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A. O. Helikh, Ph.D., Associate Professor

Pang Yongfeng, Ph.D. student

*Sumy National Agrarian University*e-mail: [anna.helikh@snau.edu.ua](mailto:anna.helikh@snau.edu.ua)

ORCID: 0000-0003-3769-1231

ORCID: 0009-0003-6573-139X

## INNOVATIVE TECHNOLOGY FOR DOUGH SHELLS IN MINCED SEMI-FINISHED PRODUCTS BASED ON THE SYNERGY OF GLUTEN-FREE RAW MATERIALS AND MICROALGAE PROTEIN ISOLATE FOR MILITARY AND HEALTHY DIET

*Summary.* This research presents a comprehensive theoretical and experimental framework for advancing the technology of dough shells used in dual-use minced semi-finished products, specifically tailored for military rations and crisis-resilient nutrition. We have scientifically validated the integration of a protein isolate derived from the microalga *Euglena gracilis* alongside a selection of gluten-free plant materials, including rice, white lupin, flaxseed flour, and corn starch. This strategic formulation is designed to enhance both the nutrient density and biological value of the final product. Furthermore, it addresses a critical gap in specialized nutrition by catering to individuals suffering from gluten intolerance or stress-induced exacerbations of celiac disease.

In evaluating the functional, technological, and rheological performance of these model dough systems, our findings highlight a significant synergy between white lupin flour and the microalgae isolate. This interaction provides the structural and mechanical resilience necessary to maintain the integrity of the dough shells under the rigors of extreme logistics, deep freezing, and field-based thermal processing. By identifying the optimal balance between protein fortifiers and structure-forming agents, we have established a robust production technology for high-energy, special-purpose dough shells. Comprehensive assessments of organoleptic, physicochemical, and safety parameters further confirm that this technology offers an effective solution for ensuring sustainable nutrition and food security in demanding environments.

*Keywords:* alternative proteins, microalgae protein isolate, *Euglena gracilis*, flour-based dough shells, military nutrition, crisis-resilient nutrition, gluten-free diet, white lupin flour.

*Problem Statement.* In the current landscape of societal development, particularly under the pressures of martial law and ongoing crisis, there is an urgent demand for advanced, science-driven solutions in specialized food production. The primary objective is to develop sustainable military rations that integrate high nutrient density and ease of consumption with the resilience required for extreme logistical environments. While minced meat semi-finished products are essential to these rations, a significant technological hurdle remains: ensuring the structural and mechanical durability of their dough shells during freezing, transit, and thermal preparation in field conditions.

At the same time, the challenge of food intolerances has become increasingly critical. Intense and chronic stress can lead to the exacerbation of gastrointestinal conditions among both military personnel and civilians. Current statistics indicate that celiac disease affects approximately 1 in 200 people in Ukraine, with a notable upward trend in recent years. For these individuals, a strict gluten-free diet is the only effective means of restoring physical function and maintaining quality of life. Consequently, the development of gluten-free rations has evolved beyond a mere medical requirement into a vital element of food security and the operational readiness of personnel with specific dietary needs.

However, many commercial gluten-free products currently fall short, often characterized by low levels of complete proteins and vitamins, poor organoleptic quality, and excessive brittleness. While research suggests that raw materials such as rice, sorghum, and flaxseed flours, along with corn starch,



offer promising functional and nutritional benefits, their effective application remains a challenge. In Ukraine, although the production of such specialized foods is strictly governed by safety and quality regulations, market analysis reveals frequent non-compliance, including low protein content, short shelf lives, and high costs.

To meet the rigorous standards of military nutrition, dough formulations must be fortified with high-quality proteins to support rapid physical recovery. A transformative solution lies in the use of protein isolate from the microalga *Euglena gracilis*. Integrating this isolate into gluten-free dough not only elevates the product's biological value through essential amino acids and immunomodulating  $\beta$ -glucans but also creates a synergy with flaxseed flour that enhances elasticity and plasticity. This ensures the stability and balance of the final product. Given the vital need for balanced, specialized nutrition, refining the technology for gluten-free dough shells using plant-based materials and microalga isolates stands as a critical task for modern food science.

*Analysis of Recent Research.* The design of military rations and the maintenance of food security during crises require the development of specialized products that offer both high nutrient density and an extended shelf life [1]. Under the constant stress of martial law, the prevalence of gastrointestinal disorders among both soldiers and civilians has become an acute concern [2]. Current statistics show that celiac disease affects approximately 1 in 200 people in Ukraine, with a clear upward trend in recent years. To date, the only viable and accessible method to stabilize a patient's condition and normalize digestive function is the lifelong adherence to a specialized diet centered on gluten-free cereals and flours [3].

Extensive research by both domestic and international scholars has evaluated the potential of various plant-based raw materials for these purposes. Literature reviews consistently identify rice flour, sorghum, amaranth, flaxseed flour, and corn starch as the most effective components for specialized food production [4]. Studies on model dough systems involving white lupin flour have garnered particular interest. For instance, it has been observed that the monolithic particles in amaranth-where starch is tightly bound to protein-contribute essential elasticity to the dough. Furthermore, research suggests that a 1:1 ratio of rice flour to starch optimizes moisture levels and soaking properties while enhancing the product's overall sensory appeal [5]. Similarly, the inclusion of flaxseed flour has been shown to improve viscosity and elastic properties, while the chemical profile of sorghum continues to be a major focus of scholarly investigation [6].

Despite these advancements, perfecting the quality of gluten-free products remains a global challenge for the food industry [7]. Achieving superior physicochemical and organoleptic standards is a complex undertaking. A specific technical hurdle is the creation of a durable dough shell capable of surviving extreme logistics; such a shell must resist cracking during both low-temperature storage and the rigors of boiling [8].

To address protein deficiencies and provide the necessary structural integrity, the use of microalgae proteins has emerged as a groundbreaking innovation. Current research demonstrates that integrating an isolate from *Euglena gracilis* significantly enhances the microstructure of gluten-free dough [9]. The unique protein profile of *Euglena*, combined with its storage polysaccharide, paramylon ( $\beta$ -1,3-glucan), functions as a high-performance hydrocolloid [10]. This synergy provides the system with exceptional water-holding capacity, stabilizes the starch matrix of rice and corn, and results in a highly elastic dough shell [11]. Additionally, the presence of  $\beta$ -glucans introduces vital immunomodulatory properties—a key requirement for functional military nutrition [12].

Today, improving gluten-free technology has moved beyond simple dietetics; it is now a matter of strategic importance for food security and military readiness [13]. Creating a durable gluten-free matrix that remains stable through freezing and field processing is a formidable task [14]. Therefore, advancing the technology of dough shells for crisis-resilient semi-finished products—through the



innovative combination of plant materials and microalgae protein isolates-is both a timely and essential mission [15].

*Formulation of the Article's Aim.* The aim of this study is to improve the technology of dough shells for minced semi-finished products designed for military rations and use in crisis situations.

*Main part.* Since the chemical composition of GFRM directly affects the functional, technological, and rheological properties of dispersed systems, and consequently, the structural and mechanical strength of dough shells under extreme logistical conditions, the next stage involved a study of their chemical composition. Additionally, an innovative functional protein additive-protein isolate from the microalga *Euglena gracilis*-was introduced to the GFRM complex. The research results are presented in Table 1.

Table 1

Chemical composition of GFRM and *Euglena gracilis* microalgae protein isolate ( $\alpha = 0,05$ )

Name	Moisture, %	Protein, %	Carbohydrates, %	Fat, %	Ash, %
Rice flour	10.6	7.9	78.6	2.5	0.4
White lupin flour	8.5	38.5	16.0	9.5	3.5
Flaxseed flour	6.0	33.8	36.5	18.9	4.8
Amaranth flour	6.9	8.6	75.3	6.4	2.8
Corn starch	11.3	1.0	87.3	0.1	0.3
<i>Euglena gracilis</i> isolate	5.2	68.5	15.3	6.5	4.5

The analytical data reveal that flaxseed and white lupin flours are distinguished by an elevated protein content, a factor that directly drives their superior structure-forming capabilities. When integrated with the *Euglena gracilis* microalgae protein isolate-which boasts a remarkable purity of 98.5 % protein-these raw materials act in synergy to establish a robust protein framework. This structural network effectively compensates for the absence of gluten while ensuring the high nutrient density essential for military nutrition. However, it is noteworthy that the increased fat content in these specific flours may pose limitations for large-scale applications where long-term storage is a primary concern.

In contrast, rice flour, amaranth, and corn starch contribute a high concentration of starch polysaccharides. Their ability to gelatinize even at lower temperatures provides the model dough systems with necessary rheological flexibility, balances the caloric profile, and enriches the product with highly digestible carbohydrates.

The dynamics of biochemical transformations occurring during the kneading process are closely correlated with the functional and technological properties of the raw materials. Specifically, indicators such as Fat-Binding Capacity (FBC), Water-Absorption Capacity (WAC), Water-Holding Capacity (WHC), and Fat-Holding Capacity (FHC) serve as the scientific basis for optimizing kneading parameters. To ensure consistency, all experimental studies were conducted at a controlled temperature of  $23 \pm 2$  °C.

Experimental data reveal that among the plant-based raw materials studied, flaxseed flour exhibits superior Water-Holding Capacity (WHC), Fat-Holding Capacity (FHC), and Water-Absorption Capacity (WAC). Notably, the maximum Fat-Binding Capacity (FBC) of 122 % was recorded in white lupin flour. The introduction of microalgae protein isolate significantly amplifies the system's water-absorption properties, with WAC reaching a peak of 310 %. These findings are fundamentally linked to the ratio of key biopolymers and the fractional composition of the proteins. Specifically, the high concentration of water-soluble proteins-with albumins reaching up to 44 % and 57 %-combined with hydrophilic non-starch polysaccharides in flaxseed, amaranth, and white lupin flours, drives these maximum WAC and swelling values. In contrast, the prevalence of starch polysaccharides and



Table 2

Functional and technological properties of GFRM and *Euglena gracilis* microalgae protein isolate ( $\alpha = 0,05$ )

Name	WHC, %	FBC, %	FHC, %	WAC, %
Wheat flour (control)	89.3	109.0	91.4	109.0
Rice flour	93.5	107.6	82.2	146.0
Amaranth flour	89.9	108.7	91.3	182.0
White lupin flour	115.1	122.0	95.4	188.0
Flaxseed flour	124.3	115.0	110.3	289.0
Corn starch	77.3	102.0	80.1	103.6
<i>Euglena gracilis</i> protein isolate	135.0	110.0	105.0	310.0

alcohol-soluble protein fractions (glutenins) in rice flour, along with the hydrophobic amino acid profile found in wheat flour, results in comparatively lower WAC and FBC values [12].

These results underscore the strategic importance of incorporating rice, amaranth, and white lupin flours into gluten-free formulations. This selection is further validated by our analysis of chemical composition and structural-mechanical performance. The prospect of combining white lupin flour with microalgae protein isolate is particularly promising, as it substantially enhances the mixture's functional properties. This synergy is driven by high WHC, FHC, and WAC, alongside the presence of lipids,  $\beta$ -glucans, and pentosans [15]. Together, these components exert a crucial cryoprotective effect, increasing dough plasticity and preventing structural failure during processing or storage.

Special consideration must be given to how the *Euglena gracilis* isolate influences the organoleptic profile of the dough shells. Due to the natural pigment composition of the microalgae, including residual chlorophyll and carotenoids, the isolate imparts a distinct light greenish tint to the dough. Within the context of military-grade rations, this color shift is viewed as a positive attribute. It functions as a natural visual marker of high nutrient density—a «military-style» aesthetic—that allows for easy product identification without the need for synthetic dyes. Finally, to ensure full compliance with «Food Safety» regulations, the developed dough shells were tested against rigorous standards for toxic elements and radionuclides, with the results detailed in Table 3.

Table 3

Hygienic requirements and safety indicators of dough shells

Substance (Element)	Maximum Permissible Level, mg/kg (for radionuclides – Bq/kg)	Test Results
Toxic elements: Lead	0.5	Not detected
Arsenic	0.1	Not detected
Cadmium	0.05	Not detected
Mercury	0.03	Not detected
Radionuclides: Cesium-137	200	Not detected

The safety analysis confirms that the developed dough shells are entirely free from toxic elements or radionuclides that could pose a risk of food poisoning or toxicosis. These results validate the product's suitability for human consumption, even under the physiological strain of crisis conditions.

Beyond safety, the practical application of this technology is highly promising for military and emergency logistics. Given the rigorous demands of military nutrition and the frequent lack of stable refrigeration (cold chain) in conflict zones, these dough shells are ideally suited for advanced dehydration methods, such as freeze-drying or convective drying. Utilizing these techniques extends the shelf life of the product to between 12 and 24 months, even under unregulated storage temperatures. This exceptional stability ensures that the dough shells fully meet the stringent requirements for special-purpose rations, providing a reliable and nutritious food source where it is needed most.



**Conclusions.** The synthesis of theoretical and experimental research presented in this study offers a viable solution to the pressing challenge of enhancing dough shell technology for dual-use semi-finished products. Our findings lead to the following key conclusions:

Experimentally substantiated the effectiveness of combining a gluten-free flour mix (rice, flaxseed, amaranth, white lupin, and corn starch) with *Euglena gracilis* protein isolate. The research establishes that the synergy between white lupin flour and the high-purity isolate (98.5 % protein) creates a robust protein framework that successfully compensates for the structural absence of gluten.

The integration of flaxseed flour and microalgae isolate remarkably amplifies the system's water-absorption capacity (with the isolate reaching 310 %), as well as its water-holding and fat-holding capacities.

Comprehensive sanitary-chemical and radiological assessments confirm that the developed dough shells fully comply with international food safety standards. No toxic elements or radionuclides were detected, ensuring the product's safety for human consumption.

The application of dehydration technology extends the product's shelf life to 12–24 months under unregulated storage temperatures. This exceptional durability makes it an ideal component for specialized rations in demanding environments.

In summary, the developed dough shells represent a high-quality, structurally stable, and biologically valuable advancement in food technology. This innovation not only contributes to national food security but also significantly expands the range of specialized nutrition available to military personnel and individuals with gluten intolerance.

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**А. Геліх, Пан Юнфень**

Сумський національний аграрний університет

## **ІННОВАЦІЙНА ТЕХНОЛОГІЯ ТІСТОВИХ ОБОЛОНОК ДЛЯ ФАРШЕВИХ НАПІВФАБРИКАТІВ НА ОСНОВІ ПОЄДНАННЯ БЕЗГЛЮТЕНОВОЇ СИРОВИНИ ТА ІЗОЛЯТУ БІЛКА МІКРОВОДОРОСТЕЙ ДЛЯ ВІЙСЬКОВИХ РАЦІОНІВ ТА ХАРЧУВАННЯ У КРИЗОВИХ СИТУАЦІЯХ**

### **Анотація**

Виконані комплексні дослідження, що дозволяють теоретично та експериментально обґрунтувати удосконалення технології тістових оболонок для фаршевих напівфабрикатів подвійного призначення – для раціонів військового харчування та використання у кризових ситуаціях. Науково обґрунтовано доцільність введення ізоляту білка мікродорості Евлени (*Euglena gracilis*) у комплексі з безглютеновою рослинною сировиною (рисовим, білого люпину, лляним борошном та кукурудзяним крохмалем) як фізіологічно-функціональних інгредієнтів. Таке композиційне рішення спрямоване на підвищення нутрієнтної щільності та біологічної цінності продукту, а також задоволення потреб споживачів зі стрес-індукованими загостреннями целіакії та непереносимістю глютену. Досліджено функціонально-технологічні та реологічні властивості модельних тістових систем. Встановлено, що синергія борошна білого люпину та ізоляту мікродоростей забезпечує необхідну структурно-механічну міцність тістових оболонок, що гарантує збереження їх цілісності під час екстремальної логістики, заморожування та термічної обробки в польових умовах. Визначено оптимальне співвідношення білкових збагачувачів та структуроутворюючих компонентів у рецептурі. Розроблено комплексну технологію виробництва високоенергетичних тістових оболонок для фаршевих напівфабрикатів спеціального призначення. Досліджено органолептичні та фізико-хімічні показники, а також основні показники безпеки тістових оболонок, що підтверджують його ефективність для забезпечення продовольчої безпеки та сталого харчування.

**Ключові слова:** альтернативні білки, ізолят білка мікродоростей, *Euglena gracilis*, борошняні тістові оболонки, військове харчування, кризостійке харчування, безглютенова дієта, борошно люпину білого.