DOI: 10.55505/SA.2024.2.10
UDC: 636.5; 637.56

POULTRY COMB-BASED FOOD PRODUCTS: APPROACHES TO SHELF-LIFE PREDICTION AND QUALITY ASSESSMENT

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Abstract. Poultry combs are considered as a valuable raw material for the production of various food products. A flowchart outlining the industrial manufacturing process for these products is developed and substantiated. The study details the physical and chemical properties of poultry combs, and the results are presented. To evaluate the alimentary value of the product developed, a comprehensive analysis of the chemical traits was fulfilled. The findings conclude that ready-to-eat products made from poultry combs are nutritious, technologically feasible, and accessible to a wide range of consumers. The chemical composition of thermally treated poultry combs, particularly the high protein content, contributes to the limited shelf life. This implies the need for scientifically-based predictions of safe storage periods, which can be achieved through practical research (which is time and labor-intensive but reliable) or sophisticated mathematical modeling (which is easier to implement but may be less reliable). This scientific paper substantiates the application of factorial testing methods to predict the shelf life of perishable meat products.

Keywords: *Poultry, Processing, Meat products, Broiler chickens, Poultry combs, Shelf life, Mathematical modeling.*

INTRODUCTION

Food security, as an integral component of national security, must be ensured through comprehensive measures, including resource-saving strategies applied throughout the entire agri-food chain, from field to fork. Also, the agri-food sector requires substantial energy input and generates significant amounts of waste at various stages of production. Sources of waste include food manufacturing processes, surplus products within supply chains, discarded waste, solid municipal waste, and packaging. At present, many recommended systems fall short of effectively integrating agri-food resources into sustainable practices. However, the efficient utilization of these resources is imperative , as one of the primary goals of sustainable development is to ensure food safety. (Grumeza-Clefos, I. 2019; Hessel, C.T. et al., 2019).

In Ukraine, there is a growing trend toward increasing the share of poultry-derived raw materials within the overall material balance of the meat industry. This shift is primarily driven by the higher profitability of rearing and processing poultry compared to traditional slaughter animals. Additionally, the long-term transition to poultry meat remains relevant for various consumer demographics. In high-income regions, customers favor poultry products due to their health benefits and convenience, while in less affluent areas, consumers are drawn to the affordability of poultry products .

The poultry industry, however, generates substantial amounts of waste, including heads, legs, bones, entrails, feathers etc. These by-products are often recycled into livestock feed, fertilizer, or pet food, or discarded entirely. This disposal poses environmental hazards, potential risks to human health, and leads to the loss of valuable biological resources such as proteins, enzymes, and lipids (Lasekan, A. et al., 2013).

The effective utilization of these secondary raw materials presents an opportunity for economic and environmental benefits, underscoring the need for theoretical and practical research to support sustainable practices in the poultry industry. One of the possible directions for using secondary poultry raw materials is the production of therapeutic, prophylactic, and specialized foods that serve as rich sources of nutrients, particularly proteins (Zmiievska, T. et al., 2014).

An actual trend in the industry is the development of ready-to-eat meat products directly at poultry processing facilities. This approach adds significant value, with the surplus value of 1 kg of heat-treated products from poultry meat and by-products estimated to be at least 1 EUR. These products remain cost-effective for consumers while adhering to stringent food safety and quality standards. Additionally, a growing segment of health-conscious consumers seek products made from secondary poultry raw materials as elements of healthy, dietary lifestyle. (Verbytskyi, S., 2011; Patsera, N.M. et al., 2023).

MATERIAL AND METHODS

The study focused on the physical properties and chemical composition of poultry secondary raw materials, including the quantitative content of the main microelements and amino acids. Analyses were conducted using equipment and devices available at the Department of Meat Products Technology and the Department of Analytical Research and Food Quality at the Institute of Food Resources, National Academy of Sciences of Ukraine. Standard research methods, along with industry-accepted protocols and guidelines, were employed to ensure accuracy and reliability . The research object comprised poultry secondary raw materials, specifically combs of hens and roosters, sourced from domestic poultry processing enterprises: Private Enterprise “Ular” (Lviv region) and “Magrok” Ltd. (Dnipro city).

RESULTS AND DISCUSSIONS

According to the research objectives , physico-chemical parameters of hen and rooster combs were analyzed. Sample selection and preparation were carried out in accordance with the applicable regulatory standards and guidelines . The values of the measured parameters are summarized in Table 1.

Table 1. *Physico-chemical parameters of combs from hens and roosters*

Samples	Content, % (by mass)				Bound water to meat, %	Bound water to total water, %	pH
	Protein	Water	Fat	Ash			
Sample № 1 Private Enterprise “Ular” (Lviv region)	12.11±0.09	85.82±0.19	1.24±0.22	0.84±0.24	54.41±0,20	75.22±0.19	6.53±0.25
Sample № 2 “Magrok” Ltd. (Dnipro city)	16.21±0.12	81.95±0.15	1.06±0.11	0.78±0.25	51.03±0.22	71.15±0.21	6.64±0.23

As shown in Table 1, the pH value is close to neutral. The high water content was also characteristic, of which approximately 75% is in a bound state. The fat content was notably low, not exceeding 1.24%. The amino acid composition of the combs of chickens and roosters was also studied (Patsera, N.M., Verbytskyi, S.B., 2023), revealing a significantly higher content of hydroxyproline and proline - 5.0 and 1.1 times greater, respectively, compared to first-category chicken meat . The above data indicates the abundance of connective tissue proteins in combs, making them a distinctive source of such proteins.

Further analysis focused on the mineral and vitamin composition of the combs in comparison to first-category chicken meat (Voitsekhivska, L. et al., 2022). The results demonstrated a markedly higher concentration of key microelements in combs, including iron (15 times more), zinc (2 times more), and chromium (112 times more). Importantly, no limiting amino acids were detected in the chicken combs, further highlighting their nutritional potential.

Poultry combs have long been integrated into traditional cuisines around the world, maintaining stable demand among consumers. For example, Japanese cuisine features grilled chicken combs prepared using the yakitori technique . The combs are characterized by high moisture content – ranging from 85.7% to 87.4%, of which approximately 70% is in a bound state; the amount of fat does not exceed 1.5%; pH value is close to neutral (6.4). Heads are currently processed without separating combs while these destemming and can complement the nomenclature of by-products of the poultry processing industry. To further enhance the utility of this by-product, we have proposed a novel processing technology for hen and rooster combs (Fig. 1). This technology ensures important safety and quality parameters making combs a viable addition to the range of products derived from poultry processing by-products (Patsera, N.M., Verbytskyi, S.B., 2023).

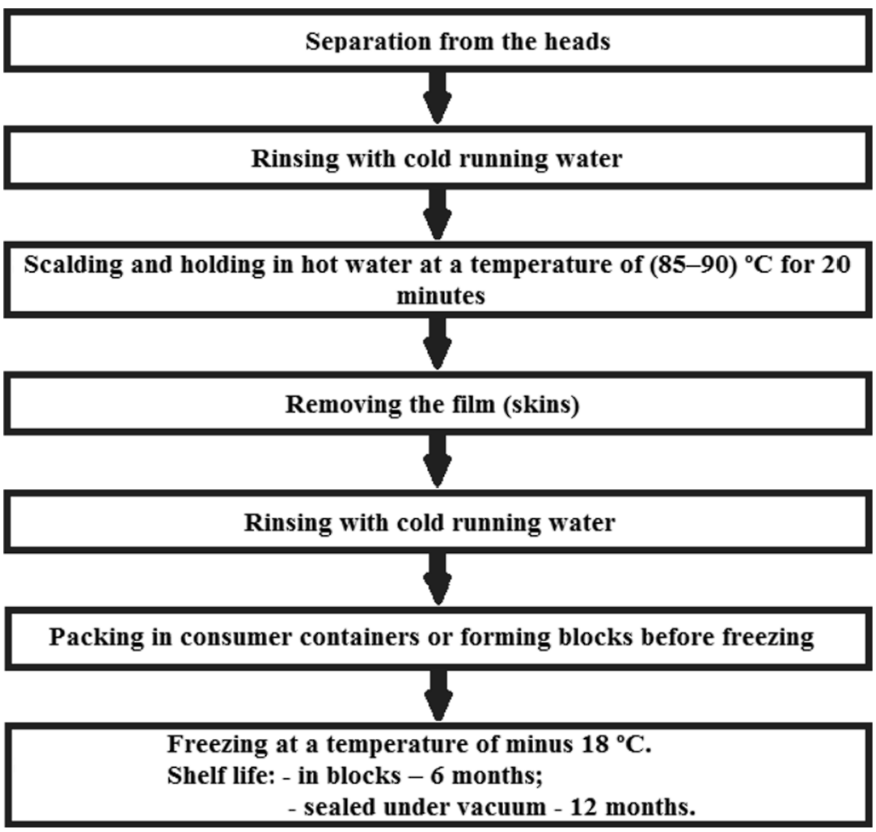

Figure 1. *Processing chart of poultry combs*

(Source: Patsera, N.M., Verbytskyi, S.B., 2023)

Based on literature review and the experimental studies discussed above, it was considered appropriate to develop a heat-treated meat product using whole poultry combs. Since this product falls under the category of fully cooked, ready-to-eat foods, it is important to address storage stability in order to ensure proper food safety and optimize logistics.

Predicting the safe storage duration of ready-to-eat meat products is best achieved through mathematical modeling. This approach helps to determine the timeframe during which the product remains safe and suitable for consumption when stored under conditions prescribed by current standards and regulations (Taormina, P.J., 2021). Mathematical storage predictive models are recognized as integral components of broader food quality management systems (Motuzka Yu.M. et al., 2018). According to Koval, O.A., and Guts, V.S. (2008), the food spoilage model should include mutually dependent indicators y(t), which alternate dynamically and affect the product's shelf life, and also independent factors, such as environmental and storage conditions, determining directly the product's durability and suitability for consumption :

$$-m_i \frac{d^2}{dt^2} y(t) + a_i \frac{d}{dt} y(t) + T_i \frac{d}{dt} y(t) + k_i y(t) = 0 \tag{1}$$

where

- m_i is the reduced mass of the i-th indicator or group of homogeneous indicators; ai is an exponential coefficient reflecting the accumulation of harmful substances, microbial growth, changes in rheological traits, and other homogeneous indicators; T_i is a factor coefficient considering shelf life variations based on the dynamics of the impurities; k_i is the reduced kinetic constant that refines the modelto enhance its predictive accuracy.

Considering that food products are highly prone to spoilage due to a limited number of factors acting with significant speed, the spoilage rate of a food product can be expressed using the following formula:

$$-m_i \frac{d^2}{dt^2} y(t) + a_i \frac{d}{dt} y(t) = 0 \tag{2}$$

Being differentiated the formula can be written as:

$$\frac{d}{dt} y(t) = V_{oy} e^{\frac{a_i t}{m_i}} \tag{3}$$

Although the method described above is effective in addressing local problems related to determining the quality and storage capacity of food products (e.g.,Guts, V.S. et al., 2020), determining the coefficients in formula (3) is often practical. A more feasible approach is outlined in the work of Bocharova-Leskina, A., and Verbytskyi, S. (2019), where the relative proportion of a food product's shelf life and its influencing factors is assessed through a full factorial two-level experimental design, which includes N = 2^n experiments. The ongoing experiments involve the available sets of levels of n factors, which determine the response of the function with Y value and y_1, y_2, y_3, ... values. The value Y provides the duration (in days) during which the influencing factors remain below threshold levels, ensuring the product's acceptability for consumption. The studies conducted have demonstrated that the acceptability of cooked meats is influenced by four primary factors. Therefore, we consider that the regression analysis, assuming the distribution of the modeled value follows a normal distribution (e.g., with a probability of 95%), is applicable. In this context, the probable safe storage period of these foods can be determined using the regression equation, namely an incomplete polynomial of the fourth degree:

$$y=b_0+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_{12}X_1X_2+b_{13}X_1X_3+b_{14}X_1X_4+$$
$$+b_{23}X_2X_3+b_{24}X_2X_4+b_{34}X_3X_4+b_{123}X_1X_2X_3+b_{124}X_1X_2X_4+ \quad (4)$$
$$b_{134}X_1X_3X_4+b_{234}X_2X_3X_4+b_{1234}X_1X_2X_3X_4$$

This approach allows to determine the safe storage periods when the factors take real values. To achieve this, the coded factors are converted according to equation (4). By assigning appropriate numerical values to the variables x_1, x_2, x_3, x_4 in the regression equation, based on experimental data matrix, we can obtain an interpolation formula, which can be used to predict the safe shelf life of a food product, taking into account the initial conditions applied.

The approach substantiated above is applicable for predicting the safe storage periods of perishable meat products. For this purpose, the factors X_1 ... X_4 are identified as the most significant ones for ensuring the safety and quality of cooked poultry combs. The factors necessary to determine the probable shelf life are given hereafter:

X_1 characterizes the complex concept of microbial contamination;

X_2 characterizes sensory issues, including taste, smell, and texture ;

X_3 characterizes physical properties and chemical composition of the product;

X_4 characterizes the oxidative spoilage, which leads to the degradation of fats and other compounds.

Research is essential to identify the appropriate indicators for cooked poultry combs and to develop corresponding interpolation formulas for predicting the safe shelf life of these products. Objectively predictable safe storage periods of ready-to-consume meats with short shelf lives are important for planning manufacturing and logistics procedures (Amorim, P. et al., 2011). However, ensuring the overall food safety of the manufactured products still remains the top priority.

CONCLUSIONS

Poultry processing routines inevitably generate large amounts of waste, a number of those still being valuable secondary raw materials that can be utilized for various beneficial products, including food items. The results of the literature review and conducted research demonstrate the potential of using poultry combs, a by-product of slaughter, as a raw material for creating delicacies and specialty foods with unique taste profiles and high nutritional and biological value.

It can be concluded that the ready-to-eat products made from poultry combs represent a e valuable source of nutritious meat, which is technologically feasible to produce and accessible to a wide range of consumers. As these products are perishable, there is a clear need for scientifically-based predictions of safe storage periods. This can be achieved through practical experiments as well as applying full factorial experiments or other acceptable mathematical modeling techniques.

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Conflict of Interests

The authors declare that they have no conflict of interest.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Paper history

Received 21.09.2024; Accepted 05.12.2024