UDC 664.66.022.39
DOI: 10.15587/2706-5448.2025.341512

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DETERMINING THE INFLUENCE OF PHYTOEXTRACTS ON THE QUALITY FORMATION OF BAKERY PRODUCTS

The object of the study is the technology of bakery products using Clitoria ternatea extracts and establishing their impact on the consumer characteristics of buns. The paper considers the possibility of using environmentally safe plant raw materials in the production of food products.

One of the problem areas in the use of the extract is the sensitivity of Clitoria ternatea anthocyanins to technological influences (temperature, acidity), color instability, specific organoleptic indicators of finished products and the impact on the physicochemical quality indicators of the semi-finished product and the finished product.

During the study, Clitoria ternatea and Malva mauritiana extracts were used. It was found that the extract from Clitoria ternatea has a significantly higher content of coloring substances at all levels of the hydromodule (0.5:50; 1.5:50; 2.5:50), which reflects a higher concentration of pigments in the raw material or their higher solubility, therefore Clitoria ternatea extracts were chosen. Increasing the concentration of flowers in the extract contributed to an increase in the content of polyphenols, flavonoids, a decrease in the acidity of the extracts, the density of the solutions almost did not change. Replacing water with Clitoria ternatea extract in the technology of bakery products contributed to a change in the physicochemical parameters of the dough and the finished product. The acidity of the dough and the finished product increased, the humidity decreased, the porosity of the finished product decreased.

As a result of the study, a technology of bakery products was developed using an aqueous extract of Clitoria ternatea flowers (hydromodulus 3.0:100), which provides a balance between technological and organoleptic properties. The samples had an exotic blue color, demonstrated better microbiological stability compared to the control, and the study of friability confirmed a positive effect on the preservation of crumb freshness compared to the control for 72 hours.

Keywords: *food colorants, phenolic compounds, anthocyanins, Clitoria ternatea, extraction, antioxidant activity.*

Received: 25.07.2025
Received in revised form: 24.09.2025
Accepted: 17.10.2025
Published: 30.10.2025

How to cite
Melnyk, O., Matisov, O., Foshchan, A., Sharan, L., Omelchenko, S., Dikhtyar, A., Shutyuk, V., Marenkova, T., Chepurda, L., Kurakin, O. (2025). Determining the influence of phytoextracts on the quality formation of bakery products. Technology Audit and Production Reserves, 5 (3 (85)), 49–59. https://doi.org/10.15587/2706-5448.2025.341512

1. Introduction

Actuality and problem statement. Today, bakery products remain an obligatory component of the menu of Ukrainians. Despite the fact that domestic bakery enterprises can offer buyers a wide range of products, new products account for less than 5% of the total output. Therefore, one of the promising tasks of the development of the bakery industry is to expand the range of bakery products by mastering new technologies and recipes. In addition, restaurant establishments, supermarkets are always interested in the high quality, freshness, sophistication and exclusivity of the presented products, including bakery products.

The development of modern society and the high pace of life in the last few years have significantly changed people's attitude to their own health and formed a new approach to choosing food products. Choosing a particular product, the consumer seeks to obtain not only the proteins, fats, and carbohydrates essential for the body, but also to strengthen their health, increase the protective functions of the body. Changes in consumer preferences of Ukrainians in recent years indicate the effectiveness and expediency of expanding the range of bakery products. The main directions of improvement are chosen taking into account the popularization of a healthy lifestyle [1].

At the same time, in the modern world, nutrition is increasingly perceived not as an act necessary to maintain life, but as an action that brings pleasure and evokes emotions. The main group of substances responsible for the attractiveness of food products are coloring substances. Natural dyes have long been an integral part of the usual human diet, since they are consumed without harm to health [2]. This is due to the fact that they contain biologically active components. Their use allows not only to improve the appearance, give an attractive color, but also to increase the biological and physiological value of food products.

Therefore, recently, many studies have been conducted on the use of modern plant raw materials as natural dyes for the production of various types of food products, including bakery products [3].

Natural dyes, one of which is the extract of *Clitoria ternatea* flowers, have a number of advantages and disadvantages. They are environmentally friendly and contribute to the formation of natural color of the product. However, on the other hand, their shade may depend on various factors. The extraction process is complex and the coloring properties may depend on the acidity of the medium, the effect of temperature, storage time, and others. The studies [4, 5] are devoted to the study of the process of extracting anthocyanins from *Clitoria ternatea* flowers and the choice of extraction method. They extracted anthocyanins from flowers, studied their spectral characteristics, behavior at different pH values, temperature treatment, and storage conditions, and also measured antioxidant activity. The extraction methods (hot water, organic solvents), the characteristics of ternates (polyacylated delphinidin glycosides), their resistance to pH, temperature, and light were compared. The possibilities of functional application as dyes and antioxidants were considered [6]. It was found that hot-water extraction is simple and safe for food applications. Ternates extracted from *Clitoria ternatea* flowers are stable anthocyanins, especially under neutral conditions. The use of these extracts has great practical potential, but requires standardization of the extracts and additional research on photostability and compatibility with complex food matrices.

Scientists [7] developed a technology for obtaining a powder dye from *Clitoria ternatea* flower extract by spray drying using maltodextrin, starch and gelatin carriers. It was found that drying with maltodextrin in combination with gelatin allows obtaining a powder with good stability and a longer shelf life, convenient to use as an ingredient.

The study [8] optimized the process of anthocyanin extraction from dried *Clitoria ternatea* flowers using the microwave extraction (MAE) method, determined the optimal extraction conditions, and proved the potential of field pea flowers as a reliable source of anthocyanins.

Researchers [9] considered an alternative drying technology – foam-mat drying – for encapsulation and stabilization of anthocyanins. It was determined that foam-mat drying under optimal conditions (for example, a certain drying temperature of ~ 80°C and an optimal % of foaming agent) can provide high encapsulation efficiency and preservation of the total anthocyanin content. Compared with spray-drying, this method yields a powder with other technological properties (larger particle size, worse solubility).

The possibility of using *Clitoria ternatea* in the development of food products (drinks, jams, desserts, yogurts) was also investigated. Some works describe the adaptation of recipes, color change when adding sugar, acid. Researchers experimentally confirmed the prospects of using the extract in various products, provided that technological parameters (double emulsions) are selected to preserve color and functionality, for anthocyanin delivery with higher stability [10]. The authors confirmed that butterfly pea flower extract is a promising natural ingredient for creating healthier, antioxidant- and fiber-enriched breakfast cereals produced by the extrusion method [11].

A series of experiments showed that probe ultrasonic extraction increased the yield of anthocyanins from biofilm coatings (BPF) by 246.48%. Due to the wide spectrum of colors at different pH, BPF anthocyanins are advantageous for food packaging, and their immobilization in polymer matrices changes the physicochemical properties, but retains the ability to effectively control the quality of perishable products in real time [12]. It has been found that in sweet systems (muffins, cupcakes) the colorant exhibits better stability. The use of the colorant in protein and alkaline systems requires encapsulation, which can extend the shelf life of baked foods [13, 14].

Studies of the quality of extracts were usually conducted on model systems, the possibility of their use in the production of flour products, in particular bakery products, requires separate studies. Optimal encapsulation systems for complex processes, such as baking, have only been described, but have not undergone practical testing in production conditions. The use of *Clitoria ternatea* extracts in the production of bakery products is a promising direction, however, there are a number of unresolved issues that hinder its widespread implementation. First of all, the optimal doses of extract administration have not been sufficiently studied. To simultaneously ensure a rich natural color and pronounced antioxidant effect without a negative impact on the taste, aroma and structure of the product. One of the key problems is the instability of bioactive substances, in particular anthocyanins. They are heat-sensitive and can be destroyed during baking, which reduces the functional value of the product. Additional attention needs to be paid to studying the effect of the extract on the sensory characteristics of the finished product, including color, smell and taste. Also their impact on consumer perception, since too intense or unusual coloration can be a barrier to mass consumption.

The effect of this ingredient on microbiological stability and shelf life of bakery products has not been studied, which is an important aspect of safety.

Despite these unresolved issues, the use of *Clitoria ternatea* in bakery products is advisable due to its natural properties. The extract is a source of natural anthocyanins, which give the products an intense color from blue to purple depending on the acidity of the environment. This corresponds to the current trends of replacing synthetic dyes with natural ones. In addition, anthocyanins have a pronounced antioxidant activity, which can improve the shelf life of bread by slowing down oxidation processes. They also have functional benefits, contributing to the strengthening of blood vessels, improving metabolism and protecting cells from free radical damage. Products with the addition of *Clitoria ternatea* have marketing appeal, as they meet the requirements of functional nutrition and a healthy lifestyle. Their unusual color can serve as a unique competitive advantage in the market. In addition, this raw material opens up opportunities for creating innovative products, in particular those that change color depending on the pH of the environment. This makes them interesting for the premium segment and gastronomic experiments.

Without the use of innovations, it is almost impossible to make a competitive product that would have a high degree of novelty. The use of plant raw materials allows for expanding the range of food products. It helps to improve their quality and nutritional value, provides antioxidant properties and helps to reduce the glycemic index.

In today's conditions, there is high competition in the bakery market in Ukraine: we have a wide range of products with various taste properties and nutritional value. The desire for a healthy lifestyle is prompting consumers to be interested in the composition of the product they consume. Today's customers prefer pure organic baked goods without synthetic preservatives. It is also worth noting that products made by hand in craft establishments (coffee shops, confectioneries, and fast food establishments) are gaining increasing demand.

There is a lot of data that in the conditions of modern life, it is impossible to adequately provide the body with all the nutrients necessary to maintain its vital functions through traditional nutrition [15–18]. Both in Ukraine and in Europe, bakery products enriched with minerals and beneficial additives are becoming increasingly popular. Bread of dietary and therapeutic and prophylactic directions attracts particular attention of buyers. According to World Health Organization, in many countries and regions, there is a trend towards increasing the use of plant-based substances. A study of the demand for medicinal plants in a number of countries has shown that this market has significant prospects for further development [19–21]. Plant raw materials used to provide functional properties to bakery products can be divided into groups. The first group includes non-traditional types of flour (amaranth, buckwheat, lentils, chickpeas, peas, corn, millet, sorghum, chestnuts, pumpkin flour). The second group includes fruit and berry raw materials (berries, dried fruits, purees, powders). The third group includes spices and aromatic herbs (oregano, thyme, basil, cardamom, ginger, cinnamon, etc.). The fourth group includes seeds and bran (flax, sesame, bran, chia, pumpkin seeds). The fifth group includes herbal supplements and phytoconcentrates (vegetable powders, green plants, superfoods (maca, acai, moringa, spirulina), extracts of medicinal plants, tea extracts, extracts of *Clitoria ternatea*). The use of various types of phytoresources in the production of bakery products allows to give them functional properties and influence the quality of human nutrition due to the mass consumption of bread [22, 23].

Clitoria ternatea is a species of flowering plant of the genus Clitoria of the family Fabaceae. It is a relatively new product on the international market. However, folk herbal medicine has preserved for posterity the invaluable experience of the past in the use of *Clitoria ternatea*. Aparajita, or *Clitoria ternatea*, is a well-known Ayurvedic plant and is included in the Indian Medicinal Plants Database. Its blue flowers are edible in Southeast Asian cuisine and have long been used there as a natural food coloring [24].

The flower extract of *Clitoria ternatea* is rich in anthocyanins, particularly ternates, which give products a rich blue color. This colorant is stable to high temperatures and has a long shelf life, making it attractive to food manufacturers.

Clitoria ternatea extract is used to add color to a variety of food products, including beverages, desserts, rice dishes, and confectionery. Its ability to change color with changing pH allows for the creation of products with unique visual effects.

In the United States, the extract of *Clitoria ternatea* has been approved by the Food and Drug Administration (FDA) as a food colorant that does not require certification for use in various foods and beverages.

A similar effect is also exerted by *Malva mauritiana*. *Malva mauritiana* is a perennial or biennial herbaceous perennial plant from the mallow family (Malvaceae), which is increasingly attracting the attention of scientists and producers due to its nutritional, medicinal and functional properties [25]. *Malva mauritiana* is a plant about 1 meter tall, has purple-blue flowers with darker veins, which makes it attractive as an ornamental and food crop, the origin of mallow is Southern Europe, North Africa [24].

Recent years around the world domestic and foreign scientists. Many studies are being conducted to establish the possibility of using modern phytoraw materials as plant dyes for the production of various types of food products, since plants are the main source of flavonoids and anthocyanins entering the human body with food [26–28].

In recent years, the number of scientific studies devoted to the study of the possibility of using natural preservatives in food production has increased significantly. As has been shown in numerous experiments, natural preservatives, namely antioxidants, are very important for increasing the safety of food products and extending their shelf life [29–32].

The strongest antioxidant properties are possessed by substances that determine the color of plants. Analysis of works that highlight the study of extracts *Clitoria ternatea*, shows that it contains flavonoids and anthocyanins, whose physiological functions are extremely diverse and important for reducing the risk of developing many common diseases. Researchers [33, 34] have proven that extracts *Clitoria ternatea* have a wide range of pharmacological effects, including antimicrobial, antipyretic, anti-inflammatory, analgesic, diuretic, local anesthetic, antidiabetic, insecticidal, and platelet aggregation inhibitory, and act as natural antioxidants in the fight against free radicals.

However, the amount and properties of anthocyanins are significantly affected by pH, temperature, light, and metal ions in the environment, so their use in food requires additional research to create the necessary conditions for their storage. Since during food processing, food materials undergo heat treatment and must with stand storage conditions and photostress, anthocyanins must have acceptable thermal stability, photostability and storage stability. One method to increase the stability of anthocyanins is copigmentation [35]. Therefore, scientists have conducted studies on the stability of anthocyanins from blue pea flowers in terms of their thermal stability, storage stability and photostability. It was found that at temperatures above 50°C, partial or complete degradation of anthocyanins from natural sources occurs, which leads to a decrease in color intensity. Anthocyanins from flowers *Clitoria ternatea* at an acidic pH of 3.6–5.4 they are stable in the range of 60–70°C. When the temperature exceeds 70 with the rate of degradation of anthocyanins increases [5].

Other researchers have confirmed the finding that the degradation rate of anthocyanins from *Clitoria ternatea* flowers increases with increasing temperature and under the influence of light [36]. The presence of benzoic acid in the extract extended the "stabilization period" at 27 and 37°C. Since the blue color has a relatively high thermal stability, this makes anthocyanins from *Clitoria ternatea* flowers suitable for use as a natural food color in functional foods.

Studies have shown [37] that temperature and time factors affected the extraction of phenolic compounds, antioxidant activity and physicochemical parameters. Principal component analysis revealed experimental conditions that provided extraction with the highest level of phenolics (40°C/30 min). The extract demonstrated antimicrobial activity; protective effect against erythrocyte hemolysis; inhibition of α-amylase, α-glucosidase and enzymes, inhibition of lipid peroxidation, demonstrated the ability to absorb oxygen radicals; inhibition of DNA strand breaks.

Currently, anthocyanin pigments are actively promoted all over the world [38]. The main pigment in the flower of *Clitoria ternatea* is delphinidin, the presence of which contributes to the stability of the blue color of the plant flower extract at high temperatures. It is this factor that determines the prospects of use *Clitoria ternatea* as a raw material for obtaining a biologically active food dye and the possibility its use in baking. Studies by scientists have shown that the use of the extract can help reduce the digestibility of starch, the glycemic index (pGI) of flour by inhibiting carbohydrate digestive enzymes. Foreign researchers [39] conducted in vitro studies with the addition of 0.5–2% (w/v) of the extract to different types of flour (wheat, rice, starch) and found a decrease in the activity of pancreatic α-amylase. A decrease in the content of rapidly digestible (RDS) and slowly digestible (SDS) starch, as well as an increase in the content of indigestible starch, was found. When adding 5–20% of the extract to wheat bread, a significant decrease in the glycemic index (pGI) and the rate of starch digestion was observed. Toxicological studies on rodents [40, 41], and in vitro cytotoxicity analysis [42], as well as historical use of the plant, have shown that *Clitoria ternatea* is safe for consumption at a dose of 500 and 1000 mg/kg body weight, has potent antibacterial activity and can be used for the development of both functional foods and nutraceuticals.

Malva mauritiana is also a phytoraw material used as a decoration in the confectionery industry, the extracts of which have coloring properties. Anthocyanins (malvin), flavonoids (quercetin, rutin), vitamins C, E, β-carotene, minerals (calcium, potassium, iron) have been found in mallow. *Malva mauritiana* is a promising phytoraw material for food products, as it gives finished products a purple-blue color, has anti-inflammatory, antiseptic and softening properties, has a calming effect and is unpretentious in cultivation [43]. Edible coatings with its extracts have a recognized environmental effect, are an alternative for slowing down the processes of moisture evaporation and mold growth in baked goods [44].

Thus, the analysis of recent studies and publications shows that the properties of flavonoids and their extracts are of interest to manufacturers of fortified food products. It is also worth noting that food establishments are striving to use natural plant raw materials and functional food ingredients derived from them.

At the same time, the blue color of the Thai drink (obtained by extraction from dried flowers of) and the extract of *Malva mauritiana*. It is determined by the presence of unique anthocyanins, which are in a neutral environment in the quinoid form with other phenolic compounds, is still little known in Ukraine. The main research in Ukraine is aimed at studying the components of anthocyanin extracts as the main bioactive components, the properties of which depend on pH, temperature, light exposure, etc. Their potential as natural dyes in the food industry has been emphasized [38].

The enrichment of dairy products with *Clitoria ternatea* anthocyanins was investigated. An increase in antioxidant activity in yogurts was found, and the possibility of using it as a functional component was established [45].

Pharmacological aspects of the plant were also discussed in a review article [46], such as antioxidant and cytotoxic activity, antidiabetic activity, local anesthetic effect, gastrointestinal effect, anti-inflammatory, analgesic, antipyretic activity, antihistamine activity, effects on learning and memory, antidepressant, tranquilizing and sedative activity, anticonvulsant and antistress activity, antiasthmatic activity, hepatoprotective activity and wound healing effect.

Researchers analyzed the content of phenols and anthocyanins in different products – cupcake [13], noodles [47]. It was found that the addition of *Clitoria ternatea* extract to muffins contributed to an increase in protein and moisture content, and the inclusion of the extract in the noodle formulation (20–30% w/w) resulted in an increase in antioxidant activity and a decrease in strength and extensibility.

In [48], the use of *Clitoria ternatea* flower powder in the cookie recipe was researched. The optimal concentration was found to be 6%, since the products had the best organoleptic characteristics, and a reduction in bitterness during storage was observed due to the inhibition of the formation of hydroperoxide in the cookies.

It was found [49] that the addition of (0, 5, 10, 15 and 20%, w/w) of the extract to biscuits contributed to an increase in polyphenol content and enhanced antioxidant activity, while reducing lipid peroxidation.

Research shows [50] that the leaves and flowers of *Malva sylvestris* are the most commonly used parts of the plant and contain various biologically active compounds such as flavonoids, mucilages, terpenoids, phenolic derivatives, coumarins, sterols, tannins, saponins and alkaloids, which are responsible for anti-inflammatory, antimicrobial, hepatoprotective, laxative and antioxidant activities.

Scientists have created a film made of corn starch and gum tragacanth, enriched with *Malva sylvestris* flower extract (0.5–2%), which works as a pH indicator – changes color depending on the freshness of the fillet samples (under the influence of ammonium) [51].

Also [52] a composition based on Mallow (*Malva sylvestris*) seed mucilage combined with *S. boulardii* postbiotics was considered as a potential natural preservative for meat storage. The film exhibited excellent antimicrobial and antioxidant activity, preserving the organoleptic properties of the product after 10 days at +4°C.

The possibility of using microencapsulation to stabilize anthocyanins, preserve color and bioactivity was also investigated, and the prospects for using extracts as a natural blue dye and antioxidant in food products, especially in baked goods, were established [14].

The problem of using plant raw materials is especially relevant for Ukraine, where in conditions of radiation pollution, malnutrition, and insufficient supply of vitamins and minerals, almost every resident needs adaptogens, radioprotectors, and immunomodulators to maintain health. The use of natural plant resources as sources of polyphenolic compounds, which to a greater or lesser extent exhibit their antioxidant activity, will allow not only to expand the range of bakery products, but also to improve their chemical composition.

Therefore, given that bakery products are mass-produced products, the use of *Clitoria ternatea* extract in their production will have a number of advantages. First of all, the extract of the flowers of this plant is a valuable source of anthocyanins, which act as natural dyes, giving the products an attractive blue or purple color depending on the acidity of the dough. In addition to the aesthetic effect, *Clitoria ternatea* extract has pronounced antioxidant properties, which slows down the oxidation processes of fat components and reduces the intensity of product rancidity, which has a positive effect on their shelf life. Anthocyanins and other phenolic compounds of the extract are able to have a positive effect on the human body, in particular, enhance antioxidant protection and help reduce the negative impact of free radicals. In addition, the innovativeness of the use of plant extracts opens up wide marketing opportunities for manufacturers, because products with pronounced beneficial properties are well received by consumers and can form new niches in the bakery market. Thus, the use of *Clitoria ternatea* extract in the production of buns will not only contribute to expanding the range of functional bakery products, but will also allow influencing biological processes in the human body through diet.

The aim of the research is to determine the properties of extracts of *Clitoria ternatea* and *Malva mauritiana* for the purpose of their use in bakery technology. The next stage is to improve the technology of bakery products using aqueous extract of flowers of *Clitoria ternatea*. The use of the extract gives the products an interesting blue color and has a positive effect on human health, as it gives the products functional properties.

To achieve the stated aim, the following objectives were set:

– determination of physicochemical properties of *Clitoria ternatea* and *Malva mauritiana* flower extracts;
– to establish the feasibility of using extracts of the studied raw materials in the technology of bakery products;
– to research the organoleptic and physicochemical properties of finished products;
– to establish the effect of adding extracts of the studied raw materials on the shelf life of bakery products.

2. Materials and Methods

The object of the study is bakery technology using plant extracts and determining their influence on the consumer characteristics of buns.

The research was conducted at the Sumy National University, Laboratory of the Department of Food Technology (Ukraine).

The work investigated the content of coloring substances in extracts of *Clitoria ternatea* flowers and *Malva mauritiana* in aqueous solutions. *Clitoria ternatea* flowers and dried *Malva mauritiana* flowers (rosestem) were used as a source of coloring substances.

The organoleptic and physico-chemical parameters of extracts from *Clitoria ternatea* and *Malva mauritiana* flowers were determined using standard methods:

– Dry matter (soluble) – DSTU ISO 2173:2007.
– Titrated acidity – DSTU 4957:2008.
– Mass concentration of coloring substances – DSTU 3845-99.

Infusion was carried out at a temperature of 20 ± 0.5°C, lasting 10 min. Optical density was determined on KFK-2 (photoelectric concentration colorimeter, MedTech-Price) with a wavelength of 315–630 nm, a working cell of 10 mm. Data processing and graphic material construction were carried out in the OriginPro program.

Studies of extracts from *Clitoria ternatea* flowers were conducted according to the following methods (Table 1).

Table 1

Methods for studying the properties of phytoextracts

Indicator name	Regulatory document
Active acidity, pH	DSTU 6045:2008
Mass fraction of titrated acidity, °	DSTU 4957:2008
Density at 20°C, kg/m^3	DSTU 7261:2012
Research on the content of anthocyanins in raw materials in terms of cyanidin-3-O-glycoside, %	State Federal University "Blueberries, fresh fruits"
Research on the content of hydroxycinnamic acids in raw materials, %	TFS (42U-6/37-232-96) "Canadian wormwood grass"
Research on the content of polyphenolic compounds in raw materials in terms of gallic acid, %	State Federal University "Blueberries, fresh fruits"
Content of tannins in raw materials (in terms of tannins), %	GOST 24027.2-80

The research materials included the ingredients of the bun recipe, aqueous extract of *Clitoria ternatea* flowers, semi-finished dough and finished product.

During the study, bakery products with the addition of extracts of the studied raw materials were analyzed using standard, generally accepted research methods.

Sample selection and preparation were carried out according to current standards for bread and bakery products – DSTU 7044:2009 [53]. Sensory analysis was carried out using a scoring method using a group of tasters who evaluated the samples according to established criteria, in accordance with DSTU 9188:2022 [54].

The determination of titrated acidity was carried out by the alkali neutralization method using an indicator according to DSTU 7044:2009 [53]. Determination of the moisture content of the dough and finished bread was carried out by the express drying method on the Chyzhova device. The friability and porosity of the finished bread were determined according to DSTU 9188:2022 [54].

Microbiological indicators of the finished bakery products were determined according to DSTU EN ISO 4833-1:2014 [55].

3. Results and Discussion

The study used *Clitoria ternatea* flowers (mass fraction of moisture 10.2%) in the form of Anchan tea and dried *Malva mauritiana* flowers (mass fraction of moisture 12.1%), which were collected and dried in Ukraine in 2023.

Clitoria ternatea flowers and dried mallow blossom were respectively filled with heated distilled water with a temperature of 60–70°C (ratio 0.5:50, 1.5:50, 2.5:50) and stirred thoroughly to evenly moisten the blossom. Extraction was carried out for 10 minutes. The obtained extract was cooled for 45 minutes at room temperature and filtered.

Fig. 1 shows the dependence of optical density on the hydromodulus (the ratio of the solid phase to the liquid): sample 1 (hydromodule 0.5:50), sample 2 (hydromodule 1.5:50) and sample 3 (hydromodule 2.5:50) in the wavelength range from 315 to 670 nm.

The abscissa axis in Fig. 1 shows the wavelength measured in nanometers (nm), which represents the different colors of visible light, from ultraviolet (315 nm) to the red of the visible spectrum (670 nm).

The maximum absorption peak for the extract from *Clitoria ternatea* is in the range of 315–400 nm, followed by a sharp decline in the range of 450–500 nm and a gradual increase to 550–590 nm and a decline at 600–670 nm. This profile indicates the presence of acylated anthocyanins, particularly ternatein [56], characteristic of *Clitoria ternatea*, with absorption maxima in the range (350–400 nm) and the visible spectrum (520–580 nm), which is confirmed by stability at high temperatures [57].

For the mallow extract, the maximum absorption peak is reached in the range of 500–550 nm, with local maxima at 400–450 nm and 600–650 nm and a decline in the range of 600–670 nm. This profile is typical for anthocyanins, in particular malvidin, characteristic of *Malva mauritian*, with maxima at 520–540 nm, which corresponds to a blue-green color [58].

The smaller peak at 400–450 nm indicates flavonoids, while the peak at 600–650 nm may indicate degradation products of anthocyanins (quinoids).

The absorption bands differ in the stability of the pigments. For clitoria, the peaks at 350–400 nm and 550–600 nm reflect thermostable acylated anthocyanins which can withstand high temperatures of up to 80–90°C, as confirmed by [57]. For mallow, the peak at 500–550 nm is less intense due to degradation of the anthocyanins during extraction, which is consistent with their instability at temperatures above 50°C [58].

We analyzed the content of coloring substances in the extracts (Table 2).

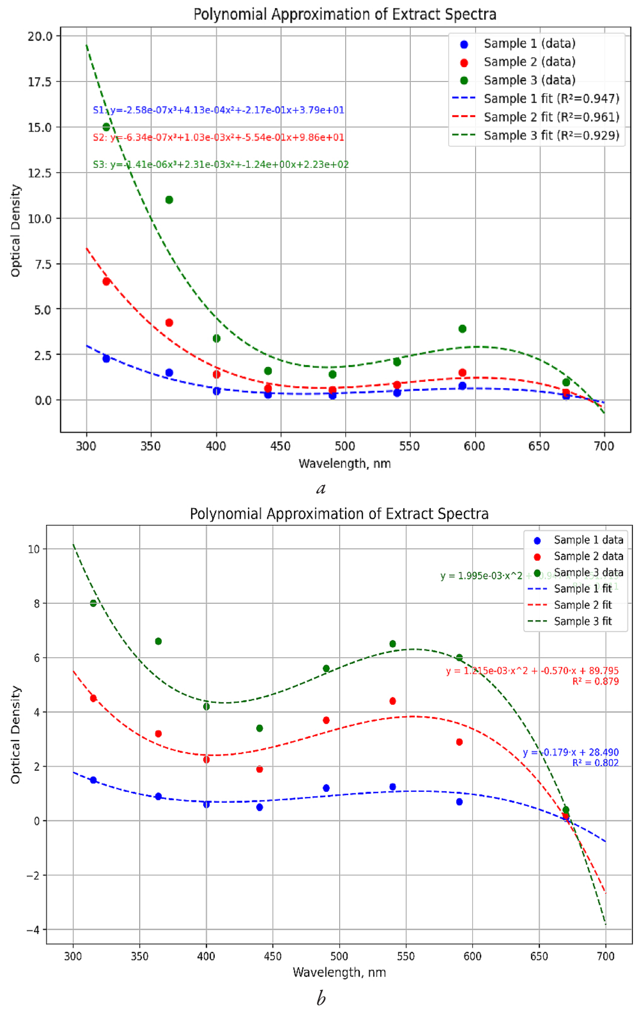

Fig. 1. Dependence of the optical density of the extracts: *a* – extract from *Clitoria ternatea*; *b* – extract from *Malva mauritiana* on the hydromodulus: sample 1 – hydromodule 0.5:50; sample 2 – hydromodule 1.5:50; sample 3 – hydromodule 2.5:50

Table 2

The content of coloring matter in extracts in terms of sulfuric acid cobalt

Sample name	Content of coloring substances, g/kg	
	Malva mauritian extract	Extract from *Clitoria ternatea*
Extract sample 1 (hydromodule 0.5:50)	3.02	19.1
Extract sample 2 (hydromodule 1.5:50)	8.5	26.1
Extract sample 3 (hydromodule 2.5:50)	13.5	38.2

According to Table 2, it is seen that the extract from *Clitoria ternatea* has a significantly higher content of colorants at all levels of the hydromodule. This reflects a higher concentration of pigments in the raw material or their higher solubility. The increase in content for both extracts with a hydromodule of 0.5:50 to 2.5:50 (4.5 times for mallow and 2.0 times for *Clitoria ternatea*) confirms the effectiveness of the higher solvent ratio, but the difference in growth rates (slowdown for mallow) may indicate degradation of its pigments. In general, the obtained data emphasize the advantage of Clitoria as a source of dyes (the content of dyes in *Clitoria ternatea* extract is three times higher than their content in mallow extract). *Clitoria ternatea* dyes do not decompose and are more stable. Taking this into account, to improve the technology of buns and give them special organoleptic and functional properties at this stage, *Clitoria ternatea* flowers were selected.

Clitoria ternatea is a promising medicinal and food plant that is widely used in the food industry, in particular as a source of natural dye. The chemical composition of *Clitoria ternatea* is extremely rich, the main components are flavonoids and anthocyanins, among which the key place is occupied by ternatein, an anthocyanin pigment that provides a rich blue color of flowers. This pigment shows a color change depending on the acidity of the environment: in an acidic environment, the infusion of Clitoria acquires a purple or pink hue, which is a useful property for creating innovative food products.

In addition to anthocyanins, clitoria contains flavonoids, in particular quercetin, kaempferol and myricetin, which have antioxidant properties. Saponins have also been found in the flowers, which contribute to emulsification and improve the bioavailability of other substances, alkaloids such as cliotides and apparatin, as well as cyclic peptides – cyclotides, which have antibacterial, antifungal and immunomodulatory effects. The plant also contains phenolic compounds such as gallic and ellagic acids, which enhance antioxidant activity, as well as water-soluble polysaccharides, which exhibit immunomodulatory properties.

Clitoria ternatea contains a significant amount of vitamins, including vitamin C and β-carotene, as well as macro- and microelements – potassium, magnesium, calcium, phosphorus, zinc and iron, which makes it a useful additive to functional food products. Due to this composition, extracts of *Clitoria ternatea* are actively used in the production of culinary products, beverages, jellies, confectionery. The extracts are also used in healthy and functional nutrition, where not only the nutritional, but also the aesthetic and functional value of the product is important. Anthocyanins, along with ascorbic acid, are among the most important natural water-soluble antioxidants. The peculiarity of anthocyanins is not only that they have the highest solubility in water among the large class of flavonoids. They also have a color that depends on pH. Therefore, anthocyanins are considered the most important natural colorants that enrich products with optional components [5].

Extraction of phenolic compounds from *Clitoria ternatea* flowers was carried out in accordance with the recommendations presented above. Since the color saturation of the crumb of a baked product depends on the color saturation of the extract, aqueous extracts were investigated to establish the required color intensity of the baked product *Clitoria ternatea* in ratios: 0.5:50, 1.5:50, 2.5:50. The finished extracts had a characteristic smell, taste and color. With increasing concentration in the finished extracts, a color change from light blue to dark sapphire was observed. Due to the high amount of extracted anthocyanins from the raw materials (70–80%), the applied technology can be considered effective.

The results of determining the physicochemical parameters of extracts from *Clitoria ternatea* flowers are presented in Table 3.

The obtained data indicate a decrease in both the active and titrated acidity of the extracts, which is probably connected with the beneficial properties of the extract and the interaction of acids with other compounds. With an increase in the concentration of flowers in the extract, the content of polyphenols, flavonoids and other substances increases, which can interact with organic acids, forming complexes that reduce their free acidity. An increase in the amount of raw materials used leads to an increase in the content of dry substances, but the density of the solution almost does not change. Since *Clitoria ternatea* flowers are a source of coloring substances, polyphenols, anthocyanins, increasing its dosage in solutions for preparing extracts contributes to an increase in the amount of these substances in extracts, which is confirmed by studies (Table 2).

The choice of the dosage of the dye for the production of a bakery product depends on the desired color and the required intensity of color, as well as on the physicochemical properties of the product. A test baking was carried out, where 100 g "Miska" bun made from high-grade wheat flour was used as the control sample [59]. The dough was prepared using a single-phase method. Instead of the traditional addition of water, aqueous extracts of various concentrations were used, as a result of which it was found that their use has a positive effect on the conduct of the technological process.

The preparation of buns in a single-phase method using the extract of *Clitoria ternatea* involves the preparation of the recipe components: sifting flour, sugar, melting margarine. *Clitoria ternatea* extract was prepared by steeping dried flowers in hot water at a temperature of 60–70°C for 10 minutes, followed by cooling to a temperature suitable for incorporation into the dough. Next, the dry ingredients (flour, sugar, salt) were mixed, yeast, margarine, and extract were added, and the dough was kneaded until a homogeneous and elastic mass was formed. The dough was left to ferment for 60–90 minutes at a temperature of about 28–30°C, during which it increased in volume by 2–2.5 times. After fermentation, the dough was divided into pieces weighing 110 g and formed into round-shaped blanks, laid out on sheets and left to rise for 40–50 minutes at a temperature of 35–37°C and a relative humidity of 75–80%. Baking was carried out in an oven at a temperature of 180–200°C for 10–15 minutes. Under the influence of high temperature, the crust acquired a brown color, the crumb of the buns had a pleasant blue tint, which gave them a special appeal. The finished products were cooled to a temperature of 20–25°C and packed in polypropylene bags for storage. The recipe for buns using clitoria extract is presented in Table 4.

Therefore, the use of *Clitoria ternatea* extract in the production of buns is advisable, as it gives the products a natural color, increases their antioxidant activity, slows down the processes of rancidity, improves organoleptic characteristics, and increases the marketing attractiveness of the finished product.

The analysis of physicochemical parameters is presented in Table 5.

Table 3

Physico-chemical quality indicators of extracts from *Clitoria ternatea* flowers

Indicator	Raw	Aqueous extract		
		0.5:50	1.5:50	2.5:50
Active acidity, pH	–	7.0 ± 0.03	6.8 ± 0.07	6.6 ± 0.03
Study of the mass fraction of titrated acidity of extracts, °	2.1 ± 0.146	0.9 ± 0.013	0.15 ± 0.0163	0.2 ± 0.0125
Soluble solids analysis, %	–	0.1 ± 0.0082	0.7 ± 0.021	0.8 ± 0.022
Density at 20°C, kg/m^3	–	1.016 ± 0.0025	1.016 ± 0.0025	1.017 ± 0.0026
Research on the mass concentration of coloring substances, g/dm^3	–	19.1 ± 0.03	26.1 ± 0.03	38.2 ± 0.032
Research on the content of anthocyanins in terms of cyanidin-3-O-glycoside, %	0.14 ± 0.0013	0.043 ± 0.0013	0.06 ± 0.0031	0.12 ± 0.0025
Research on the content of hydroxycinnamic acids in raw materials, %	0.12 ± 0.0013	0.013 ± 0.0013	0.035 ± 0.0013	0.069 ± 0.0022
Research on the content of polyphenolic compounds in raw materials in terms of gallic acid, %	0.47 ± 0.0053	0.017 ± 0.0014	0.075 ± 0.0025	0.19 ± 0.0058
Research on the content of tannins in raw materials in terms of tannins, %	2.63 ± 0.029	0.07 ± 0.0023	1.24 ± 0.018	1.38 ± 0.037

Table 4

Recipe for buns using *Clitoria ternatea* extract

Ingredients, g	Control sample	Sample 1 (1.0:100)	Sample 2 (3.0:100)	Sample 3 (5.0:100)
Top-grade wheat flour	100.0	100.0	100.0	100.0
Clitoria ternatea extract	70.0	70.0	70.0	70.0
Pressed baker's yeast	1.3	1.3	1.3	1.3
Salt	1.5	1.5	1.5	1.5
Sugar	6.0	6.0	6.0	6.0
Margarine	2.5	2.5	2.5	2.5

Table 5

Physico-chemical properties of dough and finished product with *Clitoria ternatea* extract

Indicator	Control sample	Sample 1 (1.0:100)	Sample 2 (3.0:100)	Sample 3 (5.0:100)
Physico-chemical properties dough				
Humidity, %	44.0 ± 0.5	43.7 ± 0.4	43.5 ± 0.5	42.8 ± 0.6
Acidity, degrees	0.9 ± 0.1	0.9 ± 0.1	1.1 ± 0.1	1.2 ± 0.1
Physico-chemical properties buns				
Humidity, %	43.5 ± 0.5	43.2 ± 0.5	43.0 ± 0.5	42.4 ± 0.5
Acidity, degrees	0.8 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
Porosity, %	73 ± 2	72 ± 2	70 ± 2	68 ± 2

Replacing water with *Clitoria ternatea* extract contributes to a slight change in physico-chemical indicators. The acidity of the dough and the finished product increases, the humidity decreases slightly. The nature of the porosity also changes, it becomes smaller, the quantitative indicator of porosity decreases slightly.

The finished products had good organoleptic characteristics. With increasing concentration of aqueous extracts, an increase in the saturation of the blue color in the crumb of the products was observed. The obtained samples had uniform, well-developed porosity and elastic crumb. No foreign odor or taste was observed (Fig. 2).

Based on the data obtained, a pleasant blue color and the required color intensity for the new bakery product were achieved at aqueous extract concentrations 3.0:100. With decreasing extract concentration the desired intensity of blue is not achieved, with an increase – the product becomes excessively dark in color, the volume of the product decreases slightly andits cost price increases.

a *b* *c* *d*

Fig. 2. Appearance of finished bun samples:
a – control without adding extract; *b* – sample 1 (1.0:100);
c – sample 2 (3.0:100); *d* – sample 3 (5.0:100)

Sensory analysis was performed after cooling the finished products after 4 hours, which provided optimal conditions for evaluating organoleptic indicators.

The organoleptic profile of the samples (Fig. 3) reflects the average scores for all indicators. The profile allows for a visual assessment of the strengths and weaknesses of each sample.

The control sample demonstrated the classic characteristics of a bunmade using the traditional method. The appearance was attractive: the product had an even, rounded shape without cracks, with a smooth surface. The crust had a golden-brown hue, evenly colored. The crumb was light cream in color, homogeneous, without visible inclusions. The smell was pronounced bready, with light sweet notes characteristic of a bakery product. The taste was harmonious, with moderate saltiness and sweetness, without foreign aftertastes. The structure of the crumb was distinguished by uniform medium porosity, high elasticity and softness. The crust was thin, crispy, without excessive hardness.

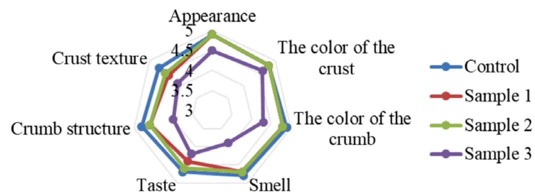

Fig. 3. Profile of the results of sensory analysis of samples

Sample 1 had characteristics close to the control, but with minor differences due to the addition of the extract. The appearance remained attractive, with an even shape and a smooth surface. The color of the crumb was light cream with a delicate blue tint, which added to the aesthetic appeal. The smell retained a bready character, but light herbal notes appeared, associated with the flavonoids of the extract. The structure of the crumb remained uniform, the crust was crispy, but slightly thicker compared to the control sample.

Sample 2 was distinguished by an optimal balance of organoleptic indicators. The appearance of the bread was aesthetically attractive: the shape was even, the surface was smooth, the crust had a distinct golden hue. The crumb had a pronounced pale blue color, uniform, without spots or inclusions. The smell combined a bread aroma with moderate herbal and floral notes associated with the extract. The taste was rich, with a light herbal aftertaste, which was in harmony with the traditional bread taste. The structure of the crumb was soft, with uniform fine porosity. The crust remained crispy with a pleasant texture.

Sample 3 had noticeable deviations from the control sample. The appearance remained satisfactory. The crust had a rich golden color with a blue tint, which seemed unnatural to some tasters. The crumb was dark blue, which affected the perception of the product as traditional bread. The smell was characterized by pronounced herbal notes. The taste had a noticeable herbal aftertaste. The structure of the crumb was dense, with fine porosity. The crust was thicker and less crispy. The bun had a smaller volume.

The microbiological stability of the buns was evaluated to confirm the possibility of extending the shelf life to 10 days due to the antimicrobial properties of the *Clitoria ternatea* extract. The analysis was performed after manufacturing and after 3, 7, and 10 days of storage at a temperature of 20 ± 2°C and a humidity of 75 ± 5%. The results of the microbiological analysis are given in Table 6.

The results of microbiological analysis indicate that samples 2 and 3 demonstrate improved microbiological stability compared to the control sample. Due to the antimicrobial action of anthocyanins, flavonoids and phenolic acids, this sample provides a reduction in the growth of mesophilic aerobic and facultative anaerobic microorganisms on the 8th day of storage. This allows to achieve a shelf life of 6–7 days that are 1–2 days exceeding the expiration date of the control sample. By microbiological indicators, the obtained data confirm the effectiveness of *Clitoria ternatea* extract.in extending the shelf life of a bun.

Phenolic compounds are the key to the antimicrobial and antioxidant properties of the aqueous extract of *Clitoria ternatea* flowers and play an important role in extending the shelf life of bakery products using it (Table 7).

ISSN-L 2664-9969; E-ISSN 2706-5448

Table 6

Microbiological indicators of bread with *Clitoria ternatea* extract, CFU/g

Indicator	Day	Control sample	Sample 1	Sample 2	Sample 3
Mesophilic aerobic and facultative anaerobic microorganisms (MAFAM)	0	$< 10^2$	$< 10^2$	$< 10^2$	$< 10^2$
	3	10^2	10^2	$< 10^2$	$< 10^2$
	7	10^4	10^3	10^2	10^2
	10	10^4	10^4	10^3	10^3
Molds mushrooms	0	< 10	< 10	< 10	< 10
	3	< 10	< 10	< 10	< 10
	7	10^2	10^2	< 10	< 10
	10	10^3	10^2	10^2	10^2
Escherichia coli bacteria	0–10	Not detected	Not detected	Not detected	Not detected
Staphylococcus aureus	0–10	Not detected	Not detected	Not detected	Not detected
Salmonella	0–10	Not detected	Not detected	Not detected	Not detected

Table 7

Analysis of crumb friability of buns with *Clitoria ternatea* extract compared to the control sample

Indicator	Duration storage of the finished product		
	Day 1	Day 2	Day 3
Crumb friability, %			
Control sample	1.15	1.30	1.43
Sample 1	1.15	1.25	1.40
Sample 2	1.14	1.22	1.36
Sample 3	1.14	1.20	1.34

The results of the crumb friability study indicate a positive effect of the flower extract on maintaining the freshness of the crumb during storage and slowing down the staling of the finished product compared to the control over 72 hours.

Thus, the analysis of the properties of the extract from the flowers of *Clitoria ternatea* and the possibility of its application in the production of bakery products allows improvement of their consumer properties. The finished product contains phenolic compounds, anthocyanins, antioxidants, saponins, which are lacking in flour systems. As a result of the addition of the extract, original, high-quality products are obtained that have an extended shelf life.

These products have marketing appeal, as products using *Clitoria ternatea* extracts are trendy in the functional and premium product segment, as they have a bright and recognizable color. The color can change at different pH, giving the products new sensory properties. In addition, the anthocyanins of the extract contribute to strengthening blood vessels, improving metabolism and protecting cells from free radicals.

Clitoria ternatea anthocyanins are heat-sensitive, but there is not enough research on their preservation at high temperatures.

The interaction of Clitoria ternatea extracts with the main structural and biochemical components of dough, particularly the protein-gluten complex, enzymatic systems, and minor ingredients, has not been sufficiently studied. Such interactions may significantly influence the rheological behavior of dough, including water absorption capacity, elasticity, viscosity, and gas-holding ability, which in turn directly affects the technological properties during fermentation and baking. Moreover, the incorporation of bioactive compounds, such as anthocyanins and polyphenols, could potentially interfere with enzymatic reactions in the dough system, altering starch hydrolysis, sugar availability for yeast fermentation, and the dynamics of crust formation during baking. These processes may lead either to improvements in nutritional and functional properties of bakery products or to undesirable changes in texture, volume, and sensory characteristics.

A further challenge in the application of *Clitoria ternatea* extracts lies in the absence of standardized technological parameters for their production and use. At present, no universally accepted requirements exist regarding extract quality, anthocyanin concentration, stability, pH range, or solubility in aqueous food systems. Variations in raw material origin, processing methods, and storage conditions can result in significant fluctuations in extract composition, thereby complicating their integration into bakery technologies. Standardization is therefore necessary to ensure reproducible technological performance and consistent product quality.

The use of *Clitoria ternatea* extract in the production of bakery products is promising, but the results of the studies depend on the conditions of extraction, dosage, and technological parameters of the technological process. The main limitation is the thermolability of anthocyanins and the effect of the extract on the structure of the dough, which makes it difficult to reproduce the results on an industrial scale. Further research should be directed towards improving the stability of anthocyanins, optimizing processing regimes, developing encapsulated forms of the extract, and studying their impact on the quality and consumer properties of the finished product to standardize production processes.

From an industrial perspective, the economic feasibility of employing Clitoria ternatea extracts in large-scale bakery production remains largely unassessed. No comprehensive cost-benefit analyses have yet been performed to evaluate the financial implications of replacing or supplementing conventional ingredients with such extracts. Key issues include the potential increase in raw material costs, the effect on production efficiency, and the impact on the final retail price of the product. Equally important is the question of consumer acceptance and willingness to pay for bakery products enriched with exotic botanical extracts. While health-conscious and innovation-oriented market segments may demonstrate interest, broader consumer demand will likely depend on balancing enhanced functional and sensory qualities with accessibility.

4. Conclusions

1. The study of the physicochemical properties of the extracts showed that the extract of *Clitoria ternatea*, in comparison with the extract of mallow, has a rich composition of bioactive compounds: anthocyanins 0.04–0.12%, coloring substances 26.1 g/dm^3, polyphenolic acids 0.075%, hydroxycinnamic acids 0.035%. The extract has a slightly acidic environment with pH 6.6–6.8, which provides antimicrobial activity against mold fungi Aspergillus, Penicillium and bacteria Bacillus subtilis. Its dark blue color and neutral taste with a slight sourness make it suitable for baking.

2. It was found that the extract from *Clitoria ternatea* flowers has a significantly higher content of coloring substances at all levels of the hydromodule, which reflects a higher concentration of pigments in the raw material or their higher solubility. The increase in the content for both extracts (*Clitoria ternatea* and *Malva mauritiana*) with a hydromodulus from 0.5:50 to 2.5:50 (4.5 times for mallow and 2.0 times for *Clitoria ternatea*) confirms the effectiveness of the higher solvent ratio, but the difference in growth rates (slowing down for mallow) indicates the degradation of its pigments. The obtained data emphasize the advantage of *Clitoria ternatea* as a source of dyes and anthocyanins (the content of dyes in the extract of *Clitoria ternatea* is three times higher than their content in the extract of mallow). The pigments of *Clitoria ternatea* do not degrade and are more stable. Therefore, the use of extract of *Clitoria ternatea* in the production of buns is appropriate and will provide them with special organoleptic and functional properties.

3. By organoleptic evaluation, it was established that the optimal concentration of *Clitoria ternatea* extract for use in bread technology is 3.0:100. This concentration provides a balance between the technological properties of the dough and the organoleptic characteristics of the product, giving the crumb a delicate blue color and a harmonious taste.

The effect of *Clitoria ternatea* extract on the physicochemical properties of the dough and the finished product was studied. It was found that with an increase in the concentration of the extract, the moisture content in the dough decreases by 0.1–0.2%, and the acidity increases by 0.1–0.2 degrees. The physicochemical properties of the finished product do not undergo significant changes compared to the control, moisture and porosity decrease slightly, and acidity increases by 0.1 degrees. The finished product has a homogeneous porous structure, delicate crumb and attractive appearance. Organoleptic indicators received high marks, indicating a harmonious taste with light herbal notes.

4. The study of the effect of extracts on the shelf life of the bun showed that samples with the addition of the extract demonstrated improved microbiological stability compared to the control sample. Probably due to the antimicrobial effect of anthocyanins, flavonoids and phenolic acids, the growth of mesophilic aerobic and facultative anaerobic microorganisms is reduced even on the 8th day of storage. This makes it possible to extend the shelf life of the studied products by 1–2 days compared to the control sample according to microbiological indicators. The results of the study of the crumb friability of the finished product confirmed the positive effect of the flower extract on preserving the freshness of the crumb during storage and slowing down the staling of the finished product compared to the control for 72 hours. Therefore, the use of the extract as a potential source of natural dye with antioxidant properties is appropriate and relevant, although it requires further research. This will allow us to abandon synthetic preservatives and influence the processes of microbiological spoilage. This will allow us to combine quality improvement, shelf life extension and innovative product design, which will increase its competitiveness in the market, especially in coffee shops, confectionery and fast food chains.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors used artificial intelligence technologies within acceptable limits to support their own verified data, as described in the methodology section.

References

1. Lebedenko, T. E., Novichkova, T. P, Sokolova, N. Iu., Miserzhi, M. D. (2011). Novye istochniki biologicheski aktivnykh komponentov dlia proizvodstva khleba. *Zernovi produkty i kombikormy, 3 (43),* 23–28.
2. Mohamad, M. F., Dailin, D. J., Gomaa, S., Nurjayadi, M., El Enshasy, H. (2019). Natural colorant for food: A healthy alternative. *International Journal of Scientific & Technology Research, 8 (11),* 3161–3166. Available at: https://www.ijstr.org/final-print/nov2019/Natural-Colorant-For-Food-A-Healthy-Alternative.pdf
3. Vega, E. N., Ciudad-Mulero, M., Fernández-Ruiz, V., Barros, L., Morales, P. (2023). Natural Sources of Food Colorants as Potential Substitutes for Artificial Additives. *Foods, 12 (22),* 4102. https://doi.org/10.3390/foods12224102
4. Fu, X., Wu, Q., Wang, J., Chen, Y., Zhu, G., Zhu, Z. (2021). Spectral Characteristic, Storage Stability and Antioxidant Properties of Anthocyanin Extracts from Flowers of Butterfly Pea (*Clitoria ternatea L.*). *Molecules, 26 (22),* 7000. https://doi.org/10.3390/molecules26227000
5. Vidana Gamage, G. C., Lim, Y. Y., Choo, W. S. (2021). Anthocyanins from Clitoria ternatea flower: Biosynthesis, extraction, stability, antioxidant activity, and applications. *Frontiers in Plant Science, 12,* 792303. https://doi.org/10.3389/fpls.2021.792303
6. Netravati, N., Gomez, S., Pathrose, B., Raj, M. N., Joseph, M. P., Kuruvila, B. (2022). Comparative evaluation of anthocyanin pigment yield and its attributes from Butterfly pea (*Clitorea ternatea L.*) flowers as prospective food colorant using different extraction methods. *Future Foods, 6,* 100199. https://doi.org/10.1016/j.fufo.2022.100199
7. Fuzetti, C. G., Castilhos, M. B. M., Nicoletti, V. R. (2022). Microencapsulation of natural blue dye from butterfly pea (*Clitoria ternatea L.*) flowers: The application of different carriers. *Journal of Food Processing and Preservation, 46 (4).* https://doi.org/10.1111/jfpp.16420
8. Riniati, R., Widiastuti, E., Ismail, M. N., Mochamad, K. (2024). Optimization of Total Anthocyanin Content Extraction from Dried Butterfly Pea Flowers (*Clitoria ternatea L.*) Using Microwave Assisted Extraction (MAE) Method. *Fluida, 17 (2),* 71–77. https://doi.org/10.35313/fluida.v17i2.6049
9. Maneeratanachot, S., Chetpattananondh, P., Kungsanant, S. (2024). Encapsulation of anthocyanin from butterfly pea flowers (*Clitoria ternatea L.*) extract using foam-mat drying. *Food and Bioproducts Processing, 145,* 105–115. https://doi.org/10.1016/j.fbp.2024.03.003
10. Koirala, P., Sriprablom, J., Winuprasith, T. (2023). Anthocyanin-Rich Butterfly Pea Petal Extract Loaded Double Pickering Emulsion Containing Nanocrystalline Cellulose: Physicochemical Properties, Stability, and Rheology. *Foods, 12 (22),* 4173. https://doi.org/10.3390/foods12224173
11. Singh, R., Yu, C.-C., Chen, G.-W., Chen, C.-H., Sinaki, N. Y., Lin, J. et al. (2022). Butterfly Pea Flower as a Novel Ingredient to Produce Antioxidant-Enriched Yellow Pea-Based Breakfast Cereals. *Foods, 11 (21),* 3447. https://doi.org/10.3390/foods11213447
12. Hasanah, N. N., Mohamad Azman, E. M., Rozzamri, A., Zainal Abedin, N. H. Z., Ismail-Fitry, M. R. (2023). A Systematic Review of Butterfly Pea Flower (*Clitoria ternatea L.*): Extraction and Application as a Food Freshness pH-Indicator for Polymer-Based Intelligent Packaging. *Polymers, 15 (11),* 2541. https://doi.org/10.3390/polym15112541
13. Thanh, V. T., Tran, N. Y. T., Linh, N. T. V., Vy, T. A., Truc, T. T. (2020). Application of anthocyanin natural colors from Butterfly Pea (*Clitoria ternatea L.*) extracts to cupcake. *IOP Conference Series: Materials Science and Engineering, 736 (6),* 062014. https://doi.org/10.1088/1757-899x/736/6/062014
14. Ab Rashid, S., Tong, W. Y., Leong, C. R., Abdul Ghazali, N. M., Taher, M. A., Ahmad, N. et al. (2021). Anthocyanin Microcapsule from Clitoria ternatea: Potential Bio-preservative and Blue Colorant for Baked Food Products. *Arabian Journal for Science and Engineering, 46 (1),* 65–72. https://doi.org/10.1007/s13369-020-04716-y
15. Generalic Mekinic, I., Simat, V. (2025). Bioactive Compounds in Foods: New and Novel Sources, Characterization, Strategies, and Applications. *Foods, 14 (9),* 1617. https://doi.org/10.3390/foods14091617
16. Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S. et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet, 393 (10170),* 447–492. https://doi.org/10.1016/s0140-6736(18)31788-4

17. Yilmaz, H., Yilmaz, A. (2025). Hidden Hunger in the Age of Abundance: The Nutritional Pitfalls of Modern Staple Crops. *Food Science & Nutrition, 13 (2).* https://doi.org/10.1002/fsn3.4610
18. Bhardwaj, R. L., Parashar, A., Parewa, H. P., Vyas, L. (2024). An Alarming Decline in the Nutritional Quality of Foods: The Biggest Challenge for Future Generations' Health. *Foods, 13 (6),* 877. https://doi.org/10.3390/foods13060877
19. Bareetseng, S. (2022). The Worldwide Herbal Market: Trends and Opportunities. *Journal of Biomedical Research & Environmental Sciences, 3 (5),* 575–584. https://doi.org/10.37871/jbres1482
20. Parvin, S., Reza, A., Das, S., Miah, Md. M. U., Karim, S. (2023). Potential Role and International Trade of Medicinal and Aromatic Plants in the World. *European Journal of Agriculture and Food Sciences, 5 (5),* 89–99. https://doi.org/10.24018/ejfood.2023.5.5.701
21. Ivanišová, E., Kačániová, M., A. Savitskaya, T., D. Grinshpan, D.; Ahmad, R. S. (Ed.) (2021). Medicinal Herbs: Important Source of Bioactive Compounds for Food Industry. *Herbs and Spices – New Processing Technologies.* IntechOpen. https://doi.org/10.5772/intechopen.98819
22. Rahaie, S., Gharibzahedi, S. M. T., Razavi, S. H., Jafari, S. M. (2012). Recent developments on new formulations based on nutrient-dense ingredients for the production of healthy-functional bread: a review. *Journal of Food Science and Technology, 51 (11),* 2896–2906. https://doi.org/10.1007/s13197-012-0833-6
23. Đurović, S., Vujanović, M., Radojković, M., Filipović, J., Filipović, V., Gašić, U. et al. (2020). The functional food production: Application of stinging nettle leaves and its extracts in the baking of a bread. *Food Chemistry, 312,* 126091. https://doi.org/10.1016/j.foodchem.2019.126091
24. Vivek-Ananth, R. P., Mohanraj, K., Sahoo, A. K., Samal, A. (2022). *IMPPAT 2.0: an enhanced and expanded phytochemical atlas of Indian medicinal plants.* bioRxiv. https://doi.org/10.1101/2022.06.17.496609
25. Al-Rubaye, A. F., Kaizal, A. F., Hameed, I. H. (2017). Phytochemical Screening of Methanolic Leaves Extract of *Malva sylvestris. International Journal of Pharmacognosy and Phytochemical Research, 9 (4).* https://doi.org/10.25258/phyto.v9i4.8127
26. Chua, L. S., Thong, H. Y., Soo, J. (2024). Effect of pH on the extraction and stability of anthocyanins from jaboticaba berries. *Food Chemistry Advances, 5,* 100835. https://doi.org/10.1016/j.focha.2024.100835
27. Lijon, M. B., Meghla, N. S., Jahedi, E., Rahman, M. A., Hossain, I. (2017). Phytochemistry and pharmacological activities of *Clitoria ternatea. International Journal of Natural and Social Sciences, 4 (1),* 1–10. Available at: https://www.researchgate.net/publication/312498930_Phytochemistry_and_pharmacological_activities_of_Clitoria_ternatea
28. Martillanes, S., Rocha-Pimienta, J., Delgado- Adámez, J.; Díaz, A. V., García-Gimeno, R. M. (Eds.) (2018). Agrifood By-Products as a Source of Phytochemical Compounds. *Descriptive Food Science.* IntechOpen. https://doi.org/10.5772/intechopen.79434
29. Czubaszek, A., Czaja, A., Sokół-Łętowska, A., Kolniak-Ostek, J., Kucharska, A. Z. (2021). Changes in Antioxidant Properties and Amounts of Bioactive Compounds during Simulated In Vitro Digestion of Wheat Bread Enriched with Plant Extracts. *Molecules, 26 (20),* 6292. https://doi.org/10.3390/molecules26206292
30. Teshome, E., Forsido, S. F., Rupasinghe, H. P. V., Olika Keyata, E. (2022). Potentials of Natural Preservatives to Enhance Food Safety and Shelf Life: A Review. *The Scientific World Journal, 2022,* 1–11. https://doi.org/10.1155/2022/9901018
31. Damani, Z., Topi, D. (2022). Application of Plant Extracts in the Food and Pharmaceutical Industry. *Novel Techniques in Nutrition & Food Science, 6 (4).* https://doi.org/10.31031/ntnf.2022.06.000644
32. Harfoush, A., Swaidan, A., Khazaal, S., Salem Sokhn, E., Grimi, N., Debs, E. et al. (2024). From Spent Black and Green Tea to Potential Health Boosters: Optimization of Polyphenol Extraction and Assessment of Their Antioxidant and Antibacterial Activities. *Antioxidants, 13 (12),* 1588. https://doi.org/10.3390/antiox13121588
33. Shoviantari, F., Erawati, T., Soeratri, W., Rahmadi, M., Permadi, G. W., Rafibahtiyar, M. (2024). Antioxidant, Anti-Melanogenesis, and Cytotoxic Effects of *Clitoria ternatea* (Butterfly Pea) Flower Extract on B16 Melanoma Cells. *Tropical Journal of Natural Product Research, 8 (12).* https://doi.org/10.26538/tjnpr/v8i12.15
34. Athallah, D. R., Rudiyanto, W., Wijaya, S. M., Angraini, D. I. (2024). Pharmacological potential of butterfly pea (*Clitoria ternatea*). *Medula Journal of Medical Profession, 14 (8),* 1613–1619.
35. Charurungsipong, P., Tangduangdee, C., Amornraksa, S., Asavasanti, S., Lin, J. (2020). Improvement of Anthocyanin Stability in Butterfly Pea Flower Extract by Co-pigmentation with Catechin. *E3S Web of Conferences, 141,* 03008. https://doi.org/10.1051/e3sconf/202014103008
36. Lee, P. M., Abdullah, R., Lee, K. H. (2011). Thermal degradation of blue anthocyanin extracts of Clitoria ternatea flower. *2nd International Conference on Biotechnology and Food Science, 7,* 49–53.
37. Escher, G. B., Marques, M. B., do Carmo, M. A. V., Azevedo, L., Furtado, M. M., Sant'Ana, A. S. et al. (2020). *Clitoria ternatea L.* petal bioactive compounds display antioxidant, antihemolytic and antihypertensive effects, inhibit α-amylase and α-glucosidase activities and reduce human LDL cholesterol and DNA induced oxidation. *Food Research International,* 128, 108763. https://doi.org/10.1016/j.foodres.2019.108763
38. Kryzhak, L. (2022). Antocyanes from Clitoria ternatea flowers. *Herald of Khmelnytskyi National University, 305 (1),* 269–272. https://doi.org/10.31891/2307-5732-2022-305-1-269-272
39. Chusak, C., Henry, C. J., Chantarasinlapin, P., Techasukthavorn, V., Adisakwattana, S. (2018). Influence of *Clitoria ternatea* Flower Extract on the In Vitro Enzymatic Digestibility of Starch and Its Application in Bread. *Foods, 7 (7),* 102. https://doi.org/10.3390/foods7070102
40. Khatib, A., Tofrizal, Arisanty, D. (2024). Toxicity effects of *Clitoria ternatea L.* extract in liver and kidney histopathological examination in Mus musculus. *IIUM Medical Journal Malaysia, 23 (1).*
41. Sri Widianti, Sunarti, Febrina, D. (2024). Bilirubin level, SGOT, and SGPT of rats on acute toxicity of butterfly pea ethanol extract (*Clitoria Ternatea L.*). *Jurnal Ilmiah Farmasi Farmasyifa, 7 (1),* 67–78. https://doi.org/10.29313/jiff.v7i1.3149
42. Jeyaraj, E. J., Lim, Y. Y., Choo, W. S. (2022). Antioxidant, cytotoxic, and antibacterial activities of *Clitoria ternatea* flower extracts and anthocyanin-rich fraction. *Scientific Reports, 12 (1).* https://doi.org/10.1038/s41598-022-19146-z
43. Mousavi, S. M., Hashemi, S. A., Behbudi, G., Mazraedoost, S., Omidifar, N., Gholami, A. et al. (2021). A Review on Health Benefits of *Malva sylvestris L.* Nutritional Compounds for Metabolites, Antioxidants, and Anti-Inflammatory, Anticancer, and Antimicrobial Applications. *Evidence-Based Complementary and Alternative Medicine, 2021,* 1–13. https://doi.org/10.1155/2021/5548404
44. Alexieva, I., Baeva, M., Popova, A., Fidan, H., Goranova, Z., Milkova-Tomova, I. (2022). Development and Application of Edible Coatings with *Malva sylvestris L.* Extract to Extend Shelf-Life of Small Loaf. *Foods, 11 (23),* 3831. https://doi.org/10.3390/foods11233831
45. Sutakwa, A., Nadia, L. S., Suharman, S. (2021). Addition of blue pea flower (*Clitoria ternatea L.*) extract increase antioxidant activity in yogurt from various types of milk. *Jurnal Agercolere, 3 (1),* 31–37. https://doi.org/10.37195/jac.v3i1.123
46. Manimaran, D. (2023). A review on the ethnobotany and phytochemical composition and functions of different parts of *Clitoria ternatea*, butterfly pea flower. *Journal of Food, Nutrition and Population Health, 7 (3).* Available at: https://www.primescholars.com/articles/a-review-on-the-ethnobotany-and-phytochemical-composition-and-functions-of-different-parts-of-emclitoria-ternateaem-butt.pdf
47. Shiau, S.-Y., Yu, Y., Li, J., Huang, W., Feng, H. (2023). Phytochemical-Rich Colored Noodles Fortified with an Aqueous Extract of *Clitoria ternatea* Flowers. *Foods, 12 (8),* 1686. https://doi.org/10.3390/foods12081686
48. Multisona, R. R., Myszka, K., Kulczyński, B., Arnold, M., Brzozowska, A., Gramza-Michałowska, A. (2024). Cookies Fortified with Clitoria ternatea Butterfly Pea Flower Petals: Antioxidant Capacity, Nutritional Composition, and Sensory Profile. *Foods, 13 (18),* 2924. https://doi.org/10.3390/foods13182924
49. Pasukamonset, P., Pumalee, T., Sanguansuk, N., Chumyen, C., Wongvasu, P., Adisakwattana, S. et al. (2018). Physicochemical, antioxidant and sensory characteristics of sponge cakes fortified with *Clitoria ternatea* extract. *Journal of Food Science and Technology, 55 (8),* 2881–2889. https://doi.org/10.1007/s13197-018-3204-0
50. Batiha, G. E.-S., Tene, S. T., Teibo, J. O., Shaheen, H. M., Oluwatoba, O. S., Teibo, T. K. A. et al. (2023). The phytochemical profiling, pharmacological activities, and safety of malva sylvestris: a review. *Naunyn-Schmiedeberg's Archives of Pharmacology, 396 (3),* 421–440. https://doi.org/10.1007/s00210-022-02329-w
51. Noghani Bahambari, F., Rajabi Islami, H., Shamsaie Mehrgan, M. (2024). Extract of common mallow (*Malva sylvestris*) petals incorporated in starch/tragacanth gum film as a halochromic indicator for monitoring of *Nile tilapia* (Oreochromis niloticus) fillet quality. *Journal of Food Measurement and Characterization, 18 (6),* 4161–4176. https://doi.org/10.1007/s11694-024-02484-z
52. Abbasi, A., Sabahi, S., Bazzaz, S., Tajani, A. G., Lahouty, M., Aslani, R. et al. (2023). An edible coating utilizing *Malva sylvestris* seed polysaccharide mucilage and postbiotic from *Saccharomyces cerevisiae var. boulardii* for the preservation of lamb meat. *International Journal of Biological Macromolecules, 246,* 125660. https://doi.org/10.1016/j.ijbiomac.2023.125660
53. *DSTU 7044:2009 Vyroby khlibobulochni. Pravyla pryimannia, metody vidbyrannia prob, metody vyznachannia orhanoleptychnykh pokaznykiv i masy vyrobiv* (2009). Kyiv: Derzhspozhyvstandart Ukrainy, 21.

54. *DSTU 9188:2022 Vyroby khlibobulochni. Orhanoleptychne otsiniuvannia pokaznykiv yakosti* (2022). Kyiv: DP "UkrNDNTs", 14.

55. *DSTU EN ISO 4833-1:2014 Mikrobiolohiia kharchovoho lantsiuha. Horyzontalnyi metod pidrakhunku mikroorhanizmiv. Chastyna 1. Pidrakhunok kolonii za temperatury 30° S metodom rozlyvu po chashkakh (EN ISO 4833-1:2013, IDT)* (2014). Kyiv: DP "UkrNDNTs", 18.

56. Marpaung, A., Paramaputri, A. (2023). UV-visible light spectra of Clitoria ternatea L. flower extract during aqueous extraction and storage. *International Food Research Journal, 30 (3),* 764–773. https://doi.org/10.47836/ifrj.30.3.18

57. Kazuma, K., Noda, N., Suzuki, M. (2003). Flavonoid composition related to petal color in different lines of Clitoria ternatea. *Phytochemistry, 64 (6),* 1133–1139. https://doi.org/10.1016/s0031-9422(03)00504-1

58. Torskangerpoll, K., Andersen, Ø. M. (2005). Colour stability of anthocyanins in aqueous solutions at various pH values. *Food Chemistry, 89 (3),* 427–440. https://doi.org/10.1016/j.foodchem.2004.03.002

59. Drobot, V. I. (2019). *Dovidnyk z tekhnolohii khlibopekarskoho vyrobnytstva.* Kyiv: Prof Knyha, 580. Available at: https://profbook.com.ua/index.php?download_id=1203&product_id=3131&route=product%2Fproduct%2Fdownload

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