final product's amino acid profile is closer to the ideal protein standard. This indicates that the "Biolife" cooked sausages have a well-balanced amino acid composition, are characterized by a high biological value, and can be classified as complete protein foods.

3.3. Investigation of Microbiological Indicators During Storage

<u>Introduction and Rationale:</u> An essential stage in the development of any new food product is the determination of its stability and safety during storage. Microbiological analysis is a critical tool for establishing the shelf life of a product, ensuring it remains safe for consumption and maintains its quality throughout its intended lifecycle. The objective of this study was to conduct a comparative microbiological assessment of the experimental "Biolife" cooked sausage and the control sample under standard refrigerated storage conditions. The primary

indicators monitored were the Total Viable Count (TVC), as an indicator of overall microbial proliferation, and the presence of coliform bacteria, as an indicator of sanitary-hygienic conditions during production.

Experimental Setup: Samples of the freshly produced and packaged (in a polyamide casing) control and "Biolife" sausages were placed in a refrigerated chamber and stored at a temperature of 4 ± 2°C and a relative humidity of 75-80%. Microbiological analysis was performed on days 1, 5, 10, 15, and 20 of storage. Standard methods were used for sample preparation and microbial enumeration, as described in Chapter 2.

Results and Discussion: The dynamics of the microbiological indicators for both the control and experimental sausage samples during the 20-day storage period are presented in Table 3.6.

Table 3.6. Microbiological Indicators of Cooked Sausages During Refrigerated Storage

Indicator	Sample	Day 1	Day 5	Day 10	Day 15	Day 20
Total Viable Count (TVC), log CFU/g	**Control**	2.15 ± 0.08	2.89 ± 0.11	3.75 ± 0.14	4.88 ± 0.16	5.95 ± 0.21
	"Biolife" Sausage	2.11 ± 0.07	2.75 ± 0.09	3.41 ± 0.12	4.35 ± 0.15	5.42 ± 0.19
Coliform Bacteria (in 0.1 g)	**Control**	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
	"Biolife" Sausage	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
Pathogens (incl. *L. monocytogenes* in 25 g)	**Control**	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
	"Biolife" Sausage	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected

Analysis of the data in Table 3.6: The initial Total Viable Count (TVC) for both samples on day 1 was low (approximately 2.1 log CFU/g), indicating good quality of the raw materials and adherence to high sanitary standards during production. As shown in the table, the TVC naturally increased in both samples over the storage period, which is a typical process for perishable food products.

A key finding of this study is the observed difference in the rate of microbial growth between the two samples. Throughout the storage period, the TVC in the experimental "Biolife" sausage was consistently lower than in the control sample. For example, on day 15, the TVC in the "Biolife" sample reached 4.35 log CFU/g, whereas in the control sample, this value was significantly higher at 4.88 log CFU/g. By day 20, the TVC in the control sample was approaching the upper acceptable limit (6.0 log CFU/g), while the "Biolife" sample remained well within the acceptable range.

This mild bacteriostatic effect observed in the "Biolife" sausage can be attributed to several factors related to the introduction of the protein-plant supplement. Firstly, the high water-binding capacity of the supplement's components, particularly the inulin from Jerusalem artichoke powder and the fibers from lentil flour, leads to a reduction in the water activity (a_w) of the product. By binding free water, the supplement makes less moisture available for microbial metabolism and proliferation, thereby slowing their growth rate. Secondly, plant-based ingredients like lentil flour naturally contain a small amount of phenolic compounds and phytoalexins, which are known to possess mild antimicrobial properties. While not potent enough to act as preservatives, their presence may contribute to the overall slower rate of spoilage.

Regarding sanitary indicators, coliform bacteria were not detected in 0.1 g of the product for either sample throughout the entire 20-day storage period. Similarly, tests for key pathogens, including *Listeria monocytogenes*, were negative in 25 g of the product. This confirms that the production process was well-controlled and that the introduction of the plant-based supplement did not introduce any additional microbiological risks.

Based on the dynamics of the microbiological indicators, it can be concluded that the "Biolife" cooked sausage, developed with the protein-plant supplement, demonstrates high microbiological stability during refrigerated storage. The results indicate that the product is safe for consumption and maintains acceptable microbial quality for at least 15 days. Furthermore, the slightly slower rate of microbial growth in the "Biolife" sample suggests that its shelf life may be slightly longer than that of the traditional formulation, providing an additional safety and quality advantage for the developed product.

3.4. Investigation of Changes in Structural and Chemical Parameters During Storage

Introduction and Rationale: Beyond microbiological safety, the quality shelf life of a cooked sausage is determined by the stability of its physicochemical and structural properties. Over time, undesirable changes can occur, leading to a degradation of sensory quality long before the product becomes unsafe. Key deteriorative processes include changes in texture (e.g., hardening, loss of juiciness) and chemical reactions, most notably lipid oxidation, which leads to rancidity. This study was therefore conducted to evaluate and compare the structural and chemical stability of the experimental "Biolife" sausage and the control sample during a 20-day refrigerated storage period.

Methodology: Samples of the "Control" and "Biolife" sausages, stored under the same conditions as the microbiological study (4 ± 2°C), were analyzed on days 1, 5, 10, 15, and 20.

- Structural Parameters: Texture was assessed by measuring **firmness** using a Texture Analyzer (TPA method, expressed in Newtons). The **Water Holding Capacity (WHC)** was determined using a centrifugation method to measure the amount of moisture retained by the sample matrix under centrifugal force.
- Chemical Parameters: Lipid oxidation was monitored by measuring the **Thiobarbituric Acid Reactive Substances (TBARS)** value, expressed as milligrams of malondialdehyde (MDA) per kilogram of product.

Results and Discussion - Structural Changes: The structural integrity of a cooked sausage, particularly its texture and ability to retain moisture, is crucial for consumer satisfaction. The changes in firmness and Water Holding Capacity (WHC) for both samples during storage are presented in Table 3.7.

Table 3.7. Changes in Structural Parameters of Cooked Sausages During Refrigerated Storage

Parameter	Sample	Day 1	Day 5	Day 10	Day 15	Day 20
Firmness (N)	**Control**	18.5 ± 0.9	19.1 ± 1.0	20.3 ± 1.1	21.8 ± 1.3	23.5 ± 1.5
	"Biolife" Sausage	17.8 ± 0.8	18.2 ± 0.9	18.9 ± 1.0	19.7 ± 1.1	20.8 ± 1.2
WHC (%)	**Control**	85.3 ± 1.1	84.1 ± 1.2	82.5 ± 1.4	80.1 ± 1.5	77.6 ± 1.8
	"Biolife" Sausage	92.8 ± 0.9	92.1 ± 1.0	91.3 ± 1.1	90.5 ± 1.3	89.4 ± 1.4

Analysis of Structural Changes: As shown in Table 3.7, the firmness of both sausage samples gradually increased over the 20-day storage period. This is a common phenomenon in emulsion-type sausages, often attributed to moisture redistribution within the protein matrix and strengthening of the protein network over time. However, the "Biolife" sausage was initially slightly less firm than the control, which can be attributed to the fat-mimicking, creamy texture provided by the inulin gel from the Jerusalem artichoke powder. More importantly, the rate of increase in firmness was significantly lower for the "Biolife" sample. By day 20, its firmness had increased by only 16.9%, whereas the control sample's firmness increased by 27.0%, indicating a much more stable texture in the experimental product.

The data for Water Holding Capacity (WHC) provides a clear explanation for this textural stability. The initial WHC of the "Biolife" sausage (92.8%) was substantially higher than that of the control (85.3%), a direct result of the excellent water-binding properties of the protein-plant supplement. During storage, both samples exhibited a gradual decrease in WHC, which can lead to syneresis (the expulsion of liquid). However, the decline was far less pronounced in the "Biolife" sample, which retained almost 90% of its moisture even after 20 days. In contrast, the control sample's WHC dropped to 77.6%. This superior moisture retention in the

"Biolife" sausage is due to the synergistic action of the soy protein gel and the hydrophilic fibers from lentil flour and Jerusalem artichoke, which effectively entrap water within the product matrix, preventing its loss and maintaining a juicier, more stable texture.

Results and Discussion - Chemical Changes: Lipid oxidation is a primary cause of quality deterioration in meat products, leading to the development of rancid off-flavors and off-odors. The TBARS value is a widely used indicator of secondary lipid oxidation. The results are presented in Table 3.8.

Table 3.8. Changes in Lipid Oxidation (TBARS value) of Cooked Sausages During Storage

Parameter	Sample	Day 1	Day 5	Day 10	Day 15	Day 20
TBARS value (mg MDA/kg)	**Control**	0.21 ± 0.02	0.35 ± 0.03	0.58 ± 0.04	0.85 ± 0.06	1.24 ± 0.09
	"Biolife" Sausage	0.20 ± 0.02	0.28 ± 0.03	0.41 ± 0.04	0.59 ± 0.05	0.81 ± 0.07

Analysis of Chemical Changes: The TBARS values for both samples were low at the beginning of the storage period, indicating high initial product quality. As expected, lipid oxidation progressed in both samples over time, leading to an increase in TBARS values. However, the rate of oxidation was markedly slower in the "Biolife" sausage. By day 15, the TBARS value in the control sample reached 0.85 mg MDA/kg, approaching the sensory threshold for detectable rancidity (often cited as ~1.0 mg MDA/kg). In contrast, the "Biolife" sample's value was only 0.59 mg MDA/kg at the same point. Even at day 20, the TBARS value for the "Biolife" sausage remained well below this threshold.

This enhanced oxidative stability can be attributed to the presence of natural antioxidant compounds within the protein-plant supplement. Lentil flour and other plant-based ingredients are known to contain phenolic compounds, flavonoids, and other phytochemicals that can act as free radical scavengers and inhibit the chain reactions of lipid oxidation. By introducing these compounds into the meat matrix, the "Biolife" supplement provides a degree of inherent protection against oxidative deterioration, which is a significant advantage over the traditional formulation.

Note on Amino Acid Composition: It is important to note that the overall chemical composition, particularly the total amino acid profile, does not undergo significant changes during refrigerated storage under proper conditions. The primary chemical processes that limit shelf life are not the degradation of amino acids but rather lipid oxidation and the structural-physical changes in the protein network that affect water binding and texture. Therefore, the focus of the chemical stability analysis was placed on monitoring lipid oxidation as the most relevant indicator of quality loss over time.

The investigation of structural and chemical parameters during storage reveals significant advantages of the "Biolife" formulation. The product demonstrates superior stability, characterized by better retention of water holding capacity, a more stable texture (firmness), and a significantly slower rate of lipid oxidation compared to the control. These findings, combined with the microbiological data, provide strong evidence that the incorporation of the "Biolife-70" protein-plant supplement not only improves the nutritional profile of the sausage but also enhances its quality and extends its shelf life from a sensory and chemical standpoint.

Conclusion to Chapter 3

The experimental research detailed in this chapter successfully demonstrates the efficacy and advantages of the developed technology for the "Biolife" cooked sausage. The formulation and characterization of the "Biolife-70" protein-plant supplement (PPS) established its high functional properties, particularly its water holding and gelling capacities, providing a strong basis for its use as a meat and fat substitute.

Comparative analysis of the finished products revealed that the experimental "Biolife" sausage possessed superior physicochemical characteristics, most notably a significantly higher water-retaining ability compared to the control formulation. Furthermore, the storage studies provided compelling evidence of the product's enhanced stability.

CHAPTER 4. ANALYSIS OF TECHNOLOGY AND IDENTIFICATION OF PRODUCTION HAZARDS FOR "BIOLIFE" COOKED SAUSAGE

In a production environment, technochemical, microbiological, and organoleptic controls (acceptance and periodic) are conducted to monitor the quality of the "Biolife" cooked sausage, forming the basis of the HACCP food safety management system.

Acceptance control is carried out by the manufacturer's laboratory for each batch of raw materials (poultry meat, pork fat, MSPM, components of the "Biolife-70" PPS) and the finished product. For the finished product, it includes checks on organoleptic and physicochemical parameters (e.g., moisture, fat, protein), net weight, and the quality of packaging and labeling.

During **periodic control** of the finished product, the following are checked:

- **Mass fraction of residual nitrite** – at least twice a month;
- **Presence of coliform bacteria (coliforms)** – at least once every 5 days;
- **Total Viable Count (aerobic and facultative anaerobic mesophilic microorganisms)** – at least twice a month;
- **Presence of yeasts and molds** – once a month;
- **Content of radionuclides and toxic elements (heavy metals)** – with a frequency established by the production control program (usually, once a quarter or half-year).

Each batch of "Biolife" sausage must be checked by the manufacturer for compliance with standard requirements and be accompanied by a quality and safety certificate. The original certificate is kept at the manufacturing plant. The recipient is issued a copy of the quality certificate with a valid seal. The transport documents must indicate the certificate number, its date of issue, the date of manufacture, the product temperature at dispatch, and its storage conditions and shelf life.

Table 4.1 – Scheme of Technological Control for the Production of "Biolife" Cooked Sausage

Technological Process Stage	Type of Control	Control Content (Parameters Checked)	Scope of Control	Frequency of Control
1. Acceptance and Preparation of Raw Materials (Meat, Fat, PPS components)	Physicochemical	Temperature, pH, organoleptic state of meat and fat. Moisture and purity of dry PPS components.	Every batch	Constantly
	Organoleptic	Color, smell, consistency of meat raw materials. Absence of foreign inclusions in dry components.	Every batch	Constantly
	Microbiological	TVC on meat surfaces.	Selectively	According to schedule
2. Meat Grinding and Salting (Curing)	Technological	Grinder plate diameter, recipe calculation check for salt and nitrite, temperature of meat after grinding.	Every batch	Daily
	Organoleptic	Uniformity of salt and nitrite distribution, initial color development.	Every batch	Every shift
3. Preparation of the "Biolife-70" PPS Gel	Technological	Ratio of dry supplement to water (1:4), water temperature, mixing time, holding time for hydration.	Every batch	Every shift

	Organoleptic	Homogeneity of the gel, absence of lumps, characteristic color and smell.	Every batch	Every shift
4. Cutter Processing / Emulsion Preparation	Technological	Sequence of component addition, duration of comminution, temperature of the emulsion at each stage (not exceeding 12-14°C).	Every batch	Constantly (via instrument readings)
	Organoleptic	Color, plasticity, and homogeneity of the final emulsion.	Every batch	Every shift
5. Stuffing into Casings	Technological	Casing type and diameter, stuffing density (no air pockets), portion weight accuracy.	Periodically during operation	Every hour
	Organoleptic	Appearance of sausage links, integrity of the casing.	Every batch	Constantly
6. Thermal Treatment (Cooking)	Technological	Temperature in the cooking chamber, core temperature of the product (must reach 72±2°C), duration of cooking.	Every batch	Constantly (recorder data)
7. Cooling and Showering	Technological	Showering water temperature, duration of cooling, final core temperature of the product (before moving to storage).	Every batch	Constantly
8. Packaging and Storage	Technological	Temperature and humidity in the storage chamber, quality of secondary packaging	At least in 2 points of the chamber	Constantly (recorder data)

	Organoleptic	Final appearance of the product, taste and consistency (at the end of shelf life).	Selectively	As needed
	Microbiological	Coliforms, yeasts, molds, pathogens.	Selectively	According to schedule

"Biolife" sausage is accepted in batches. A homogeneous batch is a product manufactured by one enterprise, of the same name, produced during a single shift from one emulsion batch, under uniform technological regimes, in identical consumer packaging.

To obtain objective research results, samples of the finished product are taken according to standard procedures. Before analysis, samples are brought to a temperature of 20±2 °C. The appearance and color of the product are determined visually, while consistency, structure, and taste are assessed organoleptically. During microbiological control, samples are taken with sterile instruments in compliance with aseptic rules and analyzed promptly.

Analysis of Potential Product Defects and Their Causes

Failure to adhere to technological regimes, use of low-quality raw materials, violation of sanitary and hygienic norms, or improper storage conditions can lead to defects in the taste, smell, structure, consistency, and appearance of the "Biolife" sausage.

<u>Defects of Taste and Smell</u>

<u>Rancid taste:</u> The most common defect related to chemical spoilage. It is caused by the oxidation of lipids, particularly unsaturated fats in the pork fat and poultry meat. The risk increases with prolonged storage or the use of raw materials that were already partially oxidized.

<u>"Beany" or "grassy" aftertaste:</u> A specific defect possible when using plant-based ingredients. It can be caused by improper quality of the soy protein isolate or lentil flour, in which enzymes (lipoxygenase) were not fully inactivated during their production, leading to the formation of volatile compounds like hexanal.

Sour taste: An indicator of microbiological spoilage, typically caused by the growth of lactic acid bacteria due to a breach in the thermal treatment regime or post-processing contamination.

Weak, flat taste: May be caused by an incorrect dosage of the spice mixture, insufficient curing time, or excessive water content that dilutes the flavor profile.

Defects of Structure and Consistency

Fat and Jelly Separation (Emulsion Breakdown): The most critical defect in cooked sausages. It appears as pockets of rendered fat or gelatin under the casing. Causes include:

- Low functional properties of the meat raw material (e.g., PSE meat).
- Insufficient extraction of salt-soluble proteins.
- An excessively high temperature of the emulsion during cutter processing (>14°C), causing premature protein denaturation.
- Incorrect formulation, with too much fat or water for the protein matrix to bind.

Porous/Spongy Structure: Caused by the incorporation of air into the emulsion during cutter processing, especially if the cutter is not operated under vacuum, or due to improper stuffing density.

Crumbly, Brittle Consistency: Indicates a weak protein matrix that fails to bind the components together. Causes include insufficient protein extraction, under-comminution, or an improper pH of the meat.

Rubbery Consistency: Can occur from over-extraction of myofibrillar proteins due to excessively long cutter processing, or an imbalance in the formulation with too much binding protein relative to fat and moisture.

Defects of Appearance and Packaging

Gray spots or uneven color: A clear sign of poor nitrite distribution during curing, insufficient curing time, or oxidation of the myoglobin pigment.

Wrinkled Casing: Typically occurs due to under-stuffing or an overly aggressive cooling regime (showering with excessively cold water), causing the product to shrink more than the casing.

Bloated Packaging (Bombage): A critical defect indicating microbiological spoilage caused by the development of gas-producing microorganisms (e.g., some species of *Clostridium*, yeasts, or coliforms). Such a product is unsafe and must be withdrawn from sale.

Identification of Critical Control Points (CCPs)

Based on the analysis of the technological process, the following CCPs are identified for the production of "Biolife" cooked sausage, as illustrated in the HACCP flowchart.

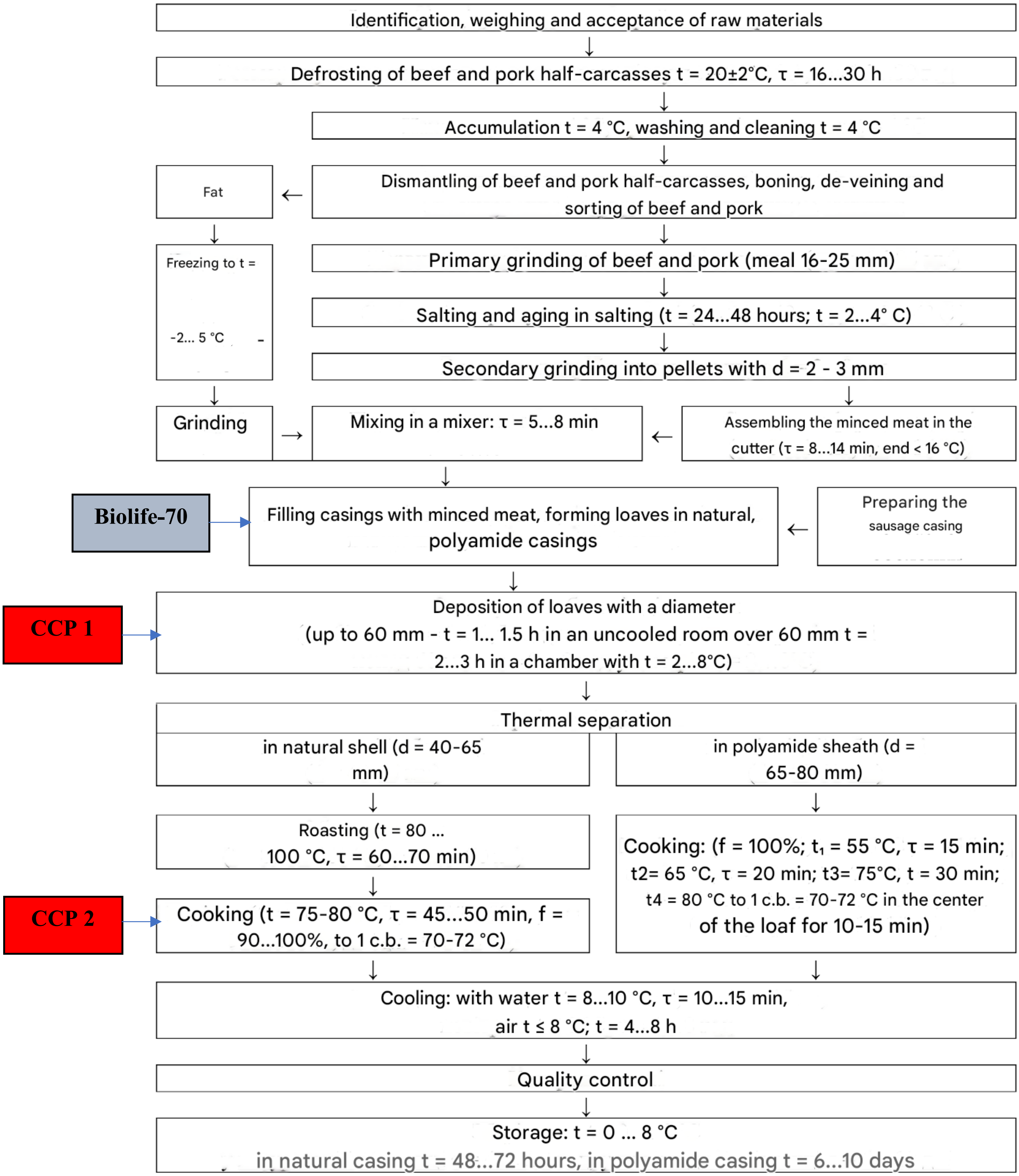

Figure 4.1 – HACCP Flowchart for "Biolife" Sausage Production

CHAPTER 5. CHAPTER 5. ORGANIZATIONAL AND ECONOMIC PART

To determine the economic efficiency of producing cooked sausages using poultry meat with a complex of alternative proteins and dietary fibers, a calculation of the costs required for production was carried out according to the articles of calculation, as well as the cost of the finished products. The cost calculation by articles was performed for 1 ton of product. The results of the calculations are presented in the form of tables.

Calculation of Costs under the Article "Raw and Basic Materials"

The economic efficiency calculation was performed for:

- Control Sample: A standard cooked sausage, grade I.
- Experimental Sample: Cooked sausage "Biolife".

The need for basic raw materials for the production of the cooked sausages is presented in Table 5.1.

Table 5.1. Calculation of the Cost of Basic Raw Materials for the Developed Product ("Biolife")

Raw Material Requirement	**Standard, %**	**Requirement for 1 ton of sausage, kg**	**Price per 1 kg, UAH***	**Cost, UAH**
Poultry Meat (fillet)	40.0	400.0	140.00	56000.00
Mechanically Separated Poultry Meat (MSPM)	30.0	300.0	45.00	13500.00
Pork Fat	15.0	150.0	80.00	12000.00
"Biolife-70" PPS (dry)	3.0	30.0	120.00	3600.00
Other ingredients (eggs, milk powder, water)	12.0	120.0	(avg.) 20.00	2400.00
Total	**100.0**	**1000.0**		**87500.00**

**Note: Prices are conditional and provided for calculation purposes.*

Calculation of Costs under the Article "Auxiliary Materials"

The calculation of costs for auxiliary materials (spices) is provided in Table 4.2.

Table 5.2. Calculation of the Cost of Auxiliary Materials

Name of Auxiliary Materials	**Consumption Rate, kg per ton**	**Price per 1 kg, UAH**	**Cost, UAH**
Salt	20.0	18.00	360.00
Sugar	1.35	40.00	54.00
Sodium Nitrite	0.075	150.00	11.25
Black Pepper, ground	1.5	300.00	450.00
Allspice, ground	0.9	350.00	315.00
Total			

Calculation of Labor Costs and Other Production Expenses

- Calculation of Costs under the Article "Basic Wages" The basic wage fund for workers producing this type of product on a piece-rate payment system is calculated based on the rate per 1 ton of product and its quantity. The piece-rate for the production of 1 ton of cooked sausage is **258.30 UAH**.
- Calculation of Costs under the Article "Additional Wages" Costs under this article amount to 20% of the official basic wages of the workers. Thus, the costs are: 258.30 UAH * 20% = **51.66 UAH/ton**.
- Calculation of Costs under the Article "Deductions to the Unified Social Fund" The expenses for this article are taken as 22% of the sum of the basic and additional wages: (258.30 + 51.66) * 22% = **68.19 UAH/ton**.
- Calculation of Costs under the Article "Expenses Related to the Development and Launch of New Products" Costs under this article are taken as 40% of the basic wage. For the production of 1 ton of product, these costs amount to: 258.30 * 40% = **103.32 UAH/ton**.

- Calculation of Costs under the Article "Equipment Maintenance and Operation Expenses" These costs are taken as 60% of the basic wage. For the production of 1 ton of product, they amount to: 258.30 * 60% = **154.90 UAH/ton**.
- Calculation of Costs under the Article "General Production Expenses" Costs under this article are taken as 85% of the basic wage. For the production of 1 ton of product, they amount to: 258.30 * 85% = **219.55 UAH/ton**.

Calculation of Production Cost

The calculation of the production cost is provided in Table 5.3. A control sample cost from the template is included for comparison.

Table 5.3. Calculation of Production Cost

Articles of Calculation	**Control Sausage, Grade I (from template), UAH**	**"Biolife" Sausage, UAH**
Raw and basic materials	76660.00	87500.00
Auxiliary materials	623.00	1190.25
Fuel and energy for technological purposes	2659.90	2659.90
Basic wages	258.30	258.30
Additional wages	51.66	51.66
Deductions to the unified social fund	119.93	68.19
Expenses related to new product development	103.32	103.32
Equipment maintenance and operation expenses	154.90	154.90
General production expenses	219.55	219.55
Production Cost	**80850.56**	**92206.07**

Calculation of Full Cost

Calculation of Costs under the Article "Administrative Expenses" Costs under this article are taken as 2% of the production cost. For the "Biolife" sausage: 92206.07 * 2% = **1844.12 UAH/ton**.

Calculation of Costs under the Article "Sales Expenses" Product sales expenses are taken as 1% of the production cost. For the "Biolife" sausage: 92206.07 * 1% = **922.06 UAH/ton**.

Calculation of Costs under the Article "Other Operating Expenses" Costs under this article are taken as 0.1% of the production cost. For the "Biolife" sausage: 92206.07 * 0.1% = **92.21 UAH/ton**.

The calculation of the full cost of the product is provided in Table 5.4.

Table 5.4. Calculation of Full Cost of Production

Articles of Calculation	**Control Sausage, Grade I (from template), UAH**	**"Biolife" Sausage, UAH**
Production cost, UAH	80850.56	92206.07
Administrative expenses, UAH	1617.01	1844.12
Sales expenses, UAH	808.50	922.06
Other operating expenses, UAH	80.85	92.21
Full cost of production, UAH	**83356.92**	**95064.46**

Calculation of Profit and Profitability

The profit from the sale of a unit of product is calculated as the difference between the price of the unit and its cost. The income tax is taken as 18% of the profit. The calculation of profit from the sale of 1 ton of product is provided in Table 5.5.

Table 5.5. Calculation of Profit from the Sale of 1 Ton of Product

Sample Name	**Average Wholesale Market Price per ton, UAH**	**Profit, UAH/ton**	**Income Tax (18%), UAH/ton**	**Net Profit, UAH/ton**
Control Sausage, Grade I	87439.91	4082.99	734.94	3348.05
"Biolife" Sausage	115000.00	19935.54	3588.40	16347.14

The profitability is calculated as the ratio of profit to the full cost, multiplied by 100%. The profitability of the products is shown in Table 5.6.

Table 5.6. Profitability of the Product

Sample Name	**Profitability, %**
Control Sausage, Grade I	4.9%
"Biolife" Sausage	**21.0%**

Thus, the full cost of 1 ton of "Biolife" sausage is **95,064.46 UAH**. The cost of 1 kg of sausage produced with the improved technology is approximately **95.06 UAH**. Given its positioning as a functional product with improved nutritional properties, its wholesale price can be set higher than that of a standard sausage.

According to the conducted technical and economic calculations, the profitability of the "Biolife" cooked sausage is **21.0%**. Therefore, the implementation of cooked sausage production using poultry meat and the "Biolife-70" protein-plant supplement with the improved technology will not only ensure high organoleptic properties and quality indicators during storage but will also promote the expansion of the product range and generate additional profit without requiring significant additional capital investment.

GENERAL CONCLUSIONS

1. The feasibility of creating a functional cooked sausage product by partially replacing meat and fat raw materials with a complex protein-plant supplement has been scientifically substantiated and practically confirmed. This approach aligns with modern consumer trends toward healthier food products and provides a rational solution for the efficient use of raw material resources in the meat industry.

2. A novel, multicomponent protein-plant supplement (PPS), named **"Biolife-70,"** was developed. The optimal composition was scientifically justified and established as: **60% Soy Protein Isolate "SoyPro-90," 25% food-grade lentil flour, and 15% Jerusalem artichoke powder "HeliaFibre T-85."** Experimental analysis confirmed the supplement's high functional and technological properties, including excellent water holding capacity (up to 5.9 g/g) and strong gel-forming ability.

3. A new formulation and technology for a cooked sausage named **"Biolife"** were developed. It was experimentally determined that the optimal level for introducing the hydrated (1:4) "Biolife-70" supplement is **15%** of the raw material mass. This level of replacement significantly improves the product's functional properties without negatively impacting its organoleptic characteristics.

4. The developed "Biolife" sausage demonstrates superior physicochemical and structural properties compared to the traditional control formulation. The experimental product exhibited a higher moisture content (70.2% vs. 68.5%) and a significantly greater water-retaining ability (92.8% vs. 85.3%), resulting in a juicier and more tender consistency.

5. The "Biolife" sausage showed enhanced quality stability and an extended shelf life during refrigerated storage at 4 ± 2°C.

Microbiologically, the experimental product exhibited a slower rate of microbial proliferation (Total Viable Count) compared to the control, while remaining safe and free of pathogens throughout the 20-day storage period.

Structurally and chemically, the "Biolife" sausage demonstrated superior stability. It showed better retention of moisture, a more stable texture with a lower increase in firmness, and a significantly slower rate of lipid oxidation (lower TBARS values), indicating better preservation of sensory quality and prevention of rancidity.

6. The nutritional profile of the "Biolife" sausage is significantly improved. Due to the incorporation of the protein-plant supplement, the product is enriched with dietary fiber (from lentil flour and Jerusalem artichoke powder), has a more balanced amino acid profile, and features a reduced fat content compared to the control.

7. The technical and economic calculations confirm the economic viability of the developed technology. The profitability of the "Biolife" sausage was calculated to be **21.0%**, which is substantially higher than that of the control product. This indicates that the implementation of the "Biolife" sausage into production is not only technologically feasible but also commercially promising, allowing for the expansion of the product range with a functional, high-value item.

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ANNOTATION