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Slovak Journal of Food Sciences

OPEN ACCESS

Received: 21.2.2024
Revised: 30.4.2024
Accepted: 1.6.2024
Published: 10.6.2024

Potravinarstvo Slovak Journal of Food Sciences
vol. 18, 2024, p. 468-479
https://doi.org/10.5219/1967
ISSN: 1337-0960 online
www.potravinarstvo.com

The rheological characteristics of the dough for semi-finished biscuits with the addition of crickets flour

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ABSTRACT

The article proposes to study the influence of new protein-containing raw materials, namely cricket flour (CF) *Acheta domesticus* on the quality of whipped flour semi-finished product (WFP) research methods. The study used generally accepted methods for determining the rheological properties of the dough: the dependence of viscosity on shear stress, temperature, and rate of deformation of the dough, as well as the elasticity of finished products and physicochemical properties of the finished semi-finished product. The mass fraction of moisture was determined by drying to constant weight. The mass fraction of ash not dissolved in 10% hydrochloric acid in absolute dry matter was determined using the dry method in a muffle furnace. The mass fraction of protein was determined by the Kjeldahl method. Alkalinity was determined by the titrometric method. The mass fraction of total sugar was determined by the iodometric method. During the manufacture of WFP, cricket flour was added to 5.0-15.0%. The results of rheological parameters showed that adding CF to the dough in an amount of 15.0% significantly affected the viscosity and plasticity of the dough, which led to a decrease in volume and porosity in the finished semi-finished product. According to physicochemical parameters, it was found that with increased BC concentration, the mass fraction of protein increases (from 4.4% in conventional WFP to 62.06% with the addition of CF in the amount of 10.0%). At the same time, the mass fraction of total sugar decreases. The mass fraction of moisture in the finished semi-finished product also changes. The resiliency and elasticity of the finished products were determined by the laboratory method using the "Labor" penetrometer. According to the results of studies of resiliency and elasticity of the finished product, it was determined that the semi-finished product with the addition of 15.0% cricket flour had the lowest indicators compared to the products with the addition of 5.0% and 10.0% cricket.

Keywords: cricket flour, whipped flour semi-finished product, rheological parameters, physico-chemical parameters, resiliency

INTRODUCTION

One of the most popular directions in producing food products is the enrichment of food products using new raw materials, which is connected with consumers' growing interest in products of increased nutritional value with a high content of nutrients. Fortification of food products is carried out due to several factors, such as increasing the nutritional value of products, correcting nutrient and mineral deficiencies, and improving consumer properties. As a result, products with a high content of vitamins, amino acids, and minerals are gaining more and more popularity **[1]**.

Also, special importance is attached to enriching raw materials with a high protein content among food products. After all, protein deficiency in the adult body leads to a decrease in appetite and body weight, increased fatigue and reduced work capacity, damage to the immune system and an increase in the level of morbidity, a decrease in the activity of enzymes, a violation of the processes of digestion and hematopoiesis, and a negative effect on the liver, cardiovascular, and respiratory systems **[2]**.

In addition, not all raw materials are equally suitable for enrichment. One of the popular products that are subject there is flour confectionery products, namely whipped flour semi-finished products (WFP) because these products are popular among the public but have a high content of carbohydrates and a low content of proteins and biologically active substances. Such foods can be enriched by directly adding innovative ingredients during preparation. Such enrichment will increase the product's nutritional value and influence its rheological, physico-chemical, and sensory properties **[1]**, expanding the range of products of this group.

WFP contains a large amount of carbohydrates, so to improve it, choose products with a high content of protein and biologically active substances, or replace raw materials with a high content of carbohydrates (e.g., sugar or flour) with raw materials with an increased content of functional nutrients.

One of the raw materials that have increased nutritional value and is recognized in the European Union as a product with a high protein content is cricket flour, which is made from the cricket genus of *Acheta domesticus* **[3]**.

In recent years, crickets have attracted the attention of researchers as a source of protein for a growing and increasingly demanding population. Cricket farming is characterized by low environmental costs during cultivation, processing, and use of cricket processing products. The widespread use of crickets in the food industry requires the safe artificial cultivation of various species of crickets, their processing into food products, the labelling and marketing of food products using insect processing products, and consumers' acceptance of this type of food **[4]**.

Most edible insects are collected from the wild and farming them for food is relatively new: breeding crickets is a good example of this new trend.

Insects can be considered a nutritious, healthy basis for obtaining raw materials used in human and animal diets, containing healthy fats, proteins, fiber, vitamins, and minerals such as calcium, iron, and zinc. The nutritional value of insect processing products depends on the insect species, stage of metamorphosis, habitat, feeding habits, and post-harvest processing methods. For example, Chen Xand et al. evaluated the protein content of 100 insect species and found that the protein content ranges from 13% to 77% of the dry matter weight. Insects are often eaten whole but can be processed into powder, pellets, or pastes and added to other foods. In addition, components such as chitin, proteins, and fats can be extracted from insects and used separately as additives in food products **[5]**. In addition, each insect has its taste, which makes it suitable for use in recipes of various foods **[6]**.

Crickets contain a variety of proteins with different molecular weights and solubility. Only ~20% of proteins are soluble in cold water. The rest is a water-insoluble fraction that contains a large amount of muscle proteins **[7]**.

It is known that proteins are biopolymers that consist of amino acid residues connected by peptide bonds. Proteins can perform functions of structure formation, regulation, contraction, or protection. They can serve for transporting, storing, or assembling parts of membranes; they can also be toxins or enzymes. Each cell of a living system can contain thousands of proteins, each performing a unique function. Their structures, as well as their functions, are very different. However, all of them are amino acid polymers located in a linear sequence **[8]**.

Proteins play an important role in the body's normal functioning and are vital for humans **[9]**. The shortage of protein in the human body causes a delay in the growth of tissues, the assimilation of certain substances, and the formation of new cells the growth of tissues, the formation of new cells, and the assimilation of various substances is impossible.

The human body cannot produce protein independently, so it is recommended to consume food of plant and animal origin with a high protein content **[10]**.

Until recently, the public did not perceive eating insects or insect processing products as innovative raw materials that would improve the chemical or nutritional composition of products and dishes. One of the main factors in not accepting insects as food is the need for a legislative and regulatory framework for this type of product. However, in 2022 the European Union issued an Implementing Regulation of the Commission (EU) which allows the use and consumption on the European Union market of frozen, dried, and powdered forms of crickets of the genus *Acheta domesticus* as a novel food product following Regulation (EU) 2015/2283 of the European Parliament and Council and amendments to Commission Executive Regulation (EU) 2017/2470 **[3]**.

Several scientists have investigated the consumer acceptability of products containing raw materials from insects in different countries. They investigated the advantages of using insects and concluded that conventional technological measures, such as masking the content of raw materials from insects in traditional food products, increase consumers' willingness to use such food products **[11]**, **[12]**, **[13]**, **[14]**, **[15]**, **[16]**.

Scientists from the USA **[7]**, Kyrgyzstan, Asia, and Africa are developing technology for obtaining insect flour. In world practice, domestic cricket (*Acheta domesticus*) is usually used to produce insect flour. Crickets are grown on special farms. For example, the Aspire Corporation (USA) grows crickets on large farms. The entire growing process is automated **[17]**. Crickets are raised on vertical farms equipped with sensors and automated systems. With the help of robotic modules, crickets receive a precisely calculated amount of food **[17]**. At the same time, Belgian farmers raised crickets on typical farms north of Brussels. Cowro Valley Farms raises thousands of insects in heated aluminium foil tents with lots of trays and hanging insect cans in California. Insects are fed with alfalfa and beans grown by the enterprise.

Since the cultivation of crickets for further processing and use in food products is becoming increasingly widespread, scientists are increasingly paying attention to designing the composition of products using insect processing products and studying their properties. Cricket flour is used for the production of various food products, including bakery products **[18]**, cookies **[19]**, muffins **[20]**, and pasta **[21]**.

Considering the chemical composition of flour from crickets, it can be used to improve the nutritional value of whipped flour products. After all, in their composition, whipped flour semi-finished products contain a large number of carbohydrates due to the content of a significant amount of sugar in the recipes, which is of technological importance since it gives the finished products high-quality organoleptic and structural properties, and also increases the temperature of pasteurisation of starch grains of flour and denaturation of egg white, while allowing the formed gas bubbles to expand **[22]**, however, makes the products high-calorie with low biological activity.

This work aims to develop a whipped flour semi-finished product with an increased protein content by using cricket flour as an innovative ingredient and studying the rheological properties of the dough and the physicochemical properties of the baked semi-finished product.

According to the set goal, the following tasks were defined:

- investigate the rheological properties of the dough;
- to investigate the resilience and elasticity of the baked biscuit semi-finished product;
- to investigate the physicochemical properties of the ready-to-use flour semi-finished product using cricket flour.

Scientific Hypothesis

Developing a functional product using cricket flour can increase the nutritional and biological value and affect the rheological and physicochemical parameters of the sponge cake and the finished semi-finished product. When cricket flour is added, we expect the physicochemical and rheological indicators to be within the normal range and increase the number of proteins in the sponge cake.

MATERIAL AND METHODOLOGY

Samples

To produce WFP, chicken eggs, sugar, wheat flour, citric acid, and cricket flour were used.

Chemicals

All ingredients (except cricket flour) for preparing the semi-finished flour batter were purchased from the local market and were of analytical quality. Cricket flour was ordered from a European company.

Chicken eggs TM Yasen Svit, sugar TM Komora Krup, wheat flour TM Hutorok, citric acid, flour from crickets TM "SENS Foods" London UK.

Instruments

The dough for the whipped flour semi-finished product was prepared using an Ariete Digimix Professional 1585 mixer and baked in a Liberton LEO-651 electric oven. The rheological properties of the dough for WFP were determined on the "Rheotest-2." The shear rate from 1.9 to 76 s^{-1} was studied using spindle No S07 at 18 revolutions and a temperature of 20 °C.

The elasticity of the finished product was determined using a "Labor" penetrometer. The degree of penetration was measured in 0.1 mm of the distance at which the indicator penetrated the material under study perpendicular to its surface. The research was conducted at 20 °C.

Laboratory Methods

The mass fraction of moisture was determined by drying to constant mass **[23]**. For this model sample, the bags were placed in a drying cabinet heated to 130 °C and dried by long-term drying for 40 minutes. After drying, the boxes with lids were placed in a desiccator for 30 minutes and weighed. For the final result of the mass fraction of moisture in the whipped flour semi-finished product, the average arithmetic value of 4 was taken.

The mass fraction of ash insoluble in 100% hydrochloric acid, based on absolutely dry matter, was determined using the dry method in a muffle furnace **[24]**. The Kjeldahl method determined the mass fraction of protein **[25]**. Alkalinity is using the titration method **[26]**. The iodometric method determined the mass fraction of total sugar **[27]**.

Description of the Experiment

Sample preparation: The whipped flour semi-finished product was prepared in four variations, each differing in the innovative ingredient. Cricket flour was added to the semi-finished product in amounts (5.0%, 10.0%, 15.0%) to replace an equivalent wheat flour. The control sample of the whipped flour semi-finished product was prepared without adding flour from crickets.

According to the technology of preparing a whipped flour semi-finished product, egg yolks were first beaten with granulated sugar until a homogeneous mass was formed and the sugar dissolved. Then egg whites were beaten with citric acid until a lush, smooth structure was formed, after which the beaten yolks were combined with the beaten proteins, and high-grade wheat flour was added (control) or a mixture of wheat flour and cricket flour into the studied samples. The mixed dough was poured into a round mold and baked for 40-50 minutes. at a temperature of 180 °C. After baking, the WFP was cooled for 12 hours at room temperature. According to organoleptic indicators, BC has a powdery appearance, light grey color, pleasant taste, and aroma of walnut **[28]**.

The round sponge cake recipe was chosen (Table 1) as an analogue of the recipe for preparing WFP **[32]**.

Table 1 Recipe for whipped flour semi-finished product using BC in different dosages.

The name of the raw material	Consumption of raw materials for 300 g of products, g			
	Control	5.0%	10.0%	15.0%
Wheat flour of the highest grade	116.82-120.00	110.98-114.00	105.14-108.00	99.30-102.00
Sugar-sand	102.57-105.60	102.57-105.60	102.57-105.60	102.57-105.60
Egg yolks	102.57-108.14	102.57-108.14	102.57-108.14	102.57-108.14
Egg whites	149.45-153.84	149.45-153.84	149.45-153.84	149.45-153.84
Citric acid	0.40-0.46	0.40-0.46	0.40-0.46	0.40-0.46
Crickets flour	-	5.84-6.00	11.68-12.00	17.52-18.00
Total:	491.26	491.26	491.26	491.26
Output of raw materials	300.0	300.0	300.0	300.0

Number of samples analyzed: We analyzed 4 samples.

Number of repeated analyses: The experimental data presented in the paper are averages with repeatability of at least 3 times.

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

Design of the experiment: At the beginning of the experiment, the dough's rheological properties and the elasticity of the finished semi-finished product were determined. The content of the mass fraction of moisture, alkalinity, ash, mass fraction of sugar, protein, fat, and chitin was studied. Based on the obtained data, the total energy value of the semi-finished product was determined.

Statistical Analysis

All assays were performed in triplicate and the obtained data are presented as means ± SEM (the standard error of the mean). Sponge cake features were tested through a two-way ANOVA on the flour type, percentage of substitution, and their interaction, with a significance level of $p \leq 0.05$. The accuracy of the measurements was determined with a reliability of d = 0.95. The method's error was estimated by the total error in percent. To determine the optimal concentrations of the main components of the whipped flour semi-finished product, we used mathematical processing of the obtained results by comparing the functions of two variables and probing space parameters. To do this, we first optimally detected the parameter space on an uneven rectangular network and then mathematically processed experimental and calculated (theoretical) values of the function F over the entire parameter space. Control experiments were performed at arbitrarily selected points in the parameter space to test the likelihood of consistent F values. Based on experimental data within the framework of the paired model, correlation and regression analysis methods were used to determine the optimal: concentrations of the components of the semi-finished product model for modeling shear stress, shear rate, and viscosity. The empirical data was approximated using the MathCAD, MathLAB application program package, and the Excel spreadsheet package. Excel provides new tools for creating and designing spreadsheets and powerful tools for analyzing business information. It is a tool that allows you to organize, process, organize, analyze and graphically present different types of data in the way you want. From the point of view of informatics, most of the documents that research engineers work with belong to the category of tabular documents, where the smallest structural unit of information exists at the intersection of columns and rows a necessary condition, and therefore the simplest. and the most efficient is processed by the table processor. Spreadsheets are the backbone of any spreadsheet. Accordingly, the empirical data were approximated using an Excel spreadsheet.

RESULTS AND DISCUSSION

WFP refers to foam structure systems characterized by a certain viscosity of the initial mass. High structural viscosity determines the dough's mechanical strength, creating an elastic frame and giving the system a solid body's physical and chemical properties. The stability of the dispersed system, which is in the WFP, is largely determined by the viscosity of the initial solutions and their resistance to the action of loads. The study of previous studies on the use of cricket flour in the production of flour confectionery **[29]**, shows that introducing cricket flour into the production technology of WFP can affect the stability of the dough system. That is why the dependence of the effective viscosity of WFP samples with different amounts of cricket flour on the deformation rate and tangential shear stress was investigated.

Viscosity is an important technological characteristic of dough for WFP. The viscosity value evaluates the intensity of the formation and destruction of the structure **[30]**. According to the study's results, the effective viscosity of the dough with the addition of cricket flour affects the structure of the dough. As a result, the system undergoes certain changes. Viscosity is the final change in the characteristic that describes the equilibrium state between the restoration and destruction of the structure in a steady flow. In turn, the effective viscosity is determined through the tangent of the pseudo-Newtonian flow angle. In this study, the effective viscosity was measured using a rotary viscometer. Previously, it was established that the effective dough viscosity decreased with increasing shear rate for WFP using spelt flour **[32]**. Also, effective viscosity decreased when wheat flour was completely replaced by rice flour using the WFP technology. However, a mixture of rice flour and sesame meal flour in a ratio of 70:30% increased viscosity indicators **[33]**.

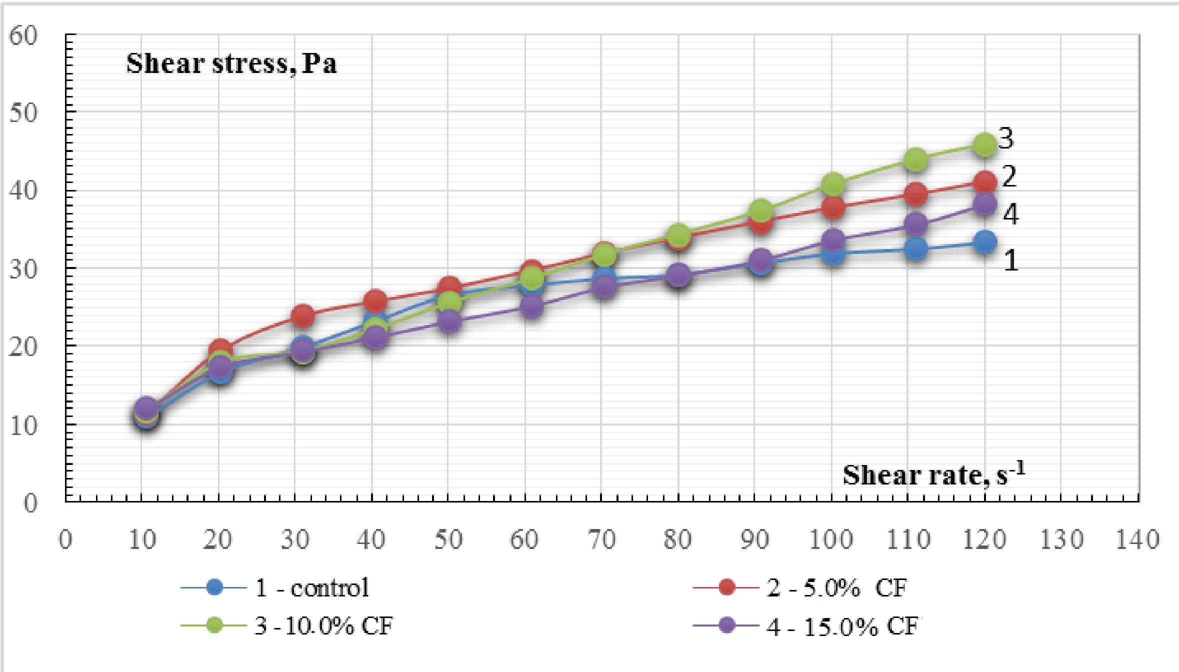

Figure 1 Dependence of shear stress on shear rate for a dough using CF.

Figure 1 shows that as the shear rate increases, the shear stress for all samples increases while the viscosity of these systems decreases. According to these data, it can be concluded that the dough for WFP belongs to non-Newtonian bodies. These systems are characterised by the ultimate shear stress, which can correspond to the elastic deformation component.

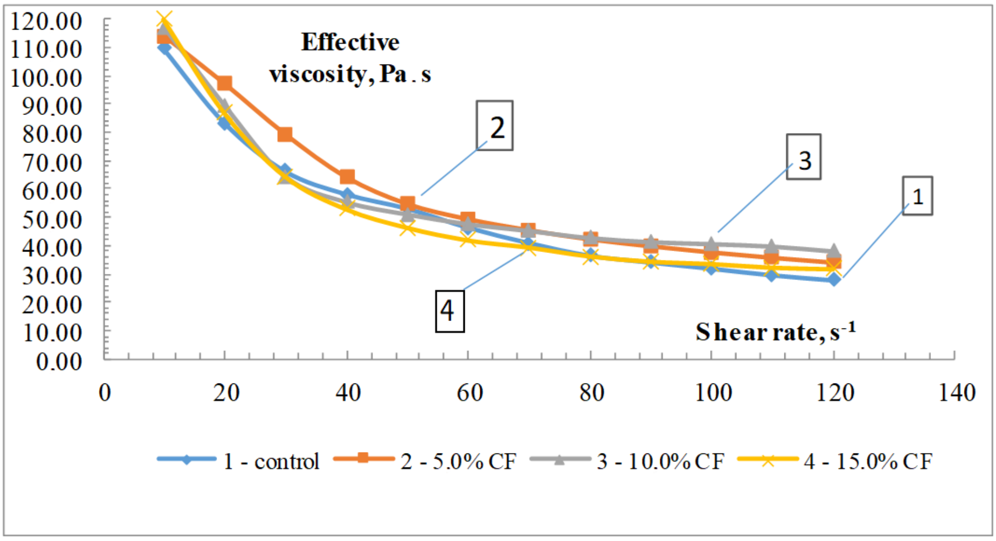

Figure 2 Dependence of effectiveness is cozily on shear rate for dough using CF.

In Figure 2, the analysis of the viscosity curves shows that no significant changes in the viscosity of the dough due to the addition of different amounts of CF were detected; a slight difference was noticeable at the minimum shear rate, the shear stress increased for the sample with the addition of 5.0% cricket flour by 10 ±0.5%, for the sample with 10.0% CF by 13 ±0.5%, for the sample with the addition of 15.0% CF by 15 ±0.5% compared to the control sample, as a result, when more CF is added, the shear stress increases. This suggests that cricket flour has a fairly high moisture-binding capacity. At high speed, the shear strength of the dough was constant for all samples except the control.

Sponge cake belongs to non-Newtonian liquids. This means that the decrease in viscosity has the effect of increasing the shear rate. In this study, the most intensive increase in effective viscosity was noted in the dough with the addition of cricket flour in the amount of 10.0% at a shear rate of 0.8 s^{-1}. However, in the future, the decrease in effective viscosity with increased shear rate is observed less intensively in all samples. The destruction of the dough's foam system can explain this viscosity change with increased shear rate. At a speed of 12.0 s^{-1}, the viscosity of all samples remained at the same level.

Therefore, when studying the rheological parameters of the dough with the addition of cricket flour in the amount of 5.0-15.0%, there are certain changes in the effective viscosity, and it increases. However, an increase in the shear rate in the range of 0.9-12.0 s^{-1} leads to stabilization of the viscosity of the systems of the studied samples. In addition, studies of the effective viscosity of the investigated biscuit dough systems with the addition of different amounts of cricket flour showed that introducing new raw materials does not significantly affect the rheological properties of the dough.

WFP has a foam-like structure characterized by the presence of a porous pulp. Adding a new ingredient to the WFP can lead to the deterioration of its structure and especially affect the elasticity of the pulp. After all, flour from crickets does not contain gluten. Therefore, it is important to determine the effect of CF addition on the elasticity of the WFP depending on the amount of the introduced innovative ingredient. The elasticity of the biscuit affects its aerodynamic properties (lightness, softness, flexibility) and texture. The addition of CF to the WFP formulation significantly increased (p <0.05) the intensity of all model samples compared to the control sample. The greater the elasticity, the lighter and airier the biscuit **[35]**.

The resiliency and elasticity of baked semi-finished products also depend on the drying process and moisture loss during baking. Since the main part of moisture in WFP is bound by gluten flour and starch, replacing part of wheat flour with flour from crickets will affect the quality of the finished product **[36]**.

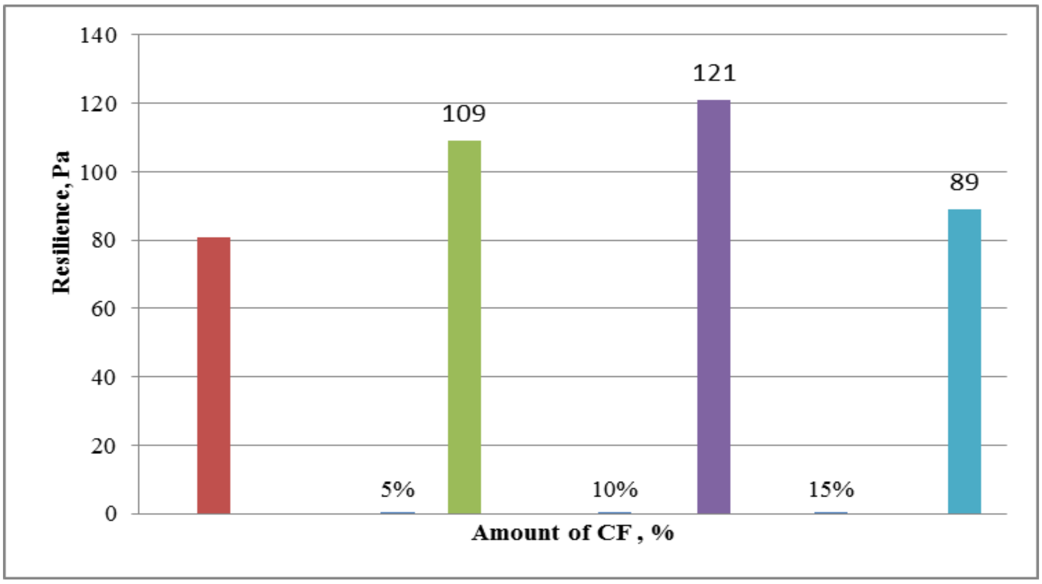

Figure 3 Resilience of biscuit products with the addition of CF.

The resilience is a measure of the ability of the biscuit semi-finished product to recover after compression **[37]**. Low elasticity was found in the control biscuit semi-finished product and semi-finished product with the addition of 15.0% CF (Figure 3). Probably, the increase in elasticity can be associated with a decrease in the volume and total content of starch, and therefore, with the formation of a denser pulp. The elasticity of WFP with adding 5.0% and 10.0% CF is slightly better than the control sample. It is likely that in these models, there is a sufficient amount and significant activity of free moisture, which causes an improvement in elasticity; when the content of cricket flour increases, the amount of protein, which requires an additional amount of moisture, increases, therefore the pulp density increases, accordingly, elasticity decreases.

It is known that physic-chemical parameters characterize the processes occurring during the kneading and baking of semi-finished products **[38]**. The main physic-chemical indicators include a mass fraction of moisture, mass fraction of ash, protein and sugar, alkalinity, and other indicators **[39]**. The ingredients in the recipe begin to closely interact with each other during the formation of the liquid phase of the dough. The stability of the dough structure during kneading and further processing largely depends on its water content and the ratio of free and bound moisture. Depending on the amount of moisture in the dough, during heat treatment of the product, water changes from a liquid phase to a gaseous phase and evaporates at a high temperature **[39]**.

The sugar content in WFP is the highest compared to other types of flour products and is in a ratio of 1:1 to flour.

The sugar content in the dough affects the degree of plasticity since sugar reduces the swelling of proteins and flour starch and significantly affects the structure of the dough and the quality of the final product. The addition of sugar to the flour confectionery recipe depends on the product's recipe, the flour's characteristics, and the temperature of kneading **[40]**.

The protein content in various formulation components determines the mass fraction of protein in WFP. According to the recipe components that are part of the ZBN, egg products up to 6 g **[29]**, wheat flour **[31]**, as well as cricket flour have a certain amount of protein, so the protein content varies depending on the concentration of CF in the WFP recipe **[41]**, **[42]**.

Ash consists mainly of metal oxides and trace elements contained in food products. For some products, the amount of ash affects quality and is a factor to consider in quality analysis.

In turn, the ash content of flour is of particular interest, as it is believed to affect baking quality. An ash content of 1.5-2% is desirable **[31]**.

Table 2 Physicochemical properties of WFP with the addition of different amounts of cricket flour.

Indicator	According to DSTU	control	5.0%	10.0%	15.0%
Mass fraction of moisture, %	16.0 ±3.0%	16.0 ±3.0	25.74 ±3.0	32.58 ±3.0	35.47 ±3.0
The mass fraction of ash not dissolved in 10% hydrochloric acid, in terms of absolute dry matter, %, no more than	0.1	0.01	0.03	0.07	0.1
Mass fraction of protein, %	No less 4.4	4.4 ±2.0	7.8 ±2.0	11.61 ±2.0	17.42 ±2.0
Alkalinity, degree	Not more 2.5	1.1 ±0.25	1.1 ±0.25	1.1 ±0.25	1.1 ±0.25
Mass share of total sugar (in terms of sucrose), %	According to the calculated content according to the recipe	60.0 ±2.5	49.8 ±2.5	31.6 ±2.5	29.4 ±2.5

Because of the importance of general definitions of physicochemical indicators in ZBN, this study analyzed and compared the content of sugar, ash, and protein, as well as determined the mass fraction of moisture and alkalinity of the products (Table 1).

As expected, the composition of the tested samples depends on the ingredients used. The protein content of the samples increased several times compared to the control sample, as cricket flour helps to increase the protein content. The highest values were obtained in the sample with 15.0% cricket flour, while the lowest protein content was found in the sample without adding the tested flour. The increase in protein with the addition of CF was also reported in the technologies of making muffins **[36]**, pancakes **[20]**, and wheat bread **[43]**. A decrease in the amount of sugar indicates a decrease in the amount of carbohydrates; therefore, a decrease in caloric content and an increase in the amount of ash indicates an increase in the content of minerals, as well as macro- and microelements.

Table 3 Comparative analysis of the nutritional value of WFP.

Samples	Moisture, %	Proteins, %	Fats, %	Carbohydrates, %	Ash,%	Chitin, %	Energy value, kcal
Control	16.00 ±3.0	4.4 ±0.14	7.02 ±0.30	60.13 ±0.07	0.00 ±0.00	0.00 ±0.00	321.55
5.0% CF	25.74 ±1.0	7.80 ±0.05	7.95 ±0.10	49.8 ±0.10	0.05 ±0.02	0.31 ±0.01	291.99
10.0%CF	32.58 ±1.0	11.61 ±0.03	8.89 ±0.10	31.6 ±0.07	0.07 ±0.02	0.62 ±0.01	246.53
15.0%CF	35.47 ±1.0	17.42 ±0.04	9.82 ±0.10	29.4 ±0.10	0.09 ±0.02	0.93 ±0.01	269.78

Because of the high protein content in the innovative WFP when CF is added, we note that the nutritional and biological value of the product changes compared to the control sample (Table 2).

Thus, when calculating the nutritional and energy value, we note that the amount of proteins in MPP with the addition of CF in the amount of 5.0% increased by almost 43.0%, with the addition of 10.0%, it increased by almost 62.06%, and with the addition of 15.0% – by 74.7% following the control sample, and the amount of carbohydrates decreased by 17.2%; 47.4%; 51.1%, respectively. The obtained results allow us to conclude that MPP with the addition of CP can be recommended as a product enriched with a protein component.

The organoleptic parameters of baked WPF were discussed in a study published earlier **[28]**. Figure 3 shows the appearance of WPF. Important indicators of products were color, taste, and smell. After all, these indicators affected the quality of the products. When cricket flour was added to BN, the color changed from light green to olive and had a score for the product with the addition of 5.0 and 10.0% – 5, with the addition of 15.0% CF – 3 (p <0.05), the smell was pleasantly nutty with the addition of 10.0% flour and pronounced nutty with the addition of 15.0%. The product's taste was characteristic of a semi-finished biscuit product, but WPF, with the addition of 15.0%, had a more pronounced taste of nuts, so the tasters gave a score of 5 (p <0.05).

Sensory scores were ≥4.75 for samples with 5.0% and 10.0% CF. A chocolate cookie based on CF was accepted with a 0.50 lower sensory score **[41]**. It should be noted that in Ukraine, flour from crickets is a new product on the market; therefore, its acceptance by consumers is related to sensory properties and the important issue of microbiological safety. Microbiological indicators of CF were determined by comparing them with wheat flour **[44]**.

When conducting research among Ukrainian consumers, flour from crickets caused different emotions from negative (i.e. rejection) to positive. Indicators of positive emotions (3.46-2.53) were better when consumers were not told about the CF content in the product. However, 85.0% of the surveyed respondents were ready to consume CF-based WFC for its quality and nutritional characteristics after the tasting.

1

2

3

4

Figure 4 Baked round biscuit with the addition of cricket flour: 1 – control; 2 – with the addition of 5.0% flour from crickets; 3 – with the addition of 10.0% flour from crickets; 4 – with the addition of 15.0% flour from crickets.

CONCLUSION

According to the study's results, when CF is added to the WFP technology, the dough's rheological parameters differ from the control's. In particular, the use of CF in WFP helps to reduce the dough's viscosity. Still, it increases its stability, which in the future will have a positive effect on the processes of forming and baking. Studies of resiliency and elasticity have shown that when CF is added to the sponge cake recipe in the amount of 5.0-10.0%, the resiliency and elasticity of the crumb increase when the ingredient is added in the amount of 15.0%, compared to the main WFP—the value of the data indicators decreases. However, these changes could be more significant and affect the quality of the finished product. In terms of physicochemical properties, the baked innovative WFP differs from the control sample; according to DSTU, the mass part of protein should be at least 4.4%, but in this study, it was determined that the addition of cricket flour to the recipe composition increases the increase in protein by 62.06%. The mass fraction of moisture in the semi-finished product with 5.0-15.0% BC increased from 1.61 to 2.22%; the mass fraction of ash decreased from 0.1 to 0.07%, and the mass fraction of total sugar decreased by 47.4%, respectively. Therefore, flour from crickets is a promising raw material. Its use will expand the range of food and culinary products, increase their nutritional and biological value, and give products new organoleptic characteristics and tastes.

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Funds:
This research received no external funding.
Acknowledgments:
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors
Conflict of Interest:
No potential conflict of interest was reported by the author(s).
Ethical Statement:
This article does not contain any studies that would require an ethical statement.
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