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Chicken combs as a raw material in the manufacturing of chopped semi-finished horse meat products

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ABSTRACT

Food safety stands at the forefront of social policies across nations. Secondary meat raw materials present a potential source for meat production. Our research objective was to analyze the nutritional value and functional-technological properties of horsemeat and protein additives of animal origin, particularly secondary meat raw materials such as chicken combs. We also sought to empirically determine their optimal quantities for developing chopped semi-finished horsemeat products, which are protein-enriched and have high consumer appeal. We aimed to establish efficient methods for utilizing collagen-rich materials like chicken combs. Additionally, we assessed the feasibility of using slaughter by-products and the potential of minced meat and pastry products as valuable raw material sources. Based on our findings, we deduce that chicken combs, a lower-value secondary raw material, possess notable physical, chemical, and safety properties. These traits underline its high biological worth and environmental benignity, qualifying it as a viable ingredient for protein enrichment and as an additive in minced meat and paste product manufacturing.

Keywords: qualimetry forecasting, food security, government strategy, combined food product, chicken combs, chopped semi-finished horse sausage

INTRODUCTION

In 2019, K.-Zh. Tokayev, the President of the Republic of Kazakhstan, in his address "Constructive Public Dialogue: The Foundation for Kazakhstan's Stability and Prosperity," outlined five priority development areas for the nation. One such area was the "Developed Agro-Industrial Complex."

While agriculture remains a pivotal resource for Kazakhstan, its potential is yet to be fully realized. The nation holds considerable prospects for producing organic and eco-friendly products demanded both domestically and internationally **[1]**. The strategic plan for sustainable growth in the Agro-Industrial Complex (AIC) emphasizes expanding local food production and ensuring food safety, thus addressing numerous socio-economic challenges facing the Commonwealth of Independent States (CIS), Kazakhstan included **[2]**, **[3]**.

In recent years, the food safety landscape has evolved with heightened competition and surging consumer expectations, making product quality and safety paramount **[4]**. Horse meat, integral to Kazakh culture and cuisine due to its unique dietary attributes, can be enhanced when amalgamated with supplementary ingredients. This combination augments the meat's amino acid profile, its vitamin and mineral content, and the functional and technological characteristics of the final product. Furthermore, a core goal of Kazakhstan's agricultural sector is to bolster local production, focusing on high-quality and safe food raw materials, including meat **[5]**, **[6]**.

Today's competitive AIC market necessitates that processing enterprises craft products meeting rigorous standards of quality and safety, aligning with consumer preferences **[7]**, **[8]**. Current industrial food production trends pivot towards curating functional products that support and enhance health. These are achieved through regulating and normalizing bodily functions, either holistically or targeted towards specific organs. Secondary products from livestock and poultry processing, rich in proteins, essential amino acids, polyunsaturated fatty acids, and other vital nutrients, play a crucial role in this **[8]**. However, developers and producers of these innovative agricultural products face challenges. They grapple with bottlenecks such as gauging consumer satisfaction with particular product attributes, understanding product quality expectations, and ascertaining the significance of certain quality metrics for both internal and external consumers **[9]**, **[10]**, **[11]**.

An efficacious approach to navigate these challenges is adopting key Total Quality Management principles like "customer focus" and "data-driven decision-making" using qualimetry techniques, inclusive of qualimetry forecasting **[12]**. Although qualimetry-based product quality forecasting is an emergent scientific discipline, its application in the AIC is sporadic. Qualimetry forecasting encompasses methods that anticipate shifts in consumer requirements pertaining to product quality and leverage these insights to enhance future product competitiveness **[8]**, **[10]**.

The directives of the Concept of State Policy in the Domain of Healthy Nutrition have delineated primary objectives for healthy dietary practices **[5]**, **[7]**. However, not all countries can consistently supply the recommended dietary meat intake, leading to meat imports that might not always meet desired safety and quality standards. Harnessing the potential of indigenous livestock breeding can offer a solution **[13]**, **[14]**. That said, innovating and integrating new food technologies might introduce new dietary risks. Therefore, ensuring food safety by identifying and mitigating potential contamination risks becomes imperative for maintaining product quality standards.

Given this backdrop, there arises a pertinent need to undertake focused research aimed at innovating and refining the techniques of employing poultry by-products in meat product manufacturing, minimizing waste, and diversifying and enhancing product quality **[11]**, **[15]**.

Scientific Hypothesis

With escalating prices and a scarcity of prime raw materials for Kazakh production, there's an urgency to maximize the use of livestock and poultry slaughter by-products. Chicken combs represent one such underutilized resource. Incorporating them as protein enhancers in chopped semi-finished products can bolster protein utilization and reduce the end product's cost. However, the feasibility of utilizing chicken combs in Kazakhstan's food production remains under-explored, highlighting the need to investigate their biological attributes. The primary objective of our research was a holistic evaluation of the safety of protein supplements derived from chicken comb processing, intended for the production of semi-finished horse meat products.

MATERIAL AND METHODOLOGY

Samples

The primary subject of our experimental research was chicken combs. Combs from 42-day-old broiler chickens, raised under the care of Ardager LLP in Semey city, EKR, were utilized for the experiments. Experimental evaluations of the nutritional and biological worth of raw meat (encompassing chicken combs and horse meat), protein complexes, and finished products were conducted as per the following sequence:

1. Marketing research
2. Physicochemical and organoleptic evaluations
3. Determination of the mass fraction of total ash
4. Mass fraction of protein, ascertained using the Kjeldahl method
5. Quantification of fat and fatty acid content
6. Measurement of meat's moisture binding capacity (MBC)
7. Analysis of water-holding capacity (WHC)
8. Determination of fat-holding capacity (FHC, %)
9. Evaluation of structural and mechanical properties (SMP)
10. Analysis of macro- and microelement content.

Chemicals

All employed reagents were of U.S.P. grade or higher. Solvents, inclusive of water, bore the LC/MS distinction.

Animals, Plants and Biological Materials

Chicken combs, integrated into chopped meat products, constituted the main focus of our experimental inquiries. The study specifically leveraged combs from 42-day-old broiler chickens, reared at LLP Ardager, Semey city, EKR.

A staggering 18,000 chickens are processed daily at the facility, yielding approximately 108 kg of combs. Individual combs typically weigh between 5-6 grams.

For this study, chicken combs from the Cobb-500 chicken cross (meat variety) were chosen. These chickens were raised under industrial conditions, nourished with industrial dry supplement feed, received disinfection and deworming (with the latter administered on the 14th day), and were last vaccinated on their 20th day of life. The last vitamin supplement was administered on the 30th day. The typical slaughter age, by the 40-42nd day, sees chickens reaching a weight of around 2.5 kg. This period ensures that remnants of disinfectants and antibiotic drugs have been eradicated, and stable immune reactivity is observed 14 days post the last vaccine administration.

For the marketing research segment, 312 Semey residents were consulted: 152 males and 160 females, aged between 18 to 60 years. It's imperative to highlight the deep-seated meat-centric Kazakh culinary traditions, given the region's nomadic history. The Kazakh ethos emphasizes robust hospitality, with a strong inclination towards satiating guests with meat. As such, regional inhabitants exhibit a pronounced preference for meat products, where factors like taste, aroma, color, and presentation significantly influence their choices **[16]**.

Instruments

Our investigative arsenal comprised an array of equipment, including:

- DK6 automated incinerator and distillation device
- Soxhlet extractor
- "Kristal-4000" gas-liquid chromatograph, complemented with a flame ionization detector and the "NetChrom" software suite
- Milk butyrometer
- Heppler consistometer
- "Dropping 105M" capillary electrophoresis system

Capillary zone electrophoresis, one of the contemporary methodologies at our disposal, is geared towards the accurate quantification of water-soluble vitamins. This technique hinges on the migration and separation of ionic forms of analyzed constituents, propelled by an electric field, and subsequently records their electrophoretic mobility at a 200 nm wavelength.

It's pertinent to note the distinct advantages of capillary electrophoresis over methods like fluometry and photometry. Comparable to HPLC, capillary electrophoresis permits the simultaneous assessment of all components under scrutiny. Its benefits, when juxtaposed with chromatographic techniques, include enhanced efficiency, minimized reagent consumption, and the non-necessity of chromatographic columns. Given their excellent solubility in aqueous and aqueous-organic solutions, water-soluble vitamins emerge as optimal candidates for separation and analysis via capillary electrophoresis.

All instruments deployed in this study underwent meticulous calibration and certification, as endorsed by the Kazakh Metrology Center.

Laboratory Methods

The mass fraction of moisture was determined according to GOST 33319-2015 **[17]**. According to GOST 9793-74 **[18]** and GOST R 51479-99 **[19]**, the moisture content was calculated following (1):

$$X1 = (m1 - m2) \cdot 100/(m1 - m) \tag{1}$$

Where:

X1 – moisture content, %; m1 – the mass of the sample with the weighing bottle before drying, g; m2 **-** the weight of the sample with the weighing bottle after drying, g; m – the mass of the weighing bottle, g.

Determination of the mass fraction of total ash was determined according to GOST 31127-2012 **[20]**.

Mass Fraction of Protein via the Kjeldahl Method: Using the DK6 and UDK129 automated incinerator and distillation apparatus, protein's mass fraction determination was executed in line with GOST 25011-2017 **[21]**. The procedure involves adjusting the DK6 (VELP SCIENTIFICA, Italy) to heat the test samples either at 420 °C for 20 minutes or at 370 °C for 60 minutes. Once heated, the samples are cooled to 50-60 °C, after which 50 ml of ammonium salt-free distilled water is added to each. A receiver, an Erlenmeyer flask, contains 25 ml of a 4% boric acid solution. Within the distillation apparatus, a tube housing a prototype is situated. To the sample, 50 ml of an alkali (35% sodium hydroxide solution) is introduced, and subsequently, 100 ml of distillate is collected. The ensuing step is titration: 10 drops of an indicator are incorporated, followed by titration with a 0.2N HCl solution. For titrating 25 mg of nitrogen present in ammonia, 8.92 ml of a 0.2N HCl solution is requisite (where 1 ml of 0.2N HCl corresponds to 2.803 mg of nitrogen).

Determination of Fat and Fatty Acid Content: This determination abided by the Soxhlet method and conformed to GOST R 55483-2013 **[22]**. For discerning the fatty acid composition, lipids were segregated from the experimental samples via hexane extraction using a Soxhlet apparatus. The resultant extract was then evaporated to dryness in a round-bottom flask, facilitated by a rotary evaporator at temperatures ranging between

30-40°C. To the dry extract, 10 ml of hexane, 400 µl of 0.5M sodium ethylate in ethanol, and 50 µl of acetic acid were added. After a vigorous 2-minute stir, the reaction mixture was allowed to settle for 5 minutes. Post-settling, it was filtered through a paper filter, rendering the solution ready for analysis. Upon procuring the ethyl esters, the fatty acid composition was ascertained through gas chromatography, utilizing the “Kristal-4000” gas-liquid chromatograph, supplemented with a flame ionization detector and the “NetChrom” software suite **[22]**, **[23]**.

Chromatography Conditions:

- Injector temperature: 188 °C
- Detector temperature: 230 °C
- Furnace temperature: 188 °C
- Analysis duration: 2 hours
- Column content: polyethylene glycol adipate (20%) on celite 545

Other analyses involved determining the:

- Mass fraction of minerals
- Mass fraction of sodium chloride
- Organoleptic evaluation of the end products, gauged on a five-point quality scale for meat products

Functional and Technological Properties of Minced Meat: The pH value was determined using the potentiometric method, adhering to ST RK ISO 2917-2009 **[24]**. In the Moisture Binding Capacity (MBC) study, designated meat samples were placed on an ashless filter situated atop a glass plate, ensuring the samples were centered. This setup was subsequently covered with a plate of identical dimensions, upon which a 1 kg weight was placed and retained for 10 minutes. Post this duration, the filter, now devoid of the weight and bottom plate, had the periphery of the moisture spot surrounding the compressed minced meat delineated with a pencil. Upon drying in air, the outer contour of the spot was discerned. The areas of the spots engendered by both the pressed meat and absorbed moisture were gauged using a planimeter. The wet spot's magnitude was computed from the difference between the aggregate area of the spot and the area crafted by the minced meat. To give a quantitative perspective, 1 cm^2 of the wet spot's area on the filter equates to 8.4 mg of water.
The formulas calculate the content of bound moisture (2) and (3):

$$x1 = (A-8.4\ B) \bullet 100/\ m0 \tag{2}$$

$$x2 = (A-8.4\ B) \bullet 100\ /\ A \tag{3}$$

Where:
x1 – the content of bound moisture, % to minced meat; A – the total moisture content in the sample, mg; B – wet spot area, cm2; m0 – weight of the sample, mg; x2 – content of bound moisture, % to total moisture.

Determination of WHC (%), a sample of 5.00 ±0.01 g was evenly applied with a glass rod on the inner surface of a wide part of the milk butyrometer. The butyrometer was tightly closed with a stopper and placed in a water bath at the boiling point with the narrow part down for 15 min. The mass of released moisture was determined by calculation of the number of divisions on the butyrometer scale (4):

$$\begin{gathered} WHC = V\text{-}VVS, \\ VVS = a\text{-}p\text{-}t\text{-}'\text{-}W, \end{gathered} \tag{4}$$

Where:
B – the total mass fraction of moisture in the sample, %; a – division price of the butyrometer; a = 0,01 cm; n – number of divisions; t – mass of the sample, g.

FHC (%) determination was determined by the method of sequential determination of the main functional properties of minced meat from one sample, developed by the employees of VNIIMP Salavatulin et al. **[25]**.
SMP properties was checked according the determination of the ultimate shear stress of minced meat **[26]** by the Heppler consistometer. The container for the product is filled with the test sample, the surface is leveled with a spatula or knife, setting its level relative to the zero division of the instrument scale. The scale determines the cone's immersion depth in the product (in mm), setting and selecting a certain weight.
The ultimate shear stress is determined by the formula (5):

Ɵ_i=К M/h^2, (5)

Where:
– the ultimate shear stress, Pa; K – cone constant, for a = 60°, K = 2.1 m/kg; m – cone mass with the bar and additional weight, kg; h – immersion depth of the cone, m.

Mass fraction of amino acids on the system of capillary electrophoresis "Dropping 105M" **[27]**.The content of macro- and microelements was determined according to GOST R 55484-2013 by atomic absorption methods similar to the determination of heavy metals **[22]**, **[28]**, **[29]**, **[30]**, **[31]**, **[32]**. Vitamin content in raw materials and food products by capillary zone electrophoresis was checked according to GOST R 55482-2013 **[33]**, **[34]**. Standard solutions of the following vitamins were used as a control sample: thiamine chloride; riboflavin; nicotinamide; and ascorbic acid. The technique is designed to measure the mass fraction of free forms of vitamins in prefixes, vitamin supplements, concentrates and mixtures, in this regard, work was carried out to select the mass of the weighed portions of the analyzed sample:

- conditions of analysis;
- buffer: for the determination of vitamins in the CZE variant (sodium tetraborate + boric acid);
- capillary: Leff/Lobsch = 65/75 cm, ID = 50 mkm;
- voltage: +25 kV;
- temperature: +30 °C;
- pressure: 0 mbar, 50 mbar;
- detection:
- stage 1. Time 899 sec, e.g. 25 kV, press.0

Microbiological Studies: Microbiological examinations adhered to ST RK GOST R 51448-2010 **[35]**, titled "Meat and Meat Products: Sample Preparation Methods for Microbiological Research." In the exploration of the microflora in long-term storage products, time-tested microbiological techniques were employed, encompassing sampling methods, sample preparation for microbiological analyses, and microorganism cultivation methods.

The studies pursued the determination of various microbial quantities: mesophilic aerobic and facultative anaerobic microorganisms following GOST 10444.15-94; E. coli bacteria group (coliforms) per GOST 31747-2012; and mold, CFU/g as per GOST 10444.12-2013 **[29]**. Other focus areas included sulfite-reducing clostridia and S. aureus **[36]**, **[37]**.

Determination of Toxic Elements Content: This assessment was carried out following GOST 26929-94 **[38]** using Atomic Absorption Spectroscopy (AAS) on the "KVANT-Z.ETA-T" spectrometer complemented by its associated software. AAS, as a method, hinges on measuring the selective absorption of optical radiation of a designated wavelength by the element's neutral atoms in question. It stands as one of the most precise and efficacious physicochemical analysis techniques.

Modern devices facilitate control and data processing via a personal computer, employing the "QUANT" software. The AAS's analytical signal is the optical density of the atomic vapor, ascertained on one of the resonance lines of the targeted element, which correlates with the element's concentration. This relationship is described by the Bouguer-Lambert-Beer law (6).

$$A_\lambda = K_\lambda \cdot C \cdot L \;\; A_\lambda = K_\lambda \cdot C \cdot L \tag{6}$$

Where:
K_λ is the absorption index at the wavelength of the analytical line; is the thickness of the absorbing layer in the atomizer.

The methodology encompasses measuring the absorption (optical density) of the atomic vapor of the element under examination, achieved via electrothermal atomization in the spectrometer's graphite furnace. These optical density measurements occur at the element's resonant spectral line, emitted by the corresponding hollow cathode lamp.

Preparation and implementation of atomic absorption measurements of heavy metals were carried out according to GOST 30178-96 **[39]**:

- determination of the content of toxic elements by AAS on a spectrometer with electrical atomization "KVANT-Z.ETA-T" with software;

- the content of pesticides by thin layer chromatography;
- the content of pesticides in raw materials (chicken combs, horse meat) and in finished products by gas-liquid chromatography using an analytical stationary gas chromatograph "Crystallux-4000M" with an electron capture detector and software "NetChrom";

The content of radionuclides by thin-layer chromatography accoding to GOST R 56931-2016 **[40]**.

Description of the Experiment

Sample preparation: Samples for the physicochemical and organoleptic testing were prepared as a weighed sample of twice crushed product weighing 2-3 g, taken with an accuracy of 0.001 g was dried in a metal bottle with a glass rod in a drying oven at a temperature of 105 °C during an hour.

For the detection of the mass fraction of protein (according to the Kieldal method) 2g of the product was sieved on a 2 mm sieve and it was dried at 105 °C until constant weight. The sample has been weighed and transferred quantitatively to a combustion tube.

For each sample, add to the test tube reagents for wet combustion: 7g of potassium sulfate (K_2SO_4), 5 mg of selenium (Se) in powder form (or two tablets of K_2SO_4 with selenium – 3.5 g), 7 ml of concentrated sulfuric acid (98%), 5 ml of hydrogen peroxide (H_2O_2) with a concentration of 35%.

For MBC study, samples of minced meat (0.3 g) were weighed on a polyethylene mug with a diameter of 15-20 mm.

For the vitamins determination, samples were prepared according using the extraction of vitamins with an aqueous solution of sodium tetraborate in the presence of sulfite ion. The extract was centrifuged (5000-6000 rpm for 5 min.) and, if necessary, filtered through a membrane filter.

Number of samples analyzed: We had 4 experimental samples and a control one in our study. A marketing study has been conducted in a form of survey in 312 residents.

Number of repeated analyses: All instrumental measurements were performed in five times.

Number of experiment replication: The number of repetitions of each experiment to determine one value was two times.

Design of the experiment: Our first step involved conducting marketing research, gathering sociological insights using internet technologies. Aimed at discerning the potential demand and benefits of a novel product, we devised questions pertinent to the population's inclination towards semi-finished products. From November 2018 to May 2019, a questionnaire survey engaged 312 residents of Samey city, encompassing 152 males and 160 females spanning diverse age groups and professions. Post this phase, we evaluated the quality and safety properties of minced meat that incorporates chicken comb elements.

Organoleptic evaluations of the end product were conducted by tasting commissions using a five-point scale. This assessment verified the product's alignment with primary quality indicators, such as appearance, sectional view, aroma, taste, and texture, relative to standard requirements **[41]**.

Safety assessments encompassed examinations of microbiological indicators and determinations of toxic and radioactive element content.

Statistical Analysis

Data analysis was executed using Microsoft Excel and Statistica 15. All experiments were replicated thrice, with reported outcomes representing the average of these determinations, accompanied by standard deviations. The Student's t-test facilitated the statistical evaluation of the derived data. All data is articulated as mean ± standard error of the mean (SEM).

RESULTS AND DISCUSSION

Food Food plays a pivotal role in influencing human health **[42]**. Presently, humankind grapples with a scarcity of food resources. Nevertheless, through the deployment of avant-garde technologies and high-yield breed crossings, we possess the means to tackle this challenge **[43]**. An avenue worth exploring is the utilization of secondary raw materials from the animal breeding industry for food production **[44]**. A method to extract protein from less-valued raw materials is through its hydrolysis. This process enables the extraction of isolated collagen proteins of exceptional purity, suitable for the fabrication of sausages and minced semi-finished products **[45]**. These proteins are renowned for their impressive solubility and fat-retention properties and find frequent application in the crafting of pâtés and assorted sausages. Given that hydrolysates are rich in collagen degradation products, they enhance pâtés with dietary fibers and augment the bound moisture content in minced meat concoctions **[46]**, **[47]**. Motivated by these attributes, our research delved into assessing poultry's secondary raw material (chicken combs) – a treasure trove of proteins. We approached this through the lens of modern combinatorics, nutrition science, and food engineering. This strategy empowers us to refine food technology and conjure novel food compositions with superior nutritional and biological worth **[48].**

Application of Qualimetry Prediction in Quality Assessment

As we venture into the realm of new meat product development, it becomes imperative to align with consumer anticipations and adhere to sanctioned quality and safety benchmarks of food ingredients and end products. Miles and Frewer **[49]** have recently articulated apprehensions regarding the diminishing caliber of meat products, particularly in their organoleptic facets. Put succinctly, many products on the market exhibit indistinguishable taste and aroma profiles. In this backdrop, echoing the voice of consumers during product development emerges as a priority. The doctrine of qualimetry prediction is instrumental here. Qualimetry forecasting of product quality indices rooted in consumer preferences is an emergent paradigm **[50]**, **[29]**. Encompassed within are the product quality attribute tree, holistic qualimetric evaluation, qualimetric scaling, expert qualimetry, and prognostic qualimetry **[51]**. The qualimetry blueprint for product quality prognostication aids in delineating the array of product quality and safety markers aligned with consumer expectations. It ensures the harmonization of organoleptic attributes of nascent products with consumer tastes right from the conception phase **[29]**. Essentially, qualimetry prediction equips us to steer product and service quality, meeting imminent demands and ensuring robust market competitiveness **[52]**. By leveraging the qualimetry modus operandi, we have enhanced the efficiency and adaptability of our quality management system, both for pioneering and established products **[51]**.

To gauge consumer predilections for minced semi-finished items, we orchestrated a questionnaire survey from November 2018 to May 2019, engaging 312 residents of Samey, consisting of 152 male and 160 female participants spanning varied age brackets and professions.

The qualitative benchmarks for these semi-finished products were ascertained based on organoleptic factors such as appearance, aroma, hue, form, and sectional view. Our selection algorithm utilized information detailing the interrelations among pairs of objects, emphasizing the existence of stringent preference dynamics between them. For this purpose, we introduced a relational variable.

This novel approach grants us the capability to embed performance metrics into the holistic assessment of our target products. The relational matrix, illustrating the alternative solutions based on the organoleptic attributes of minced horsemeat products containing BO, is presented herewith (7):

$$a_{ij} = \begin{cases} 1, if\ i\ variant\ equivalent\ to\ j \\ 3, if\ i\ variant\ \ exceeds\ moderately\ to\ j \\ 5, if\ i\ variant\ \ greatly\ exceeds\ to\ j \end{cases} \tag{7}$$

A square matrix ||a|| of the relationships in the decision alternatives (8) was constructed from the obtained data:

$$a_{ji} = \frac{1}{a_{ij}}, a_{ii} = 1, i, j = \overline{1, n} \tag{8}$$

Using the ||a|| matrix, the priority vector was calculated (9). We calculated the sum of the columns.

$$\mathrm{Xj} = \sum_{i=1}^{n} a(ij),\ \mathrm{j} = 1,\ldots,\mathrm{n} \tag{9}$$

of the matrix ||a|| in the form of a vector-string {2.283; 7.500; 9.000; 6.600; 8.866} and divided each column element by this sum. As a result, a new matrix of ||a *|| values were obtained, which allows to estimate the importance of each individual indicator in the overall assessment of product perception (9).

View – 1, Smell – 4, Taste – 2, Consistency – 3, View on the cut – 5.

Finding the average value of each i-j string allowed us to obtain a vector-column of priorities {0.442; 0.151; 0.109; 0.150; 0.147}.

Within the distribution of priorities between the indicators of organoleptic evaluation appearance – 44.2%, then smell follows – 15.1%, then the view on the cut – 14.7%, consistency – 15.0%, taste – 10.9% is characterized by the greatest weight coefficient.

In the formulation of chopped semi-finished product technologies, it's vital to integrate consumers' perspectives. These insights underpin the construction of a qualimetry model, ensuring product quality with optimal organoleptic attributes. The merit of mathematical methodologies in processing expert evaluations of food product quality is that they yield objective outcomes. This assertion finds resonance in our findings and is further corroborated by Bezerra et al. **[53]**, who presented evidence that chicken combs are a promising source of animal protein. Furthermore, aspartic and glutamic acids, stemming from chicken comb hydrolyzation, possess chelate properties with antioxidative effects, thus influencing the flavor and texture of the end product. Studies by Zinina et al. **[6]** and Srisantisaeng et al. **[54]** align with our data, attesting that incorporating chicken combs into meat products augments the quality attributes, given the pronounced proteolytic characteristics of chicken comb hydrolysates.

Identification of Critical Control Points in Chopped Semi-finished Product Technology

From the vantage point of the content and utilization of biologically active components in meat substrates, the processing of secondary poultry products – namely chicken legs and combs – proves intriguing **[48]**, **[55]**, **[56]**. A paramount directive in pioneering a new meat product is the assurance of utmost wholesomeness and unwavering safety standards. The product's safety hinges on the presence or absence of pathogenic and non-pathogenic microbes, toxins they might produce, chemical contaminants such as heavy metal salts, disinfectants, pesticides, antibiotics, hormones, antiparasitic agents, and radionuclides, as well as mechanical pollutants like metal fragments, bone shards, or glass **[37]**, **[38]**, **[39]**, **[40]**.

Quality, in the context of a product, is an ensemble of attributes determining its aptness to fulfill specific needs. Chiefly, meat and its derivatives' quality is gauged by: constituents utilized by our physiology for biological synthesis and energy requisites; organoleptic facets like appearance, hue, texture, and aroma; and the absence of noxious substances and harmful microbes. Equally pivotal is the stability of these properties and the retention of their quality markers throughout storage and transit **[4]**, **[50]**, **[57]**, **[58]**.

The quality metrics of meat and its products are influenced by the nature and properties of raw materials, applied recipes, technological processing conditions, and storage dynamics. A holistic and objective assessment of these interdependencies forms the bedrock for discerning factors that sway product quality and safety. Ensuring superior quality necessitates meticulous raw material selection, rigorous adherence to production, storage protocols, and sanitation standards.

All produced items undergo scrutiny to ascertain alignment with quality standards, be it the TC regulations of national and transnational standards or technical specifications (TS) for emerging semi-finished products **[4]**, **[59]**. Figure 1 elucidates a block diagram delineating the production pathway for semi-finished meat items, pinpointing the critical control junctures for the fabrication of such products.

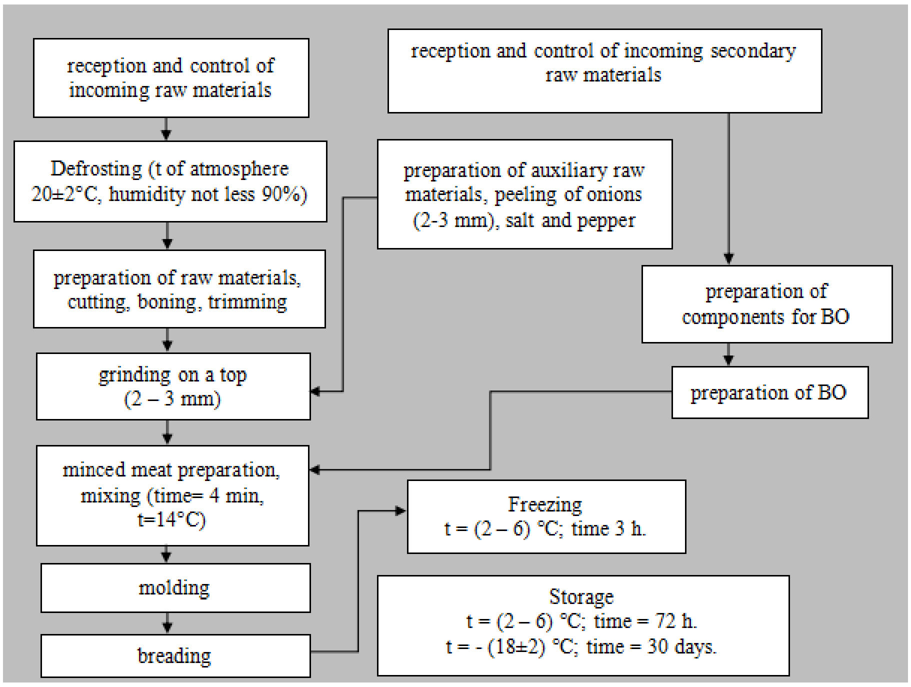

Figure 1 Block diagram of meat semi-finished product production.

The deployment of detection algorithms emerges as a sound approach to manage and effectively oversee facets including the acceptance and preliminary scrutiny of meat and supplementary raw materials, freezing protocols, and periodic evaluations, all integral to preserving quality and safety.

Our challenge was centered around engineering a technology for chopped semi-finished products via protein augmentation. This entailed validating the adoption of secondary food resources (namely, chicken combs) for protein enhancement, which would offer superior food and biological value metrics, and orchestrating a strategy for managing pivotal control junctures throughout the fabrication of a novel meat item **[60]**. The realm of semi-finished meat product manufacturing constitutes a substantial, niche industry, poised for promising expansion given the contemporary societal dynamics and burgeoning consumption patterns **[61]**. The refinement of emerging methodologies amplifies the operational efficacy of meat enterprises. Bazhenova **[5]** underscores that the integration of hydrolysates can bolster the product's digestibility by 2.0 to 2.5-fold, compared to solely harnessing the foundational raw material. Insights from Smith **[9]**, as well as from Zhumanova and Rebezov **[62]**, have unearthed promising results from their endeavors to produce hydrolysates derived from the heads and limbs of terrestrial birds. Accelerating the momentum of scientific exploration in the domain of multifaceted meat products is buoyed by the following elements: a deficit in local meat resources, a significant influx of sub-par imported meat, and its ever-escalating price point.

The surging consumer appetite for processed meat commodities spurs producers to amplify production capacities and diversify their product portfolios. A myriad of nutritional studies have accentuated the pressing imperative to birth functional foods, replete with vital micronutrients. Presently, meticulously crafted recipes and methodologies have been established, permitting the confluence of meat semi-products under varied thermal regimes, leveraging both animal and vegetal raw materials. The fusion of both animal and plant-derived proteins in semi-finished products not only diversifies the product spectrum but also champions the judicious exploitation of raw material assets, satiating the populace with quality nourishments, optimizing both nutrition and practicality. The trajectory of meat and its derivatives production and consumption is on an upward curve. Projections posit that the meat market will burgeon at an annual clip of 10% over the impending triennial period. The chilled meat product segment is witnessing the most brisk expansion, roping in not just meat processors but also retail entities. This momentum owes to the irreplaceable nutritional essence of meat. However, one must remain cognizant that meat, apart from potentially being substandard, can also manifest as a vector for foodborne illnesses. For instance, muscles from debilitated or fatigued animals exhibit depleted glycogen levels and diminished enzymatic activity, culminating in compromised meat quality. Additionally, a surge in muscle acid content and heightened levels of protein hydrolysis products foster environments conducive for pathogenic microflora proliferation, truncating shelf-life. Muscle tissue from critically unwell animals is notably more taxing to digest and less palatable for human consumption compared to that from hale specimens. It is also acknowledged that refrigerated semi-finished items possess a rather constrained shelf-life, and any dereliction in adherence to storage protocols adversely affects product quality. It's imperative to note that semi-finished meat items are designed for subsequent culinary applications.

Research on the Chemical Composition and Safety Metrics of Chicken Combs as a Protein Augmentation Raw Material

Analyzing from the perspective of biologically active constituent content in raw meat, secondary poultry products emerge as a domain of intrigue **[55]**. Their chemical makeup boasts a rich ensemble of proteins, polyunsaturated fats, enzymes, vitamins, carbohydrates, and mineral salts, making them apt for not just conventional meat products but also specialized items **[48]**.

The outcomes of our investigative pursuits suggest that chicken combs, a relatively untapped meat industry by-product for culinary applications, hold potential **[63]**, **[64]**. These combs are repositories of connective tissue proteins, notably collagen, which exhibits commendable biological and functional attributes such as superior water-retention and texture-forming capacities. Moreover, their mineral content renders them versatile across various culinary paradigms.

To validate the feasibility of employing chicken combs in the formulation of horse-meat culinary items, a comprehensive gamut of evaluations was undertaken: safety metrics of raw materials were ascertained, overarching chemical compositions were delineated, and mineral content was gauged (Table 1).

The raw material (chicken combs) was tested for radiological safety. The total specific activity of β- emitting nuclides and the content of cesium-137 (Cs-137) isotopes were determined. Cs-137 content has been calculated by the following formula (10):

$$\mathrm{A}_{\mathrm{Cs}-137} = \frac{n_0}{\text{Х.В.}} \frac{k_{\text{св}} k_{оз}}{pm} 1000 \quad (10)$$

Where:

n is the preparation count without background, imp./min; k_{CB} is the coefficient of communication set by the standard reference; k_{o3} is the ashing coefficient of the sample; *m* is an ash sample taken for analysis, g; *C.E.* is a chemical yield of the carrier; *P* is a correction for self-absorption in the sample.

Table 1 Content of mineral elements in chicken combs.

Mineral substances	Content, mg/kg
Macro elements	
Magnesium	46.8
Potassium	393.7
Calcium	102.3
Sodium	2500.9
Microelements	
Iron	46.3
Copper	0.39
Zinc	1.90
Chrome	5.60
Manganese	0.19
Nickel	<0.1
Cobalt	<0.1
Macro elements	
Magnesium	46.8
Potassium	393.7
Calcium	102.3
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Microelements	
Iron	46.3
Copper	0.39
Zinc	1.90
Chrome	5.60
Manganese	0.19
Nickel	<0.1
Cobalt	<0.1

Note: Based on the test report.

Table 2 demonstrates the results of the experimental checking combs. We have found that the total specific activity of β-emitting radionuclides in chicken combs is within permissible norms (Table 2) which allows using the raw material in the production of protein enrichment.

Table 2 Content of toxic elements in chicken combs.

Name of indicators, units of measurement	Normative documents	Norms according the normative document	Actually received
Toxic elements, mg/kg (not more)			
Lead	GOST 30178-98	0.5	0.077
Arsenic	GOST 31266-2004	0.1	0.022
Cadmium	GOST 30178-96	0.05	not detected
Mercury	MUK 4.1.1472-03	0.03	not detected
Antibiotics, mg/kg,			
Levomycetin	STRK ISO 13493-07	not allowed	not detected
Tetracycline group	STRK 1505-2006	not allowed	not detected
Pesticides mg/kg, (not more)			
Hexachlorocyclohexane, (α, β,γ-isomer)	MI 2142-80	0.1	not detected
DDT and its metabolites	MI 2142-80	0.1	not detected
Radionuclides, Bq/kg (not more)			
Cesium-137	GOST 32161-2013	200	7.9
Strontium-90	GOST 32163-2013	-	6.7

Table 2 Cont.

Name of indicators, units of measurement	Normative documents	Norms according the normative document	Actually received
Toxic compounds, mg/kg (not more)			
Lead	GOST 30178-98	0.5	0.077
Arsenic	GOST 31266-2004	0.1	0.022
Cadmium	GOST 30178-96	0.05	not detected
Mercury	MUK 4.1.1472-03	0.03	not detected
Antibiotics, mg/kg (not more)			
Levomycetin	STRK ISO 13493-07	not allowed	not detected
Tetracycline group	STRK 1505-2006	not allowed	not detected
Pesticides mg/kg (not more)			
Hexachlorocyclohexane (α, β,γ - isomer)	MI 2142-80	0.1	not detected
DDT and its metabolites	MI 2142-80	0.1	not detected
Radionuclides, Bq/kg (not more)			
Cesium-137	GOST 32161-2013	200	7.9
Strontium-90	GOST 32163-2013	-	6.7

Note: Based on the test report.

Microbial purity is an essential safety indicator and critical checkpoint in food manufacturing. So, raw materials were studied by the microbiological analysis for the content of QMAFAnM, CFU/g, and ECGB, and fungal contamination. The checking has been conducted for the 0.0001 g of product in CFU/g (Table 3).

Table 3 Microbiological parameters of chicken combs.

Name of indicators, units of measurement	Norm according to the ND	Actual results
Microbiological indicators:		
- QMAFAnM, CFU/ g, not more	5×10^6	1×10^6
- ECGB in 0,0001 g of a product	not allowed	not detected
- mold, CFU/ g, not more	500	3

Note: Based on the test report.

In analyzing of the presented in the Table 3 data, it can concluded that the raw materials under investigation comply with the requirements of TR/CU 034/2013 regarding microbiological safety indicators. At the next step, comb‘s physical and chemical parameters were tested (Table 4).

Table 4 Chicken combs physical and chemical indicators studied in the experiment.

Indicators	Content
Protein, %	10.20
Moisture, %	87.65
Fat,%	1.25
Ash, %	0.90
pH	6.4
Water-holding capacity, % to total moisture	70.28

Note: Based on the test report.

From the data presented in Table 4, it is evident that the combs retain a substantial moisture quotient, with over 70% existing in a bound state, and exhibit a nearly neutral pH of 6.4. Further, an examination of the mineral constituents of the raw material under our research purview (as depicted in Table 1) revealed an appreciable concentration of both Cr and Zn. Chromium plays a pivotal role in modulating carbohydrate metabolism and blood glucose levels. A dearth of Cr in the organism might manifest as heightened fatigue and pronounced anxiety **[58]**. Zinc's biological significance is underscored by its salutary impact on the endocrine, immune, and nervous systems. Intriguingly, an adequate Zn content in products can mitigate the levels of toxic elements and heavy metals by as much as 30% **[64]**.

Thus, having meticulously appraised the raw materials in terms of their physicochemical attributes and safety benchmarks, it can be posited that seemingly undervalued secondary raw materials, like chicken combs – distinguished by their elevated biological merit and ecological benignity – can be seamlessly integrated into the realm of protein augmentation, serving as additives in the fabrication of minced meat and paste-based offerings.

CONCLUSION

An exhaustive perusal of existing literature underscores the latent potential of collagen-rich resources in both the meat and pharmaceutical sectors. In the quest to evolve the methodologies of chopped semi-finished product production, it becomes paramount to resonate with consumer sentiments. These insights then become the bedrock upon which a qualimetry model is architected, striving for optimal consumer-centric organoleptic attributes. Such a qualimetry paradigm for a nascent product is holistic; it's not merely an exercise in crafting quality and safety benchmarks, but rather a composite ensemble of quantitative stratagems aimed at gauging quality. This ensures alignment with anticipated consumer aspirations, alongside formulating recommendations to perpetuate this envisioned quality. Resorting to mathematical nuances while interpreting expert critiques on the consumer quality of edibles yields an unbiased, definitive outcome. The hierarchy of priorities, in terms of organoleptic appraisal, unfolds as follows: appearance assumes paramount significance at 44.2%, succeeded by aroma at 15.1%, visual appeal upon slicing at 14.7%, texture at 15.0%, and flavor at 10.9%. Concomitant with our investigative revelations, combs were found to harbor an abundant moisture content, with the majority (over 70%) being bound. The pH profile of this entity hovered close to neutrality, registering a value of 6.4. A detailed mineralogical exploration spotlighted the pronounced presence of both Cr and Zn. It is imperative to accentuate that despite their perceived modest value, chicken combs – when gauged on physicochemical and safety metrics — emerged as repositories of profound biological value and environmental congruence. Consequently, they stand poised to be harnessed in protein enhancement ventures, especially as fortifying agents in minced meat and pasty concoctions.

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