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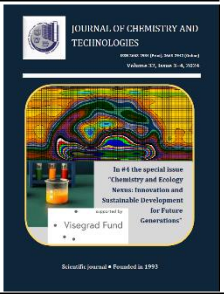

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METHODOLOGICAL BASES FOR DETERMINING THE BIOLOGICALITY OF FOOD PRODUCTS FOR ENVIRONMENTAL LABELLING

Galyna Krusir[1,2], Hanna Korkach[1], Liudmyla Pylypenko[1], Galyna Khomych[3]
[1]*Odesa National University of Technology, St. Kanatna, 112, Odesa, Ukraine, 65039*
[2]*Institute for Ecopreneurship, School of Life Sciences, University of Applied Sciences and Arts Northwestern Switzerland, Hofackerstrasse 30, 4132, Muttenz, Switzerland*
[3]*Poltava University of Economics and Trade, Ivan Banka Str. 3, Poltava, Ukraine, 37000*

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Abstract

The study is devoted to identifying, highlighting and solving problems related to the biologicality of food products, which includes their quality, naturalness/organicity, safety and environmental friendliness for ecological labelling in modern food systems. The methodology of determining the biologicity of food products for ecological labelling and formation of food and crop safety monitoring system has been substantiated and developed. The complex safety indicators of the finished product were evaluated by the method of biotesting using the culture of Colpoda steinii infusoria and it was found that the content of toxic substances was insignificant in two samples. The complex indicators of naturalness/organicity of bakery products were studied by the crystallographic method, namely biocrystallisation. It was found that the biocrystallogram score of the test sample with the use of hop sourdough is 0.74 points, and the control sample is 0.49 points, indicating that the sample made with the use of hop sourdough has the highest value of naturalness/organicity according to the results of biocrystallisation. According to the expert assessment by the method of relevant tables, the life cycle of the studied bakery products received a score of 0.5 points, which characterises its environmental impact as moderate.

Keywords: biologicality; food products; bakery products; naturalness; environmental friendliness; biocrystallization; biotesting; eco-labelling; product's life cycle.

МЕТОДОЛОГІЧНІ ЗАСАДИ ВИЗНАЧЕННЯ БІОЛОГІЧНОСТІ ХАРЧОВИХ ПРОДУКТІВ ДЛЯ ЕКОЛОГІЧНОГО МАРКУВАННЯ

Галина Крусір[1,2], Ганна Коркач[1], Людмила Пилипенко[1], Галина Хомич[3]
[1]*Одеський національний технологічний університет, вул. Канатна, 112, м. Одеса, Україна, 65039*
[2]*Інститут екопідприємництва, Школа наук про життя, Університет прикладних наук і мистецтв Північно-Західної Швейцарії, Хофакерштрассе 30, 4132, Муттенц, Швейцарія*
[3]*Полтавський університет економіки і торгівлі, вул. Івана Банка, 3, Полтава, Україна, 37000*

Анотація

Дослідження присвячено виявленню, висвітленню та вирішенню проблем, пов'язаних з біологічністю харчових продуктів, яка включає їх якість, натуральність/органічність, безпечність та екологічність для екологічного маркування в сучасних продовольчих системах. Обґрунтовано та розроблено методологію визначення біологічності харчових продуктів для екологічного маркування та формування системи моніторингу безпечності харчових продуктів і рослинництва. Оцінено комплексні показники безпечності готового продукту методом біотестування з використанням культури інфузорій *Colpoda steinii* та встановлено, що вміст токсичних речовин був незначним у двох зразках. Комплексні показники натуральності/органічності хлібобулочних виробів досліджували кристалографічним методом, а саме методом біокристалізації. Встановлено, що оцінка біокристалограми дослідного зразка з використанням хмелевої закваски становить 0.74 бала, а контрольного зразка – 0.49 бала, що свідчить про те, що зразок, виготовлений з використанням хмелевої закваски, має найвище значення натуральності/органічності за результатами біокристалізації. За результатами експертного оцінювання методом релевантних таблиць життєвий цикл досліджуваної хлібобулочної продукції отримав оцінку 0.5 бала, що характеризує її вплив на навколишнє середовище як помірний.

Ключові слова: біологічність; харчові продукти; хлібобулочні вироби; натуральність; екологічність; біокристалізація; біотестування; екомаркування; життєвий цикл продукту.

**Corresponding author: e-mail:* krussir.65@gmail.com

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Introduction

Food production is a defining issue of the 21st century, with wars, pandemics, climate change and biodiversity loss threatening the world's food supply. All countries depend on globally functioning ecosystems and stable supply chains, while the current international food system is the driving force behind the growth of current and future crises [1–3]. The food industry and agriculture must not only produce enough food in terms of calories to feed the growing global population, but also produce a variety of foods that promote human health and are able to maintain environmental sustainability [4–7].

Food and nutrition security is achieved when adequate food (in terms of quantity, quality, safety, and socio-cultural acceptability) is available and accessible to all people at all times and is appropriately used and digested by them for a healthy and active life [8].

Food production using modern methods degrades land, using huge amounts of water, energy, fertilisers and pesticides [9–11]. Food production is responsible for 70 % of freshwater withdrawals and 78 % of global eutrophication, primarily caused by nutrient runoff from fertilisers used in agriculture, leading to dead zones in oceans and freshwater bodies [12]. All of this leads to environmental losses and a significant share of global greenhouse gas emissions associated with climate change. The Living Planet Index 2022 provides a figure showing the ecological footprint of humanity's activities, and the largest footprint (30 %) is accounted for by ‘food’ activities [13]. According to the UNEP report, the global food system accounts for up to 37% of global greenhouse gas emissions from what we eat, what and how we grow, the reduction in the amount of forest we cut down and the food we throw away [14]. All of this exceeds the Earth's absorption capacity, is responsible for about 37% of global greenhouse gas emissions, and is a crucial factor in the loss of biodiversity. At the same time, unwanted species such as invasive plants, animals and crop pathogens thrive in an imbalanced ecosystem.

Ecosystems and biodiversity are an integral part of many of the Sustainable Development Goals and related targets, as they directly contribute to human well-being and development. The health of the world's population depends on natural systems that provide ecosystem services such as water, food, energy, etc. In order to make the food system more sustainable, it is necessary to change the structure of food demand. A number of policy documents and reports call for a shift to a more plant-based diet in rich countries, which could yield a ‘double climate dividend’ in terms of reduced emissions and increased land area for carbon sequestration [15–18]. It is estimated that by reducing food waste and switching to a more plant-based diet, this will lead to a reduction in livestock and feed crop production, and organic agriculture could feed more than 9 billion people in 2050 [19–22]. Organic agriculture has many benefits that are not always easy to measure, such as greater biodiversity and the absence of pesticide residues in the environment and in the food produced, allowing for a regenerative approach to agriculture that focuses not only on doing less harm but also on creating healthy, resilient ecosystems and can revitalise the soil, water, flora, fauna, livelihoods, cultures and health of the planet. Both innovation and a shift in our thinking will be crucial to managing the necessary changes [23–25].

Thus, the existing systems for determining the biologicality of food products require the determination of numerous quality and safety indicators, and the existing methods are costly, requiring significant time, expensive instruments, equipment, reagents, etc. That is why it is important to develop a methodological framework for determining the quality of food products for eco-labelling and the formation of a food and crop safety monitoring system that provides information on their condition and forecasts in near real time and can contribute to the fight against climate change, biodiversity loss, and have a positive impact on human/animal/environmental health. This will help to inform about the state of food security, urban and rural security, develop early warning systems and prevent food crises, monitor food quality, and develop and implement measures to prevent and minimise the negative impacts of their life cycle on the environment. The aim of the study was to develop a methodological framework for determining the biodegradability of food products for environmental labelling and to test it for assessing the biodegradability of bakery products, including food quality indicators, taking into account organoleptic indicators, comprehensive safety indicators, naturalness/organicity/environmental friendliness and redox indicators of products, as well as indicators for assessing the impact of the food life cycle on environmental components.

Materials and methods

Using the developed methodology for assessing the biologicality of bakery products, the following bakery samples were evaluated: Sample 1 (Control) – prepared according to the method of trial baking (no-dough method with the addition of 3.0 % of pressed yeast) using 1st grade wheat flour, sample 2 – experimental, prepared using 1st grade wheat flour according to the developed technology with wheat spontaneous hop sourdough, which is added in the amount of 30 % by weight of flour.

The main objective of eco-labelling is to create a methodology focused on obtaining a healthy, high-quality and safe food product (FP) based on environmental efficiency and food safety criteria. To determine the environmental criteria, it is necessary to study the FP life cycle to the fullest extent possible. Ecolabelling should take into account the environmental impact of products throughout their life cycle (LC).

The biologicality of a food is established if it meets the criteria for eco-labelling of two main indicators: product quality and the environmental impact of the product's life cycle.

In other words, to receive an eco-label, a food must meet not only high quality but also environmental safety. Accordingly, environmental labelling should take into account the following criteria:

I. The quality criterion of the FP (K1), which is estimated by multiplying of the following indicators: organoleptic quality indicators; complex safety indicators of the FP, which are assessed by biosensor testing; complex indicators of «naturalness/organisiti» of the FP by the method of biocrystallisation; an indicator assessed by the value of the redox potential of the FP.

II. The criterion of the impact of the life cycle of the FP on environmental components (K2), calculated using the relevant environmental impact tables.

The criteria for environmental labelling of biologicality of FP are given in Table 1.

Table 1

Criteria for environmental labelling of FP

Name of the criterion	Limits of variation of the indicator
Quality of food products, K1	
Organoleptic quality indicators, C1	from 0 to 1
Food safety indicators, C2	from 0 to 1
Composite indicator of ‘naturalness/organicity’ of food products by biocrystallisation method, C3	from 0 to 1
Biological activity indicator measured by redox potential value, C4	from 0 to 1
Impact of the life cycle of the FP on environmental components, K2	
Indicators of the relevant tables of the impact of the life cycle on environmental components, C5	from 0 to 1

Thus, the biologicality of a FP is determined by the following formula:

$$\text{Biologicality} = K1{*}K2 \qquad (1)$$

The quality of the product is determined by the following formula:

$$K1 = C1{*}C2{*}C3{*}C4 \qquad (2)$$

The impact of LC of the food product on environmental components determined by the following formula:

$$K1 = C5 \qquad (3)$$

The quality assessment of food is based on the following indicators:

C1) Organoleptic quality indicators of food products. Compliance with the norm is assessed at 1 point, non-compliance - 0 points. The total score is determined as the arithmetic mean of the sum of the scores of all organoleptic indicators. The scale for assessing the organoleptic characteristics of FP on the example of bakery products is given in Table 2.

Table 2

Evaluation of organoleptic characteristics of bakery products

Shape	round, oblong, or oblong-oval, not blurred without pressing
Surface	without large cracks, undermining with incised relief and circular relief, rough
Colour	light yellow to dark brown
Odour	characteristic of this product
Taste	characteristic of this product, without any foreign flavour
Condition of the crumb	
Roasting	baked, not wet, elastic, after light pressure with fingers, should take its previous shape
Kneading the dough	without lumps and traces of unleavened bread
Porosity	developed without voids and densities

C2) Comprehensive food safety indicators are determined using the *Colpoda steinii* biosensor bioassay method.

Product safety is characterised by the absence of toxicity according to these biosensors. The criterion for assessing the safety of test samples is the presence of infusoria mobility after 3 hours of incubation in aqueous and hexane extracts of raw materials and final products, which ensures the detection of toxic substances of polar and non-polar nature. The total score is determined as the arithmetic mean of the sum of the scores. The scale for assessing the toxicity of FP is given in Table 3.

Table 3

Scale for assessing the toxicity of products

Toxicity profile	*Colpoda steinii*	Scores
Toxic	Most *Colpoda steini* die in 10 minutes	0
Slightly toxic	Less than 30 % of *Colpoda steinii* die within 3 hours	0.5
Not toxic	All *Colpoda steini* remain mobile for 3 hours	1

C3) Comprehensive indicators of ‘naturalness/organicity’ by the biocrystallisation method. The criterion for evaluating the prototypes is the ratio of the distance from the centre of crystal growth to the shortest branch and from the same centre to the longest branch. The division of these distances corresponds to the score obtained [26].

Table 4

Scale for assessing the ‘naturalness/organicity’ of FP

*Value of a	Scores
0 – 0.5	0.5
0.5 – 1.0	1

*Value of the ratio of the length from the centre of crystal growth to the end of the shortest branch and the length from the centre of crystal growth to the end of the longest branch

C4) Biological activity indicator measured by redox potential value. The criterion for evaluating the sample is the experimental value of the ORP obtained using an ORP meter (Hanna Instruments H1981216 Germany). The total score is determined as the arithmetic mean of the sum of the scores. The scale for assessing the value of the ORP of FP is given in Table 5.

Table 5

Scale of product evaluation

The range of values of the ORP, mV	Scores
100–150	1
150–250	0.5
250–400	0

Life cycle impacts of products on environmental components (K2)

C5) The life cycle impacts of the product on environmental components shall be assessed using relevant tables or other life cycle assessment method. The relevant tables assess the environmental impacts of the main and auxiliary raw materials, stages of the product manufacturing process, enterprise departments, life cycle stages, input and output aspects of the production process. It is assessed according to the environmental component on a scale: 0 - no impact, 5 - moderate impact, 10 - significant impact. A summary scale for assessing the impact of the LC of FP is shown in Table 6.

Table 6

Scale for assessing product life cycle impacts

Maximum score	Degree of impact	Impact value	Scores
0–100	Insignificant	A	1
100–700	Moderate	B	0.5
700–1200	Significant	C	0.01

The scale for the final assessment of the sum of all environmental criteria and the result for environmental labelling are shown in Table 7.

Table 7

Summarised assessment of the considered biologicality criteria for FP for environmental labelling

Generalising assessment	Conclusion	Result
1 – 0.5	Positive	The product is assigned an eco-labelling mark
0.5 – 0.03	Positive with room for improvement	Needs to be improved and minor changes made
0.03 – 0	Negative	Complete change in product manufacturing technology

The total score of the criteria, which ranges from 1 to 0.5 points, recognises the biologicality of the product and the minimal negative impact on human health and the environment. With such a score, it is possible to issue a certificate for the use of the environmental labelling mark for the product under study.

A score of 0.5 to 0.03 points indicates the need for further development and minor changes to the product life cycle stages. After correcting the factors that adversely affected the biologicality of the product, it is necessary to re-evaluate the product samples according to the proposed methodology and determine their biologicality.

Enterprises whose products received a score of 0.03 to 0 points should fundamentally review all components of the production process and make the necessary changes.

Determining the toxicity of food products by bioassay using the *Colpoda steinii* culture.

The method is based on the extraction of various fractions of polar toxic substances from the test samples using water and non-polar toxic substances using hexane to determine the effect of these extracts on the culture of *Colpoda* infusoria. Living dry cysts of *Colpoda steinii* in culture medium are capable of excysting after a 16-hour incubation at 28°C. When they come into contact with toxic substances, they lose their motility. Thus, the time after which the infusoria stop moving indicates the degree of toxicity of the sample under study.

Colpoda steinii infusoria produced by Biotest, Odesa, Ukraine, were used in this study. Culture composition: 1 ml of *Colpoda* culture contains: cysts of *Colpoda steinii* infusoria - 5000 live motile cells, spores of *Bacillus subtilis* bacteria - up to 10 million cells;

1 litre of nutrient medium contains: enzymatic peptone - 0.12 g, glucose - 0.03 g, sodium chloride - 0.1 g, potassium chloride - 0.01 g, calcium chloride - 0.01 g, magnesium chloride - 0.01 g, sodium bicarbonate - 0.02 g, add water to 1 litre.

Preparation for the experiment. Two vials of *Colpoda steinii* culture are inoculated with 2 ml of culture medium 12-24 hours before the test. The vials are sealed with cotton gauze stoppers and kept in a thermostat at 26-28°C. Immediately before the test, the activity of the culture in a hanging or crushed drop is monitored under a microscope (80-150 magnification). At least 5 cells of the colpodea culture should move in the field of view.

Preparation of the FP sample for the study. To determine the toxicity of raw materials and bakery products, samples are taken from which the average sample for the study is prepared. Sampling and preparation of the average sample is carried out according to [18]. The middle sample is ground until it passes through a sieve with 0.2 mm holes.

Preparation of the aqueous extract of the test sample. A 20 ± 0.1 g sample is placed in a 250 cm^3 flask and 100 cm^3 of distilled water is added. The flasks are shaken for 30 minutes and then left for 15 minutes to allow the heavy fractions to settle. The resulting extract is filtered through filter paper.

Conducting the test. The suspension with excised infusoria is combined with an equal volume of the test sample. The mixture is incubated at 28°C and a drop of the mixture is examined in a crushed drop under a microscope after 3, 10 minutes and 3 hours. The criterion for assessing the toxicity of the test samples is the absence of infusoria mobility: after 3 minutes - highly toxic, 10 minutes - toxic, 3 hours - non-toxic.

Determination of food naturalness/organicity by biocrystallisation [26].

Preparation of the test sample. The FP must be crushed using a chopper. Then, 5 g of the sample is mixed with 9 ml of distilled water for 30 minutes at room temperature and left for 15 minutes to settle the coarse particles. After this time, the extract is filtered through filter paper. Pre-prepare a 10% $CuCl_2$ solution.

Conduct the test. Mix the FP extract (2 ml) and 10% $CuCl_2$ solution (2 ml) in a 1:1 ratio, then apply to the prepared glass plates and leave to dry in special chambers. The process of crystallisation of the biological substance takes place in a thermostat at 25°C for 48 hours. The pattern of the biosubstrate crystals is examined with a microscope and a photo is taken.

Determination of the redox potential of bakery products.

Sample preparation. The bread is crushed using a laboratory grinder. Then, 5 g of bakery products are mixed with 50 ml of distilled water for 30 minutes (in a ratio of 1 : 10) at room temperature and left for 15 minutes to settle large particles. After this time, the extract is filtered through filter paper.

Experimental procedure. The experiment is carried out on an ORP meter (Hanna Instruments HI 5221, Germany). The electrode of the device is dipped into a container with the bakery product extract. After a few minutes, when the device shows an unchanged value, we record the value of the redox potential of the sample.

Results and discussion

Assessment of food product quality/biologicality

Evaluation of organoleptic quality indicators of bakery products

Organoleptic evaluation is a set of operations that includes the selection of a range of organoleptic quality indicators, the determination of these indicators and their comparison with the baseline. In some cases, organoleptic assessment can provide a conclusion on parameters such as the freshness of raw materials and production process irregularities much faster than instrumental methods, although it is an expert method whose main disadvantage is subjectivity. The accuracy and reliability of these indicators depends on the abilities, qualifications and skills of the persons determining them.

Bakery products are a product that is eaten without any additional processing, so their quality is subject to particularly high demands. Bakery products deteriorate rather quickly because, after heat treatment, they retain a certain proportion of microorganisms and a certain number of heat-resistant microbes. These microorganisms are activated under favourable conditions when humidified and stored in poorly ventilated, warm rooms and cause intensive protein decomposition with the formation of gaseous products (hydrogen sulphide, ammonia) and other decomposition products (indole, scatol). Organoleptic evaluation is the easiest and fastest way to determine the presence of degradation products in low concentrations in a product. The results of the sensory analysis of the samples are shown in Table 8.

Table 8

Evaluation of organoleptic characteristics of bread

Name of the organoleptic parameter	Compliance with the norm	Scores	Compliance with the norm	Scores
	Sample 1		Sample 2	
Shape: round, oblong, or oblong-oval, not blurred without pressing	+	1	+	1
Surface: without large cracks, undermining with incised relief and circular relief, rough	+	1	+	1
Colour: light yellow to dark brown	+	1	+	1

Continuation of Table 8

Odour: peculiar to the product	+	1	+	1
Taste: typical for this product, without foreign flavour	+	1	+	1
Crumb state: baked - baked not wet, elastic, after light pressure with fingers, takes its previous shape	+	1	+	1
Condition of the crumb: kneading - without lumps and traces of unleavened crumb	+	1	+	1
Condition of the crumb: porosity - developed, without voids and densities	+	1	+	1
Total score:		**1**		**1**

As can be seen from the results of the sensory analysis, all the organoleptic characteristics of the products studied meet the regulatory requirements for shape, surface condition, colour, taste and odour, as well as the condition of the crumb.

Evaluation of complex safety indicators of finished products by bioassay using the culture of *Colpoda steinii* infusoria [27].

One of the most important areas in applied biotechnology is the development of effective biological methods for assessing the condition of various environmental objects, which are nowadays contaminated with toxic substances. Even if it were possible to determine the content of all xenobiotics in the object of study, such information would be insufficient for any predictions, since toxicometric parameters have been established for only a small part of these substances. In addition, the result of the combined effect of two or more toxic substances present in the sample in small quantities is difficult to predict. Substances that are not toxic in isolation can cause pathological effects when exposed to a combination. Therefore, tests on various living organisms are used to assess the toxicity of food products, as well as new chemicals for food use. Providing little information about the nature of the pollutants, biotesting makes it possible to determine the degree of integral toxicity of the object of study with greater certainty.

Among the organisms used for bioassays are representatives of the protozoa. Biotesting methods are highly sensitive, expressive, reliable, versatile and low-cost. They are easy to perform, can be instrumented and automated, and their results are easy to interpret. Unlike chemical and physicochemical methods of analysis, biotesting on infusoria allows predicting the integrated effect of the object under study on living organisms, since the reaction of a biological test system depends not only on individual toxic compounds contained in the object of study, but also on their interaction with each other, as well as on the presence of substances that have a pronounced effect on the toxicity of these compounds. Compared to biotests on higher animals, biotesting on infusoria has significant advantages in the economic, methodological and ethical spheres.

To determine the integrated toxicity of bakery products, biosensors – Colpoda steinii cultures - were selected. These cultures are highly sensitive and versatile. The degree of toxicity of bakery products was assessed according to the scale for assessing the toxicity of products (Table 3).

In the experiment, water and hexane samples with the extract of the bakery products under study were used to determine the effect of toxic substances of polar and non-polar nature. The results of the assessment of the integrated safety indicators of the finished products are shown in Table 9.

Table 9

Evaluation of complex safety indicators of finished products by biosensor bioassay (*Colpoda steinii*)

Product name	Water sample	Hexane sample	Toxicity	Scores
	Colpoda steinii			
Sample 1	Less than 30% of colpods die within 3 hours	Less than 30 % of colpods die within 3 h	Slightly toxic	0.5
Sample 2	All colpods remain mobile within 3 hours	All colpods remain mobile for 3 hours	Not toxic	1

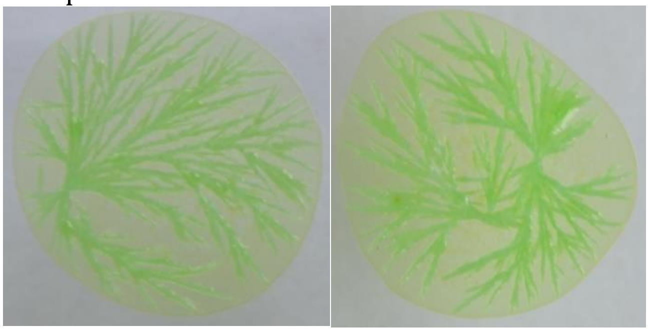
According to the results of biotesting with *Colpoda steinii* biosensors, the content of toxic substances is insignificant in two samples. To determine the presence and degree of toxicity of polar substances, an aqueous sample was taken from the extract of bakery products, and a hexane sample was taken to determine non-polar substances. The result of the analysis of the water and hexane samples of sample 2 is a score of 1, which indicates their non-toxicity. Sample 1 (control) is slightly toxic according to the results of the water and hexane samples, which indicates the presence of certain toxic substances of non-polar and polar nature. The overall safety score of the control sample is 0.5 points.

Assessment of bread naturalness/organicity by biocrystallisation method

One of the experimental methods for determining the naturalness/organicity of food products is biocrystallisation. As a result of the process of biocrystallisation of the bread sample extract, crystals of various configurations are formed. The symmetry of the pattern and size of the crystals indicates the natural origin of the FP. Asymmetry and deformation of the pattern of crystals of a biological fluid indicates the aggressive impact on the food product (for example, using thermal or chemical treatment), or contamination.

For the most complete extraction and adequate decoding of the information capacity of a biomaterial, it is necessary to use the achievements of chemistry (nature of crystallogenesis, features of crystalline and amorphous structures), physics (assessment of the energy component and physical basis of dehydration), mathematics and computer science (modelling crystal formation to create equations for predicting the state of the product) and the medical and biological field.

As a result of the experiment, a photo of the formed crystals of a mixture of a 10 % $CuCl_2$ solution and an extract from bakery products was obtained. Biocrystallograms of bakery products samples are shown in Fig. 1.



a) b)

Figure. Biocrystallograms of: a) sample 1 b) sample 2

As can be seen from the experimental data presented in Fig. 1, the most symmetrical biocrystallogram is characterised by sample 2, which indicates its higher degree of naturalness/organicity, which is probably determined by the replacement of yeast with hop sourdough.

The biocrystallogram is characterised by the presence of a significant number of needle branches of different lengths. Crystals are mostly formed on the periphery of the droplet and grow from one edge to the other. The tips of all branches are sharp, and the branch structure is dense and clearly visible without aids. The values of the ratios of the distance from the centre of crystal growth to the end of the shortest branch and the distance from the centre of crystal growth to the end of the longest branch of different biocrystallograms of the tested product samples and their evaluation are given in Table 10.

Table 10

Evaluation of naturalness/organicity of FP by biocrystallisation

Name of the product	*Value of a	Total score
Sample 1	0.49	0.49
Sample 2	0.74	0.74

*Value of the ratio of the length from the centre of crystal growth to the end of the shortest branch and the length from the centre of crystal growth to the end of the longest branch

The results of the computational studies presented in Table 9 allow us to conclude that the product samples are characterised by symmetry indicators of biocrystallograms that vary from

0.49 to 0.74, indicating that the sample made using hop sourdough has the highest value of naturalness/organicity according to the results of biocrystallisation.

Assessment of the redox potential of bakery products

The main processes that ensure the vital activity of any organism are redox reactions, i.e. reactions associated with the transfer or addition of electrons. The energy released as a result of these reactions is used to maintain the homeostasis of the body's vital functions and regenerate the body's cells, i.e. to ensure the body's vital functions today and in the future. One of the most significant factors in regulating the parameters of redox reactions in any environment is the electron activity or ORP of that environment. Normally, the ORP of the internal environment of the human body is usually in the range from minus 200 to plus 100 millivolts (mV), i.e. the internal environment of the body is in a reduced state.

If the product entering the body has an ORP close to the ORP value of the internal environment of the human body, the electrical energy of cell membranes (the vital energy of the body) is not spent on correcting the activity of electrons and the product is immediately absorbed, as it has biological compatibility in this parameter.

The imbalance of the mechanisms of regulation of redox processes in the human body is currently considered to be the most important cause of many human diseases, the body wears out, ages, and vital organs lose their function. However, these negative processes can be slowed down if the body receives food that has the properties of the internal environment of the body, i.e., protective and restorative properties.

The quality of a food product depends on many factors. As for the quality of bakery products, it is important to ensure that all metabolic processes in the product are uniform and natural. Determining the redox potential of a product indicates its quality, freshness, natural origin and organicity; for a raw material, flour, it is an indicator of the overall chemical composition, proper storage and efficient processing.

Redox systems play a special role in maintaining chemical equilibrium, as they significantly affect the direction and intensity of redox reactions in the product. In turn, these reactions are responsible for the rate and accumulation of intermediate products, many of which are directly involved in the formation of the most important quality indicators of the product as a whole.

These systems are especially important in the storage of finished products. The fat component of this product is of particular importance. Fats are easily subject to oxidative changes, and the resulting peroxide compounds can interact with the sulfhydryl groups of low-molecular-weight thiols and thiol proteins. Determining the ratio of the oxidised and reduced forms of a given redox system is important for obtaining an understanding of the state of redox processes in finished products and raw materials, during their processing and storage, and, accordingly, for judging the effectiveness of the processing methods used and the storage of these products. The values of redox potentials of the studied samples of bakery products are given in Table 11.

Table 11

Values of the redox potential of bread and their evaluation

Name of the product	The value of the ORP	Scores
Sample 1	+105	1
Sample 2	+90	1

The redox values of the control and test samples are within the permissible range (from +90 to +105), which indicates the freshness of the products and proper storage conditions. To maintain the permissible range of the ORP value, it is necessary to choose appropriate storage conditions and packaging materials that will prevent the oxidation of the product.

Assessment of the life cycle impact of bakery products on environmental components using relevant tables

The impact of the product on the environment occurs not only during the production of the product, but also at the stages preceding it (extraction, processing of raw materials) or at the stages of product consumption and waste disposal. An objective environmental assessment of a product should take into account all stages of its life cycle [20]. The stages of the life cycle are as follows: marketing and market research; product design and development; extraction of raw materials (growing crops); transport (transport emissions); production (technology); packaging and storage; sales, distribution, service, control; operation; disposal (of production and consumption waste).

For food products, the most significant stages of the life cycle are the cultivation of raw materials, production, transportation, consumption and disposal.

Table 12

Assessment of the impact of the life cycle stages of bakery products produced using hop sourdough and under environmental conditions on environmental components

lements of the environment		Life cycle stages					Evaluation	Compliance
		Cultivation of raw materials	Production	Transport	Consumption	Utilisation		
Air	CO_2	2	5	10	0	5	22	A
	CO	2	10	10	0	5	27	A
	NO_x	2	10	10	0	5	27	A
	SO_2	2	10	10	0	10	32	A
	Organofluorine compounds/chloro-organic compounds	0	10	0	0	0	10	A
	Low molecular weight volatile organic compounds	2	10	10	0	10	32	A
	CH_4	5	0	10	0	0	15	A
	N_2O	2	0	10	0	0	12	A
	Acids/alkalis	2	0	2	0	0	4	A
	Inorganic substances	0	2	0	0	0	2	A
	Particles	2	10	10	0	0	22	A
	Heavy metals	10	10	2	0	0	22	A
	Waste heat/cool	0	10	0	0	0	10	A
	Steam	0	10	0	0	0	10	A
Water	BOD5	2	2	0	0	0	4	A
	COD	0	2	2	0	0	4	A
	Acids/alkalis	0	2	2	0	0	4	A
	$N(NH_3+,NH_4)$	2	2	0	0	0	4	A
	NO_3	2	2	0	0	0	4	A
	NO_2	2	2	0	0	0	4	A
	Organic materials	2	2	10	0	0	12	A
	Salts	2	2	2	0	0	6	A
	Amines	2	2	0	0	0	4	A
	Waste heat/cool	2	2	0	0	0	4	A
	Heavy metals	2	2	5	0	0	9	A
	Solid particles	2	2	2	0	0	6	A
Soil	N	10	0	0	0	0	10	A
	P	10	0	0	0	0	10	A
	K	10	0	0	0	0	10	A
	Pesticides	0	0	0		0	0	A

Continuation of Table 12

	Heavy metals	2	0	10	0	0	12	A
	Halogen-containing materials	5	5	0	0	0	10	A
	Waste heat/cool	2	0	0	0	0	2	A
	De-icing salt	2	0	10	0	0	12	A
	Soil treatment	10	0	5	0	0	15	A
	Extraction of raw materials	5	0	10	0	0	15	A
Waste	Hazardous waste	0	0	5	0	0	5	A
	Inert substances	0	0	0	0	0	0	A
	Residues	5	0	10	0	5	42	A
	Combustible raw materials	0	10	10	0	0	20	A
	Secondary raw materials	5	5	10	0	5	25	A
	Sewage sludge	2	0	5	0	0	7	A
Raw materials	Flammable substances	0	10	10	0	0	20	A
	Metal substances	0	0	10	0	0	10	A
	Non-metallic substances	0	0	5	0	0	5	A
	Reducing substances	0	2	0	10	0	12	A
	Water	10	5	5	2	0	22	A
Risk	Explosive substances	2	10	10	0	0	22	A
	Fire hazardous substances	2	10	10	0	0	22	A
	Toxic substances	0	5	5	0	0	10	A
	Substances that pollute water	2	0	5	0	0	7	A
	Corrosive materials	0	0	5	0	0	5	A
	Oxidising agents	0	2		0	0	2	A
	Danger of infection	10	0	0	2	0	12	A
	Gases under pressure	2	2	5	0	0	9	A
	Reactions with water	0	0	0	0	0	0	A
	Reactions with acids	0	0	0	0	0	0	A
Evaluation		147	181	252	14	45	639	
Compliance		B	B	B	A	A	C	

Using the relevant tables, it is possible to assess the impact of the main and auxiliary raw materials, stages of the technological process of product manufacturing, enterprise departments, life cycle stages, input and output aspects of the production process on the environment, including the impact of the main factors of the product life cycle on environmental elements (air, water, soil), assessment of waste generation and resource consumption, physical impact and risky environmental aspects.

This paper assesses the impact of the life cycle stages of organic bakery products that are essential for food (sample 2) on environmental components, and the results of this assessment are presented in Table 12.

Having analysed the data in Table 12, we can conclude that logistics has the greatest environmental impact, with a score of 252 points, while the bakery's activities also have a significant impact on the air, with a score of 181 points. The main pollutants released into the air during the production of bakery products are low molecular weight volatile organic compounds and SO_2, which are formed during the production of bakery products and whose impact is 32 points according to the expert assessment. The residues of bakery products (waste) also have a significant impact on the environment, with a score of 42. Modern water treatment systems ensure regular treatment of industrial and domestic wastewater, which significantly reduces the impact on the hydrosphere. Organic farming has helped to significantly reduce the anthropogenic burden on soils, namely by eliminating the use of pesticides, mineral fertilisers and transgenic crops. Organic farming involves the use of only organic fertilisers, which solves the problem of land contamination with toxic substances, the ingress of such substances into food and the disposal of animal waste.

The results presented in Table 12 suggest that the life cycle stages of consumption and disposal of FP have a minor environmental impact, with a score of 14 and 45 points respectively. The transport life cycle stage (252 points) takes into account the additive impact of transport from cradle to grave, i.e. at the stages of raw material cultivation, production, consumption and disposal.

Assessing the impact of the life cycle stages of organic bakery products (sample 2) with the inclusion of hop sourdough on environmental components, it can be concluded that the impact of such bakery products on environmental components is moderate and is estimated at 639 points and does not have a significant negative impact on the atmosphere, water resources or soil.

The impact of the life cycle stages of traditional bakery products (sample 1) on environmental components that are essential for food was also assessed, with a score of 1087 points, which characterises this impact as significant (Table 13).

Table 13

Life cycle impact assessment of bakery products using relevant tables

Bakery products	Maximum score according to the relevant table	Degree of impact	Impact value	Score in points
Sample 1	1087	Significant	C	0.01
Sample 2	639	Moderate	B	0.5

Having analysed the results of the research, it can be concluded that the sample of bakery products with the inclusion of hop additives has an overall score for all the criteria of the methodology for determining biologicality in the range of a positive conclusion with the need for further development. The biologicality score of the sample with the use of hop sourdough is 0.37, and the control sample is 0.00245.

Thus, the biologicality of sample 2 is 151 times higher than the biologicality content of the control sample produced using traditional technologies (Table 14).

Table 14

Evaluation of eco-labelling criteria for organic bakery products

Name of the criterion	Value of the indicator	
	Sample 2	Sample 1
Quality of FP, K1		
Organoleptic quality indicators of FP, C1	1	1
Safety indicators of food products, C2	1	0.5
Comprehensive indicators of ‘naturalness/organicity’ of FP by biocrystallisation method, C3	0.74	0.49
Indicator by the value of redox potential, C4	1	1
The impact of the LC products on environmental components, K2		
Environmental impact indicators using relevant tables, C5	0.5	0.01
Summarising assessment	0.37	0.00245

The results of the evaluation of the biodegradability criteria for sample 2 with the inclusion of hop sourdough are in the range of 0.5 to 0.03 (sample 2–0.37), which demonstrates a positive result, but is not sufficient for eco-labelling. In order to obtain an eco-label that would certify the biologicality of bakery products, it is necessary to refine and make minor changes to the technology and LC of these products.

Bakery products produced using conventional technology with a generalised score of 0.00245 require a complete revision of the production technology and significant changes to their LC, namely, reducing the impact of production on environmental components and increasing the ecologicality of the food product's LC by using raw materials only from organic farms and additional raw materials with the appropriate environmental labelling.

Conclusions

Thus, we have substantiated and developed a methodology for determining the biologicality of FP, which is advisable to use, in particular, for environmental labelling of FP. The developed methodology allows assessing the quality of FP using expert and experimental methods and quantitatively taking into account all input streams (raw materials, resources, including fuel and energy), output streams (solid waste, gas emissions, wastewater) and risky environmental aspects at all stages of the product life cycle.

The first stage of the methodology is to assess the quality criteria of food products, which include organoleptic characteristics of FP, food safety indicators, indicators of integrated organicity/naturalness and biological activity of food.

The organoleptic characteristics of bakery products comply with regulatory requirements and were assessed with the maximum score. The safety indicators of FP were investigated by the method of determining the integral toxicity by bioassay with *Colpoda steinii* infusoria. According to the results of bioassay with *Colpoda steinii* biosensors, the content of toxic substances is insignificant in two samples. The result of the analysis of water and hexane samples of sample 2 is a score of 1, which indicates their non-toxicity. Sample 1 (control) is slightly toxic according to the results of the analysis of water and hexane samples, which indicates the presence of certain toxic substances of non-polar and polar nature. The overall safety score for the control sample is 0.5.

Comprehensive indicators of naturalness/organicity of the products were studied using the crystallographic method – biocrystallisation. The biocrystallograms of the samples were examined for morphological features, symmetry, their interconnection and overall image quality. After interpreting the above features, the biocrystallogram score of the test sample using hop sourdough was 0.74 points, and the control sample was 0.49 points.

The evaluation of the biological activity of the product was determined according to the value of the redox potential of the samples. For the test sample, the ORP was +90 mV, for the control sample + 105 mV, both values are within the permissible range and were scored at 1 point each.

According to the expert assessment by the method of relevant tables, the LC of the tested bakery products was rated at 0.5 points, which characterises its environmental impact as moderate.

The tested bakery samples have an overall score for all the criteria of the methodology for determining biologicality in the range of a positive conclusion with the need for further development. The biologicality score of the sample using hop sourdough is 0.37, and the control sample is 0.00245.

Thus, the biologicality of the test sample is 151 times higher than the biologicality of the control sample made using pressed yeast. The conducted studies indicate the prospects of using the methodology for determining the biologicality of food products, in particular, for their environmental labelling.

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