CHAPTER 4

Evaluation of the usage of spontaneous fermentation sourdough starters and their influence on the quality indicators of wheat bread

Nataliia Slobodyanyuk
Oksana Tkachuk
Tetiana Brovenko
Tetiana Lebedenko
Halyna Tolok
Tamara Novichkova
Petro Drozd
Mykola Gruntkovskyi

Abstract

The limited availability of production laboratories at mini-enterprises, as well as outdated regulatory approaches to quality control which do not fully meet the modern range of bakery products, technological solutions, and consumer demands, significantly complicate the implementation of innovative technologies in the industry.

The aim of this study was to evaluate the feasibility of using and the effect of spontaneous fermentation sourdough, prepared in two different ways (dry and liquid starters based on wine yeast) on the quality indicators of wheat bread.

In the process of forming requirements to the quality of wheat bread, the physical, chemical, and biotechnological indicators of dry and liquid sourdough were determined; their sensory characteristics were evaluated.

As a result of the test baking, the quality indicators of wheat bread made using spontaneous fermentation starters based on wine yeast were evaluated.

Bread samples prepared with 5% and 7% of sourdough to the weight of flour, and control bread prepared without sourdough were compared in terms of shelf life and sensory properties. The dough preparation technology provides for a leaven-free method, with thick and liquid leaven; control samples were prepared using traditional technology. The addition of sourdough significantly affected the specific volume and porosity and slowed the loss of moisture during storage. Sensory

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properties improved compared to the control samples. Using 7% of liquid sourdough gave the most effective results.

The obtained results substantiate the technological feasibility of using the studied spontaneous fermentation sourdough starters in the production of bread products and demonstrate their potential for improving their quality indicators. Technologies and methodologies are recommended for mini-enterprises and craft bakeries.

Keywords

Bread products, sourdough starters, wine yeast, spontaneous fermentation, quality indicators.

4.1 Introduction

Bakery products for many nations of the world are synonymous with well-being, national wealth and food security, they have long accompanied a person from the first days of birth and throughout life as the most stable source of energy and nutrients and biologically active substances. Bread, its recipe and cooking technology are one of the points of national identification, an integral part of history, traditions and culture [1]. However, over the past half century, the US and EU countries have seen a decrease in the consumption of primarily traditional bakery products, and there is a growing trend towards a gluten-free diet [2] This is associated with the inconsistency of sensory characteristics, physical and chemical indicators, safety, and product range with consumer demands [3].

Quality criteria that cause concern also include the low content of nutrients and biologically active substances in significant volumes of products; high calorie content and amount of easily digestible carbohydrates; significant amount of salt; the use of a wide range of synthetic additives at all stages of industrial production (growing grain, obtaining flour, making bread); wheat and products made from it are among the top ten allergens, including due to gluten; the threat from yeast and genetically modified organisms; high content of acrylamide, which is formed during bread making and has carcinogenic properties, etc. All this raises doubts among consumers and a number of nutritionists about the safety of bread and fears of the spread of a whole range of diseases: diabetes, celiac disease, allergies, depression, cardiovascular diseases, cancer, metabolic disorders, gastrointestinal tract, nervous system [4].

In this regard, research has been intensified to study the nutritional characteristics of bread and the factors of their formation and influencing factors and to find answers to the question: "Why could our ancestors consume and digest bread, but for today's consumers this is a problem?" One of the reasons is the transition to industrial accelerated preparation of dough and bread using active commercial yeast, the loss of the traditions of long-term dough preparation with sourdough, including spontaneous fermentation [5].

The popularity of craft bread is growing since it uses long-term fermentation technologies which ensures the formation of strong bread sensory characteristics, the transformation of biopolymers with improved digestibility, storage stability without the use of synthetic improvers, etc. [5, 6].

In times of crisis during the pandemic, hostilities, destruction of infrastructure, restrictions on logistical connections, rising energy prices and blackouts, craft and artisanal bakeries and technologies for long-term dough preparation using local raw materials have gained special importance. They play an important role in ensuring accessibility to basic food products due to their flexibility, high level of adaptability, and proximity to the raw material producer and consumer [7].

Restoration of ancient national culinary traditions, the use of technologies that were formed under the influence of history, culture, available raw materials, nature and climate can help in solving the problems of production and consumption [8].

4.2 History and traditions of bread baking: the basis for the formation of scientific principles for integrating wine yeast into spontaneous sourdough bread technology for sustainable production of quality products

For the sustainable development of modern bread baking in European countries, five associations (AIBI – Association of Plant Bakers; CEBP – European Confederation of national Bakery and Confectionery Organizations; COFALEC – Confederation of European Yeast Producers; European Flour Millers; Fedima – Federation of European Manufacturers and Suppliers of Ingredients to the Bakery, Confectionery and Patisseries Industries), which unite small, medium and large manufacturers of bakery products, flour mills and manufacturers and suppliers of yeast and other ingredients, created a coalition in Brussels in 2016 and signed a Memorandum on the formation of the "Bread Initiative".

The main tasks are to revive the history and introduce innovations in bread baking, declare bread and its technology as UNESCO World Intangible Cultural Heritage, debunk myths and unfounded stereotypes about the harm of bread products to the human body, and support developments aimed at creating a range of products that will better satisfy the views of consumers, doctors, and producers [9].

As part of the "Bread Initiative" project, a program document "Let's Keep Bread on the Table" was prepared and adopted, which proposed key measures for 2024–2029 to implement the adopted strategy for the development of bread baking to maintain the image and improve the production of bread as a nutritious and tasty staple food in the diet of Europeans, guarantee sustainable production and food security, taking into account the challenges of modernity, particularly the pandemic [10].

Therefore, one of the tasks of the European "bread initiative" is to preserve the cultural heritage associated with bread, collect information on the history of bread baking, which will allow to offer measures proven over the centuries to improve the quality and nutritional value of products. For example, it is possible to preserve and enhance the valuable physiological properties of grain and improve the consumer characteristics of bread, reduce the risk of its allergenic properties as a result of a better use of cereals by returning to ancient crops such as spelt that have not undergone selection and genetic changes [11], as well as by reviving ancient recipes and technologies of bakery products traditional for different peoples, which involve long-term ripening of dough and the use of sourdough starters with natural microflora [12]. Consumers, doctors, and specialists around the world note the relevance of studying the centuries-old experience of making bread in the context of eras, territories and peoples, establishing promising technological techniques in terms of effective comprehensive formation of product quality. This coincides with the statements of the European "Bread Initiative" that the revival of ancient national technologies should become the basis of an alternative strategy for the development of modern bread baking.

But this is an extremely difficult, global and multidisciplinary task, since the information is largely lost and ambiguous, and thus requires search and restoration, conducting modern research and analysis of archaeological finds, historical references, documentary sources and ethnography of different peoples, and their systematization with the participation of specialists from various fields.

The generally accepted history of bread baking, which has been adhered to for a long time, is as follows. Cereals were used by man as a food product as early as 7000 BC. The first loaves of bread were found in the Neolithic period, which are from 6000 to 9000 years old. According to one hypothesis, sourdough, as a mixture of flour and water, fermented by natural lactic acid bacteria and wild yeast, was first used to leaven bread in Ancient Egypt, about 4000 BC. From Egypt, the art of bread baking, according to this hypothesis, spread north to Ancient Greece, where bread was also the main product, and more than 70 different savory and sweet types were produced. References to this date back to the 5th century BC. The Romans adopted the technology of sourdough bread production and spread it throughout Europe.

According to the works of the ancient Roman historian Pliny the Elder, sourdough bread was widespread in the Roman Empire in the 2nd century BC [13].

According to another hypothesis, which appeared much later, the first traces of yeast bread come from Europe, when it appeared in the 5th millennium BC. During this period, agriculture and grain cultivation flourished from the Balkans to Ukraine, and remains of leavened bread have been found in Romania, in the Danube Delta, in the Swiss Alps, and elsewhere in Europe [14].

Recent studies of the yeast genome have shown that the canonical brewer's and baker's yeast *Saccharomyces cerevisiae* originated in China and, according to another hypothesis, it was from there that they spread to the West along the Silk Road 16–14 thousand years ago [15].

In recent years, the database on the evolution of cereals and bread has been expanding. Thus, modern archaeological and botanical studies indicate that cereals have been used by humanity for more than 14 thousand years [16], first beer was produced about 13 thousand years ago, and the first bread from yeast-free (unleavened) dough was made about 12 thousand years ago. Genetic studies of wine residues have given grounds to assume that it was the microflora from the surface of grapes that was used approximately 8500–4000 BC. in winemaking, bread making and even for grain fermentation in beer brewing and preparation of other fermented beverages. Such a culture, according to the authors [17], was traditional for the Middle East, Mesopotamia, the Black Sea region (Trypillian culture, Caucasus, Transcaucasia, Eastern Turkey, Ancient Italy, and other countries), where grapes were grown.

The Gauls (ancient tribes in what is now France, Belgium, parts of Switzerland, Germany, Romania, and Northern Italy) and the Iberians (in modern Spain) used foam skimmed from beer when making dough. Some sources attribute the Celtic people to the first use of beer brewing by-products to simplify bread making. British texts from the 11th century mention the use of dried foam, called "*barm*", which appeared on the surface of the fermenting liquid used in the production of traditional ale. According to the authors, this method became widespread in Europe in the 14th and 15th centuries [13].

Sourdough continued to be used in Europe, especially for the production of rye bread, which requires high acidity. Rye sourdough, including based on spontaneous microflora, is still widely used for dough preparation in the countries of Northern and Eastern Europe, where a lot of rye bread is traditionally consumed.

As for the Ukrainian history of bread baking, there is little information as well. It is known that the beginning of grain farming, the cultivation of wheat and barley in Ukraine dates back to the 7th millennium BC, it is associated with the Trypillia culture. The ability to cook unleavened bread is indicated by clay models of loaves, which were discovered in settlements of the 6th millennium BC. Barley grains that underwent fermentation dated to the 5th millennium BC have been found, which proves the ability to make beer. In settlements of the Black Sea region of the same period, grape seed prints were found, which indicates the possibility of winemaking in this territory. That is, the preparation of alcoholic drinks begins about 7 thousand years ago [18, 19].

This is the basis for the assumption that under such conditions it is possible to use wine and beer yeast to prepare "fermented" ("yeast", "sour", "leavened") dough, but archaeological, documentary evidence for this has not been found. There is no unanimous opinion among scientists regarding the source of the dough leavening method in Ukraine, and the exact time frame for the beginning of its use in bread making has not been established. The appearance of sourdough bread in various sources [20] dates from the 3–4th centuries AD, which is hypothetically explained by borrowing the term "hlaifs" of Gothic origin for the name of leavened bread, to the 6–7th centuries AD, confirmed by the finds in Slavic settlements of ritual clay loaves that imitated baked leavened loaves. Although, given the close ties with Ancient Greece, the undeniable existence in the Northern Black Sea region of the Greek city-states of Tyre, Olbia and others, founded as early as the 7–5th centuries BC, it is worth noting the assumption that the spread of the traditions of leavened bread came from here and the term "bread" may come from the Ancient Greek word "klibanos": the name of a conical baking dish.

However, documentary references to baking leavened (sourdough) bread date back to the times of Kievan Rus (11th century), which prove the use of various types of leavens in Orthodox churches, monasteries and households [21]. According to the famous Ukrainian ethnographer, academician M. Sumtsov, the invention of "sourdough" bread occurred as a result of the fact that the dough, which remained in an uncleaned vessel, began to ferment and turned into sourdough, which induced fermentation in the new dough [22].

Sourdough recipes and methods of making them have varied somewhat across the regions of Ukraine and over time. They were made from rye or wheat flour, less often mixed with buckwheat or corn flour, with the addition of water and possibly hop decoction, yarrow, whey, sour milk, brewer's yeast, wine must, bean broth, boiled beets, potatoes, etc.

The process of making sourdough bread was complex and time-consuming. The bread was kneaded in a wooden trough or in a bowl, kneading a portion of the flour with warm water and adding "roshyna" (a piece of dough left over from the previous preparation of bread), "rozkryshka" (a loaf of bread kneaded in hop water) or another type of microbiological and biochemical starter. Enrichers of the water-flour mixture were also added, which created better conditions for the reproduction of fermenting microflora. For example, sometimes the dough was made with "grits" (steamed rye bran that had fermented); in some villages, tartar or boiled potatoes were added. This steamed mixture, called "prima", was left to ferment in a warm place. When the mass began to ferment, it was kneaded, adding the main flour. The dough was kneaded for a long time, until it began to peel from the walls of the vessel and from the hands. After that, it was left in a warm place again to rise, then kneaded again and made into loaves. Ukrainians baked leavened bread from rye, wheat, oat or barley flour. In the Hutsul region, it was also prepared from corn flour, and sometimes rye flour was mixed with corn or barley flour [18].

Significant changes in the preparation and quality of products are associated with a new stage in the development of world baking in the 19th century, namely with the improved process of obtaining yeast. Then the first yeast factories were created, which facilitated the work of baking enterprises, but caused significant damage to the technology of sourdough bread. The use of commercial yeast allowed to reduce the duration to 5–12 hours and stabilize the bread baking process.

In 1961, scientists at the Chorleywood Flour Milling and Bakery Research Association Laboratories in Hertfordshire, UK, developed a new industrial process for rapid mass production of bread. Bread could now be made in just three and a half hours, from flour to finished product, reducing the lengthy fermentation process to a minimum. To produce acceptable quality bread in the shortest possible time, Chorleywood technology required not only the use of special high-speed dough mixers, but also a whole arsenal of additives: additional yeast or their highly active strains, gluten, fat to improve the softness of the crumb, reducing agents to obtain a more elastic dough, soy flour for better volume and softness, emulsifiers to slow down staling, preservatives to extend the shelf life and various enzymes that are not legally required to be indicated on the label. As noted in a 1974 report by the Center for Consumer Technology Assessment, British bread is considered the most chemically processed in Western Europe [23].

This technology spread throughout the world. Mass production of bread drove many bakeries out of business, leaving only large bread factories. But at the same time, the quality of the products steadily declined, which became the root cause of the constant decline in bread consumption.

At the end of the last century, in various countries of the world (France, Italy, the northern countries of Europe and others), when manufacturers faced the above-mentioned problems of a long-term and significant decline in demand for their products, a "retro-innovation" movement (the restoration of ancient traditions) was launched.

For Ukraine, the revival of ancient recipes and technological techniques for making bread, the study of centuries-old culture, wisdom and craftsmanship of our people, the basis of Ukrainian cuisine, combined with the wealth of our soil, nature and some of the oldest traditions of agriculture, can become the basis for the development of retro-innovative bread technologies.

Such technologies include the preparation of dough with wine yeast. This technology is widespread in the southern regions of Ukraine [24] and was included as a unique ingredient in baking and as a valuable gastronomic heritage in the atlas "Ark of Taste of Ukraine".

The issues of the revival of regional bread-making traditions and their adaptation to modern conditions were addressed by such domestic scientists in the field of bread-making as V. Drobot, V. Yurchak, V. Rak, O. Naumenko, G. Pshenyshnyuk, T. Sylchuk, L. Mykhonik, V. Chelyabieva, S. Mykolenko, N. Sokolova, N. Getman, T. Semko and others, ethnographers S. Tvorun, L. Artyukh, N. Sumtsov, A. Zyubrovsky, M. Glushko, S. Tsypishev and other researchers.

A typical feature of ancient national bread-making technologies is the long preparation of dough using spontaneous starters. Wheat, rye or other types of flour were used to produce them; brewer's and wine yeasts or other carriers of fermentation microbiota were added for faster formation of the specified technological properties; hop extracts, spicy and aromatic plant additives, etc. were added to control the species composition of the starter microbiome.

Bread technologies based on spontaneous starters have a number of advantages, which are the reason for the growing interest in them from consumers, producers and researchers:

1) the formation of strong taste and aroma;

2) improvement of the structural and mechanical properties of the crumb, its elasticity and texture;

3) shelf life extension, elimination of excessive brittleness;

4) increase of microbiological stability during storage;

5) improvement of the functional and physiological properties of bread: digestibility and bioavailability of nutrients and biologically active substances, reduction of the allergenic effect of gliadin, glycemic index, etc.

However, the production of bread based on spontaneous fermentation, in addition to the above-mentioned advantages, also has problems that hinder its implementation. There is limited information in this area regarding recipes and technological process of sourdough development, its management in production, dough preparation, the lack of clear requirements for the quality of raw materials, technological properties and microbiome of sourdough starters, semi-finished products based on them, as well as sensory characteristics, physical, chemical, functional and physiological indicators of finished products. There are no recommendations on effective methods for assessing raw materials, semi-finished and finished products and controlling the flow of the technological process, which ensures the formation of a given quality of products. The scientific research is aimed at solving these problems.

Effective integration of wine yeast into bread baking technology requires a comprehensive scientific justification of the stages of their preparation. The key task is to optimize the process of obtaining dry wine yeast, taking into account their further functioning in the dough.

Particular attention is required to establish and systematize data on the influence of factors of raw material origin: grape variety, region and agroclimatic conditions of cultivation on the formation of physiological and biochemical properties of yeast cultures. No less important are the parameters of production of dry wine yeast (cultivation, drying, stabilization regimes), which determine their fermentation activity, stress resistance, enzymatic potential and ability to adapt to the environment of wheat dough.

Systematic analysis of these factors allows predicting technologically valuable characteristics of wine yeast in the context of baking production and forms the basis for developing standardized approaches to their use as part of traditional and sourdough technologies.

The purpose of the research was to assess the feasibility of using and the impact of spontaneous fermentation starters, prepared in two different ways (dry and liquid sourdough based on wine yeast) on the quality indicators of wheat bread.

4.3 Raw materials and factors of formation of physiological, biochemical and technological properties of wine yeast

Grapes, as the main ingredient for obtaining wine yeast, are characterized by a complex morphological chemical organization. Its component composition and microbiological characteristics determine the technological properties, the course of fermentation processes and the quality indicators of the final product. Systematic analysis of the mechanical and chemical composition and microbiota of grapes is a necessary prerequisite for substantiating technological processing modes and predicting biochemical activity in fermentation systems of starter cultures.

The chemical composition of grapes is a multicomponent and dynamic system, which is formed under the influence of genetic, environmental and agrotechnological factors. The composition of grapes includes water, carbohydrates, dextrans, plant gums, pectins, organic acids, phenolic compounds (tannins and dyes), aromatic components, lipids, waxes, nitrogenous compounds, enzymes, vitamins and mineral elements. The distribution of these components within fruit is uneven, which is due to the physiological specialization of its structural elements (pulp, peel, seeds, ridges). Quantitative and qualitative indicators of the chemical composition of grapes vary depending on the variety, soil and climatic conditions of cultivation, meteorological features of the growing season, agrotechnical techniques, phytosanitary conditions of the plantations and the mineral nutrition level of the plants.

The ratio of mechanical and plastic elements of grapes (pulp, peel, seeds, ridges) is a specific characteristic determined by environmental factors and affects the technological suitability of the ingredients. The mass of the grape cluster, the number and mass of fruits, the mass of peel and seeds, as well as the number of seeds are experimentally determined, which allows to assess the mechanical composition and predict the yield of the must and the concentration of extractive substances.

The pulp makes up an average of 85–90% of the fruit mass and is the main source of must. In addition to water, grape juice contains monosaccharides: mainly glucose and fructose, as well as a small amount of sucrose. Pectic substances, localized in the cell walls in the form of protopectin, pass into a soluble state during crushing and maceration of berries, affecting the viscosity and colloidal stability of the must. The second place in technological importance after sugars is occupied by organic acids. They are represented by tartaric and malic acids as dominant components, as well as citric acid and trace amounts of glycolic and glucuronic acids. Organic acids are in free, semi-bound and bound states, forming the buffer properties of the system and determining the titrated acidity of the must.

Nitrogenous substances are mainly represented by low-molecular compounds (amides, amines and ammonium salts), which are available as sources of nitrogen for yeast in the process of alcoholic fermentation. Despite the relatively low concentration, enzymes, vitamins and minerals play a significant role in the formation of the biochemical potential of the must, ensuring the metabolic activity of the microbiota and the stability of fermentation processes. The composition of the juice in the central and peripheral zones of the pulp is heterogeneous, which should be taken into account when assessing extractability and predicting fermentation kinetics.

The peel makes up an average of 9–11% of the fruit and is a concentrate of phenolic, coloring and aromatic compounds. It also contains nitrogenous and mineral substances, tartar, calcium oxalate and a waxy coating (pruin), which performs a protective function. The main component of the peel is water (60–80%). Coloring substances (anthocyanins in red varieties) in fresh berries at normal temperatures are characterized by limited solubility in the aqueous medium. Therefore, with rapid pressing, it is possible to obtain a weakly colored or colorless must even from red varieties. An increase in temperature during alcoholic fermentation, as well as the accumulation of ethanol, contribute to the destruction of the cellular structures in the peel and increased solubility of phenolic compounds, which causes intensive extraction of dyes and tannins.

The distribution of phenolic and aromatic compounds in grapes and the physiological and biochemical properties of yeast cells are interrelated. These factors determine the kinetics of fermentation processes and the formation of sensory characteristics of grape processing products.

Grape aromatic compounds are localized mainly in the inner layers of the peel, adjacent to the pulp. During the mechanical destruction of grapes (crushing, pressing), they are extracted into the must, forming a variety-specific aromatic profile. The intensity of the transition of volatile components is determined by the degree of destruction of cellular structures, temperature regime, duration of contact of the pulp with the must, and physical and chemical parameters of the environment. Tannins (eno-tannins) are also concentrated in the deeper layers of the peel, bordering the pulp. Their content varies within 0.18–4.0% in fresh peel, 0.55–7.58% in dry peel, which determines the potential for the formation of astringency, structurality, and antioxidant properties of grape processing products [25].

The main substrate of alcoholic fermentation is must monosaccharides, which are metabolized by yeast of *Saccharomyces cerevisiae* species, which are unicellular microorganisms of ascomycetes class. Yeasts are naturally present on the surface of grapes, often visible as a light coating on the fruits.

Wine yeast is a product of the area, since each microzone has its own microflora. World producers are located in the largest wine-producing countries: France, Spain, Italy, Germany. Analysis of literary sources shows that the species composition of the microbiota of spontaneously fermented grape must was studied in the leading wine-producing countries of Europe, Asia and South America. According to studies conducted in 22 countries around the world, 93 different species of yeast were found on the surface of grape berries, 15 of which are involved in the formation of wine quality, the bacterial composition includes more than 50 species. Microorganisms of grape must at the beginning of fermentation are represented by yeast, mold fungi, lactic acid and acetic acid bacteria. The quantitative and qualitative composition of microorganisms in grape must can be very diverse and largely depends on the quality of grapes, the place and climatic conditions of cultivation, the sanitary condition of grapes and the technology of its [26].

The microbiota of grape must during fermentation changes under the influence of osmotic stress caused by high concentrations of sugars, acidic environment, anaerobic conditions, high concentrations of ethanol, low temperature, etc. In grape must during fermentation, yeasts of *Saccharomyces* species almost completely replace other microbiota due to different sensitivity to ethanol. Mold fungi, due to their sensitivity to alcohol, do not develop in the fermenting must. Wine yeasts of *Saccharomyces* species predominate in grape must at the end of fermentation: *S. vini* (60–90%), *S. oviformis* (6–10%), *S. paradoxus* (up to 3.4%), and *S. chevalieri* (up to 0.3%). Along with saccharomycetes, spontaneously fermented wine must may contain yeasts of other genera, including *Brettanomyces*, *Saccharomycodes*, *Zygosaccharomyce*, *Candida*, *Pichia*, *Hanseniaspora*, etc., which are also important for the final quality of wine. They affect oxidative reactions and can enhance the taste of wine, increasing the concentration of volatile compounds responsible for the fruity aroma [27]. This microbiota has aroused interest in the organization of dough fermentation for bread baking in terms of forming special sensory characteristics and physiological properties of the product.

For use in artisanal baking, yeast cultures must meet a set of technological requirements: have high fermentation energy (complete and rapid fermentation of monosaccharides), a predominantly anaerobic type of metabolism, resistance to elevated concentrations of ethanol, osmotic pressure and side metabolites, as well as adaptability to changes in the composition of the nutrient medium. When using yeast isolated from mature must, in baking technologies, their lifting power and maltase activity are additionally evaluated.

During the fermentation of grape must, foam is formed, which was selected to obtain wine yeast. The research used two samples of red grapes of the Zaiber variety, grown in the Bilhorod-Dnistrovskyi district of the Odesa region in 2023–2024.

For the preparation of the dough, premium wheat flour of TM "Zernari" trademark and 1st grade wheat flour TM "Zolote zernyatko" (GSTU 46.004-99), table salt (DSTU 3583:2015 "Table salt. General technical conditions. As amended"), and sugar (DSTU 4623:2023 "Sugar. Technical conditions") were used. For the control sample, pressed baker's yeast "Lvivski", manufactured according to DSTU 4812:2007 "Pressed baker's yeast. Technical conditions" was used. Premium wheat flour had average baking properties.

For saccharification of the leaven, unfermented barley malt was used in accordance with DSTU 4282:2018 "Brewing barley malt. General technical conditions". When conducting experimental studies, high grade wheat flour with average baking properties was used, which corresponds to GSTU 46.004-99 "Wheat flour. Technical conditions" (**Table 4.1**).

Table 4.1 Baking properties of wheat flour

Indicators	Premium wheat flour	First grade wheat flour
Flour moisture, %	12.3	13.8
Flour acidity, degrees	2.1	2.6
Amount of raw gluten, %	21.5	26.0
Elasticity on the VDK-1 device, units	95	70
Stretchability, cm	16	13.5
Gluten color	light	light
Gluten elasticity	good	good
Humidity, %	65	63
Hydration capacity, %	185	170
Amount of dry gluten, %	7.5	9.6

The sensory evaluation of flour was carried out according to standard methods described in the manual [28]. The following was determined: color – white; smell – typical of wheat flour, without foreign odors, not musty, not moldy; taste – typical of wheat flour, without foreign flavors, slightly sweet, without crunch.

4.4 Retro-innovative method of producing dry wine yeast based on spontaneous fermentation of grape must and evaluation of their biotechnological and sensory indicators for use in bread baking

Preparation method of dry wine yeast was as follows: foam was collected from the surface of grape must, where active fermentation was taking place, finely ground corn flour TM "Skvyrianka" was added to it and subjected to fermentation. After establishing active fermentation, more corn flour was added, the mass was formed into balls and dried in the shade. Dry wine yeast was stored in a bag made of natural fabric in a dry place.

Dry wine yeast (2 samples) was used as an unconventional ingredient for bread making, which was used to prepare dough semi-finished products. The dough was made without leaven, as well as with liquid and thick leaven where the dry "wine" yeast was pre-activated in 2 variants: in a mixture of flour and water and in brewed flour.

The studies used brewed wheat flour with a ratio of wheat flour (first and high grade) to water 1:4. The flour was brewed with water with a temperature of 88 ± 2°C. The duration of sugaring the brew was 2 hours.

Liquid "wine" yeast was prepared from dry "wine" yeast by carrying out the activation stage, the breeding cycle and maintenance with daily replenishment of their nutrient mixture of flour and water with 89–90% moisture for 15 days.

The dough was prepared without leaven and with liquid (W = 68–72%) and thick (W = 48–50%) leaven. When kneading the dough (W = 44–45%), salt and sugar solutions were added (1.3 and 3.0% of dry raw materials to the weight of flour respectively). The dough development, proofing of the loaves and baking of bread were carried out according to the technological instructions for products made from wheat flour.

The quality of semi-finished products was determined by sensory indicators and moisture content.

The moisture content in semi-finished products was determined by express drying on the Chizhov PCMC device according to the method [28]. The degree of maturation and readiness of liquid "wine" yeast and semi-finished products based on them were determined by the lifting force, which was determined by the rising of a dough ball according to the method and titrated acidity, which was determined by titration of a sample according to the method [28].

Bread quality indicators were determined 4–24 hours after baking. Determination of sensory quality indicators of the products was carried out according to DSTU 7044:2009. The moisture content in bread was determined by a standard accelerated method by drying in a SESH-2M cabinet. The bread volume was determined using an OHL device [28]. The crumb porosity was measured on a Zhuravlev device according to the method. The shape stability was measured on an IFK device [28].

To ensure scientifically substantiated introduction of wine yeast into baking production, it is necessary to solve a complex of technological and biotechnological tasks at the stage of obtaining dry forms of "wine" yeast. Of particular importance is the regulation of the sequence of their preparation, as well as the generalization and systematization of data on the effect of ingredients (grape variety, region of origin, soil and climatic conditions of cultivation, etc.) and production parameters of dry wine yeast on the formation of functional and technological properties.

The technology for preparing dry wine yeast consisted of successive stages.

Selection of foam from active fermentation of grape must. Foam was removed during the period of maximum gas formation intensity, which ensures a high content of metabolically active cells.

Mixing the nutrient medium. A mixture of wheat and corn flour is added to the foam as a source of starch, nitrogenous substances and minerals. Additional sugar stimulates the rapid start of the fermentation process due to invertase activity.

In some traditional practices, a small amount of ethanol is added, which selectively suppresses bacterial microflora and promotes the selection of alcohol-tolerant strains.

Fermentation occurs at a temperature of 34–36°C for 60–90 minutes. During this period, the following occurs: intensive yeast reproduction; biomass accumulation; partial hydrolysis of starch to fermented sugars; synthesis of secondary metabolites (higher alcohols, esters, organic acids), which form the aromatic profile.

Forming and drying. After the active fermentation is completed, the mass is formed into granular forms in the form of "sticks" or "sausages" and dried at room temperature (25–30°C). Drying was carried out under conditions of natural convection without direct insolation to a humidity that ensures microbiological stability [29]. A decrease in water activity inhibits cell metabolism and puts them into a state of suspended animation. It has been proven that *Saccharomyces cerevisiae* are able to maintain viability after dehydration due to the accumulation of trehalose and expression of stress proteins.

Storage. Dry cultures are stored in air-permeable containers (linen or cotton bags), which prevents moisture condensation and secondary microbial contamination.

As part of experimental research, dry forms of wine yeast were obtained based on spontaneously fermented must of red grapes of the Zaibe variety grown in the Bilhorod-Dnistrovskyi district of the Odesa region.

The sensory properties of dry wine yeast are presented in **Table 4.2**.

Table 4.2 Sensory properties of dry wine yeast

No. s/n	Technological processes, semi-finished products	Sensory properties
1	Grape must during fermentation	The liquid is opaque, the juice contains pulp and grape peel; the smell is clean with a pronounced varietal flavor, the taste is sweetish-tart. Color: dark burgundy; light yellow; pink/red (depending on the color of the grapes)
2	Grape foam, mixing with corn flour, fermentation	Light bubbly mass. On the surface there is a layer of pink bubbles, with inclusions of ground corn flour; the smell is clean with a pronounced varietal flavor. Color: burgundy yellow, pink yellow, light yellow
3	Adding corn flour, forming dry wine yeast	Balls containing corn flour; aroma of alcoholic and lactic fermentation. Color: uneven gray-burgundy, gray-pink, gray-yellow

Fermentation temperature was 34–36°C, duration was 60...90 minutes. Experimentally determined technological parameters of drying wine yeast: 20–32°C on a wooden surface. Drying the mixture to 16–17% moisture content ensured the production of dry wine yeast with stable characteristics.

Physical and chemical properties of dried wine yeast were studied (**Table 4.3**).

Table 4.3 Physical, chemical and biotechnological properties of dry wine yeast

Indicator	Sample 1	Sample 2
Initial moisture content, %	31.6 ± 0.2	28.5 ± 0.1
Final moisture content (storage), %	16.1 ± 0.1	17.0 ± 0.2
Acidity, degrees	27.8 ± 0.3	35.0 ± 0.3
Number of yeast cells, CFU /g	9.90×10^6	3.25×10^6
Activity of lactic acid bacteria, min	136	100

It was discovered that the acidity is high, the number of yeast cells is insufficient for effective initiation of alcoholic fermentation in the dough, and the activity of lactic acid bacteria is reduced. Obviously, this is due to the characteristics of the microbiome that cause fermentation of grape must, as well as the composition and characteristics of the nutrient medium, which in these studies is based on corn flour.

To adapt the fermentation microbiota to the conditions of bread semi-finished products, its reproduction can be carried out using nutrient media of a different composition. In this direction, studies were conducted [30] where the nutrient medium was beet molasses, which complies with DSTU 3696-98, with sucrose and malt must, in which maltose is the main carbohydrate. The aim of the research was to establish the effect of the composition of these media, the concentration of sucrose and maltose on the reproduction process of yeast: bakery, beer, alcohol and wine. For the study, a solution of molasses and malt wort of four concentrations in the range of 9–20 wt.% was prepared. The initial concentration of yeast in all cases was $1.5 \times 10^6 \pm 0.2 \times 10^6$ cells per cm^3. Yeast cultivation was carried out during the day at a temperature of 25°C under the conditions of simple batch culture. Analyzing the results of the study showed that during cultivation in a nutrient medium of beet molasses with a sucrose concentration of 9%, yeast strains behave practically the same; however, in malt must with maltose there is no such pattern. At the same time, increasing the sucrose concentration to 12% did not affect the reproduction of wine yeast. Increasing the maltose concentration to 12% in the nutrient medium also caused a decrease in the activity of yeast reproduction of all strains.

Differences in yeast biomass accumulation were established, a positive effect on the reproduction of wine and baker's yeast was found in a nutrient medium containing sucrose, and in baker's and alcohol yeast in a medium containing maltose. These results can be used to enrich the nutrient medium, improve the process of wine yeast reproduction and adapt it to the conditions of bread semi-finished products.

The issue of optimizing the composition of the nutrient medium for the propagation of fermentation microbiota, modifying fermentation systems without deteriorating their functional and technological characteristics, and searching for innovative ingredients is also attracting the attention of foreign researchers.

Byproducts of the food industry are of interest. Agave pulp is one of the most common byproducts of agave processing, formed mainly during the production of tequila and mezcal in Mexico. Its share is about 40% of the total mass of the plant. In terms of chemical composition, the pulp is characterized by a high content of structural polysaccharides: cellulose (≈ 43%), hemicellulose (≈ 19%) and lignin (≈ 15%), which determines its potential as a source of dietary fiber. At the same time, increased moisture content (60–75%) limits the microbiological stability of the ingredient, reduces its shelf life and complicates logistical use, which is one of the reasons for the insufficient utilization of this resource.

The aim of this study was to evaluate the effect of adding agave pulp and *Lactococcus lactis* NRRL B-50307 during the development of sourdough intended for the production of pastries.

During the fermentation process, an increase in proteolytic activity was discovered, which indicates an effective metabolic adaptation of the starter microbiota to the fibrous substrate of agave pulp. The intensification of enzymatic processes indicates the involvement of structural components of the pulp in biotransformation, which potentially contributes to the increase in the nutritional and functional value of the final product. It is important that the addition of agave pulp did not cause a negative impact on the rheological parameters of the dough, particularly its consistency and volume during kneading.

Evaluation of the effect of drying demonstrated that the use of moderate temperature regimes minimally affected the content of bioactive compounds and antioxidant potential of the sourdough. Although an initial decrease in the viability of microorganisms after dehydration was recorded, subsequent reactivation ensured effective restoration of the metabolic activity of the culture. This confirms the functional stability of the microbiota and its ability to reverse adaptation after dehydration.

Such techniques can be considered as a promising approach to creating starter cultures with increased functional value. The use of drying and subsequent reactivation technologies opens up opportunities for optimizing starter culture storage, reducing production costs, and expanding the use of plant byproducts in the production of environmentally friendly bakery products while maintaining the stability of fermentation processes and forming high-quality [31].

The next stage of these studies was the development of a technology for reactivating dry wine yeast in order to adapt it to the conditions of flour systems, intensify the fermentation of dough carbohydrates, and determine the optimal fermentation parameters considering the physiological and biochemical characteristics of the culture.

4.5 Adaptation of liquid wine yeast to flour systems: production technology, fermentation parameters and impact on the quality of semi-finished products

The growing demand for products with a strong regional identity has led to increased interest in spontaneous fermentation as a source of autochthonous strains adapted to specific environmental conditions and substrate composition. The high adaptability of such cultures to fluctuations in the nutrient environment is an important prerequisite for their potential application in breadmaking.

If proper sanitary and hygienic requirements are observed, bacterial contamination of the must is insignificant; however, individual representatives of the genera *Lactobacillus* and *Fructobacillus* may participate in related biochemical processes.

For bread-making, yeasts of the genus *Saccharomyces* are technologically significant, particularly *S. cerevisiae*, *S. vini*, *S. uvarum*, *S. carlsbergensis*, *S. chevalieri*, *S. oviformis*, *S. chodati*. Their functional role in dough is fundamentally different from the conditions of winemaking and consists of ensuring alcoholic fermentation with the formation of ethanol and carbon dioxide, forming the volume of the loaves, the structure and porosity of the crumb, the synthesis of aromatic metabolites and increasing the bioavailability of bread components.

In flour medium, yeasts are subjected to osmotic and ionic stress due to low dough moisture and the presence of sodium chloride, and also function with a limited amount of simple sugars, using mainly maltose as the main source of carbohydrates. It has been established that wine yeasts are able to ferment glucose, fructose, sucrose and maltose, but the intensity of metabolism depends on their concentration, the ratio of sugars and the availability of nitrogen sources. The growth rate of cells is determined by the composition of the nutrient medium; the duration of the lag phase can be 4–8 hours depending on the cultivation conditions.

Thus, the enzymatic potential of grape must microbiota, particularly the ability to effectively utilize glucose, sucrose and maltose, indicates the possibility of its use to ferment bread semi-finished products. Taking into account the physiological and biochemical characteristics of wine yeast, the peculiarities of bread baking and the available experimental experience, it is advisable to introduce them into liquid semi-finished products as a way to ensure stable activation and increase fermentation activity in dough systems.

From the standpoint of modern food biotechnology, it is promising to form standardized methodological approaches to using wine yeast in baking according to a model close to the technology of liquid yeast with 85–90% moisture content. The implementation of such a scheme contributes to the gradual adaptation of the microbial culture to the starch-containing flour environment, minimizing metabolic stress and stabilizing the indicators of fermentation activity in the process of maintaining the semi-finished product.

Preparation of a liquid semi-finished product based on wine yeast was carried out according to a step-by-step algorithm. During the first stage, a saccharized flour brew was prepared, which served as a source of available carbohydrates and provided optimal conditions for the primary reactivation of cells. Partial hydrothermal destruction of starch with subsequent saccharification contributed to the accumulation of fermented sugars necessary for the intensification of the initial stages of culture growth.

During the second stage, dry wine yeast was reactivated on a prepared substrate with subsequent systematic (daily) feeding with a water-flour mixture with the specified moisture content. This regime ensured a gradual increase in biomass, the formation of a stable population structure and the leveling of acid accumulation and gas-forming ability. Regular renewal of the nutrient medium maintained the cells in an active physiological state and contributed to the selection of adapted forms with increased enzymatic potential.

To objectify the obtained results, control samples of liquid wine yeast were additionally prepared in a traditional water-flour system without the saccharification stage. Comparative analysis allowed to assess the effect of preliminary substrate preparation on the fermentation kinetics, the titrated acidity level and the lifting force of semi-finished products.

It was determined that a similar technological process is used in some households in the southern region of Ukraine, which indicates its empirically formed effectiveness. Scientific substantiation and unification of the specified approach create the prerequisites for the implementation of a reproducible technology for the use of wine yeast in bread-making systems with predicted functional and technological properties.

The nutrient medium was formed based on first grade wheat flour, which is characterized by a more complete chemical composition and a higher content of biologically active components. Given the prevalence of high-grade flour on the Ukrainian market, experimental samples were prepared in parallel with its use to assess the effect of flour variety on the course of activation. At this stage, dry wine yeast obtained from red grape varieties was used.

During the dilution (activation) cycle, the moisture content of the nutrient medium was monitored after the initial mixing and after each daily renewal, which was carried out at an interval of 24 hours. The dynamics of activation on the first day were assessed at an interval of 6 hours, then once a day. Monitoring included the determination of sensory properties, lifting force as an integral criterion of the rate of CO_2 accumulation due to the metabolic activity of yeast, as well as titrated acidity, which characterizes the total content of organic acids and dissolved carbon dioxide.

The criteria for completing the activation cycle and readiness of liquid wine yeast for use in dough systems were considered to be: an increase in the volume of the semi-finished product, the formation of a pronounced fermentation aroma, an increase in acidity and the achievement of a lifting force at the level of 20–25 minutes. The humidity of the semi-finished products after mixing was 85–90%, maturation was carried out at a temperature of 27–29°C, the content of dry wine yeast was 7% to the weight of flour.

The proposed activation process creates the prerequisites for increasing the stability of fermentation processes in bread semi-finished products (**Fig. 4.1**) and ensures the adaptation of wine yeast to the specific conditions of the flour medium.

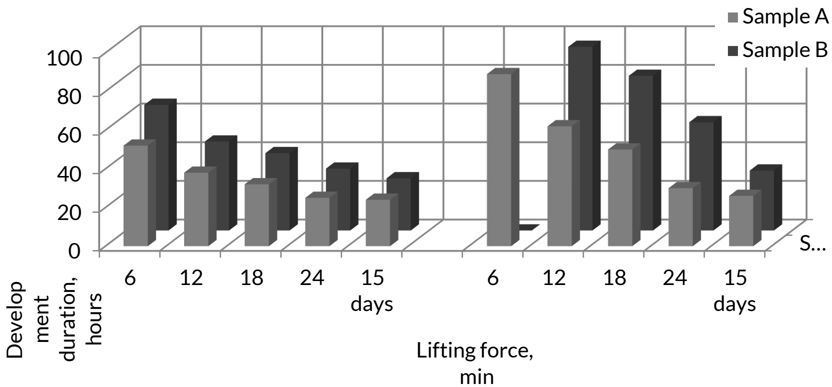

Fig. 4.1 Dynamics of lifting force during the development and maintenance of liquid wine yeast (15 days) using first and high-grade wheat flour

Analysis of experimental data shows that wheat spontaneous semi-finished products based on wine yeast achieve the technologically required fermentation activity within 24 hours (one dilution cycle) provided that saccharized flour brew from first grade flour is used as a nutrient medium. When using higher-grade flour, the time of forming sufficient lifting force is slightly increased. The development of liquid wine yeast in a traditional water-flour mixture requires 24–36 hours for first grade flour and up to 48 hours for higher-grade. At the same time, prolonged culture maintenance for 15 days was not accompanied by a decrease in lifting force, which indicates the stability of the fermentation microbiota under the selected conditions.

The dynamics of titrated acidity, as an integral indicator of the activity of lactic acid bacteria (LAB), demonstrates more intense acid formation on the first day in samples on first grade flour, especially when using saccharized brew. This is probably due to the enrichment of the medium with available carbohydrates and biologically active substances (amino acids, vitamins), which are formed during saccharification and contribute to the rapid activation of acid-forming microflora.

In samples on a water-flour mixture from high grade flour, the increase in acidity occurred more slowly, which can be attributed to the chemical composition less saturated with biologically active components and the specificity of the microbiological profile of such flour. An increase in titrated acidity was observed during the first 6–8 days. At the same time, on the 5–6th day, the indicators of samples obtained on a water-flour mixture approached the values for systems with saccharized brew; after the 6th day, the process stabilized with the formation of an acidity level of 8.6–9.2° for first grade flour and 6.8–7.5° for high grade flour (**Fig. 4.2**).

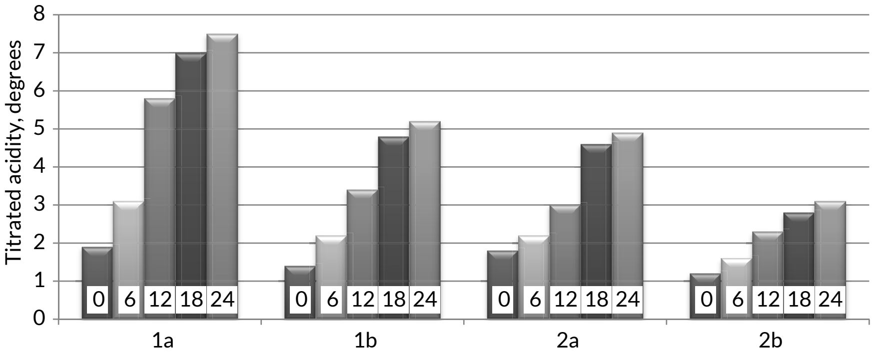

Fig. 4.2 Acid accumulation in the process of removing liquid "wine" yeast during the first 6, 12, 18 and 24 hours using as a nutrient medium a saccharized brew (1) and a water-flour mixture (2) based on flour of the first (*a*) and high (*b*) grades

Lactic acid fermentation is an important stage in the development of spontaneous sourdough starter cultures and liquid wine yeasts (**Fig. 4.3**). The technological role of lactic and related organic acids is to regulate the acidity of the medium, initiate positive structural and functional changes in flour biopolymers, create favorable conditions for the development of yeast and at the same time inhibit undesirable microbiota, particularly putrefactive bacteria and representatives of the genus *Leuconostoc*, which are associated with microbiological spoilage. The combination of these effects determines the stability and technological reliability of the resulting semi-finished products in bakery systems.

The development stage of wheat spontaneous liquid "wine" yeast (sourdough) is aimed at the initiation and selective activation of representatives of the genus *Saccharomyces*, introduced with dry wine yeast, as well as the accumulation of functionally active fermentation microbiota, including lactic acid bacteria.

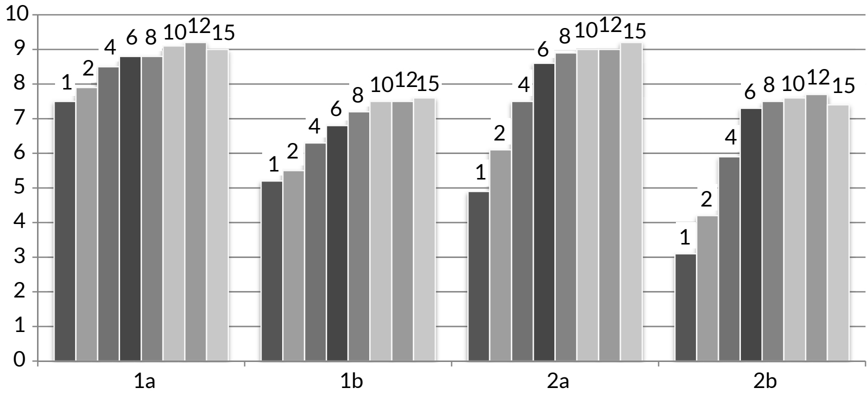

Fig. 4.3 Changes in titrated acidity during the process of maintaining liquid "wine" yeast during the first 15 days using as a nutrient medium a water-flour mixture based on flour of the first (*a*) and high (*b*) grades for samples on saccharized brew (1) and water-flour mixture (2)

The combined metabolic activity of this consortium provides intensive gas formation, synthesis of organic acids, aromatic and flavor-forming compounds and other technologically significant metabolites. At the same time, physical, chemical, colloidal and enzymatic transformations of flour biopolymers occur, which determine the structural and mechanical properties of the dough and the quality of the finished product.

It has been established that when using saccharized flour brew as a nutrient medium, liquid "wine" yeast reaches the required level of fermentation activity at the end of the first day of fermentation, which indicates effective adaptation of the culture to the carbohydrate composition of the system.

At the next stage of the research, the technological properties of liquid "wine" yeast o btained from white and red grapes were evaluated when they were added to a saccharized brew in an amount of 5 and 7% to the weight of first grade wheat flour. Given the significant differences between the conditions for fermentation of grape must and fermentation of bakery semi-finished products, as well as taking into account the production risks associated with possible power supply interruptions, the influence of temperature regimes (19–22°C and 25–27°C) on the formation of bakery properties of these cultures was additionally investigated. The generalized results of the experiments are presented in **Table 4.4**.

According to the obtained experimental data, it was established that the highest indicators of the baking value of liquid "wine" yeast are achieved when they are added in an amount of 7% to the weight of wheat flour (first grade) using a culture isolated from grapes, at a fermentation temperature of 25–27°C. Under these conditions, maximum fermentation activity, optimal indicators of lifting force, and stable acid-accumulating ability of the semi-finished product were observed.

A thorough description of sensory properties is necessary to identify the technological readiness of the semi-finished product, prevent the development of undesirable microflora and ensure the reproducibility of results when using wine yeast. This is especially important when using non-traditional yeast cultures and alternative starters, where there are no established regulatory indicators. In order to control the processes of yeast activation and maturation during the first day every 6 hours, and then daily, the sensory properties (**Table 4.5**) of a liquid semi-finished product based on wine yeast were evaluated.

Sensory evaluation showed the presence of intense visual signs of fermentation (gas formation, volume increase), a formed aromatic profile with the dominance of metabolites of alcoholic and lactic fermentation. Sourdoughs based on wine yeast from red grapes were characterized by a more pronounced tone of alcoholic fermentation products with light grape notes and a darker shade of color, which is due to the characteristics of the starting material and the spectrum of secondary metabolites.

Table 4.4 Baking properties of liquid "wine" yeast

Indicators	Wine yeast from white grapes				Wine yeast from red grapes			
	5% to the weight of flour		7% to the weight of flour		5% to the weight of flour		7% to the weight of flour	
Variant	1	2	3	4	5	6	7	8
Ripening temperature, °C	19–22	25–27	19–22	25–27	19–22	25–27	19–22	25–27
Moisture content, %	90	90	90	90	90	90	90	90
Titrated acidity, degrees (after 24 hours)	6.0	7.1	6.6	7.8	5.8	6.4	6.9	7.5
Lifting force, min. (after 24 hours)	68	29	56	25	80	50	75	32

Table 4.5 Sensory properties of liquid semi-finished product based on wine yeast

No.	Quality indicators	Sensory properties
1	Appearance	Porous, viscous
	Surface	Foam on the surface
	Color	Light gray with a faint burgundy tint; light cream; gray-pink/red (depending on the grape color in the must)
2	Scent	The smell is clean, sour-bread, fruity with a slight alcohol note. Typical for a bread semi-finished product
3	Consistence	Thick, with gas bubbles inside

Reducing the fermentation temperature to 19–22°C or reducing the dose of dry "wine" yeast was accompanied by a prolonged stage of removal and maturation of the liquid semi-finished product, which indicates a decrease in the intensity of metabolic processes and requires further optimization of cultivation modes.

In order to determine a rational technological scheme for dough preparation, comparative studies were conducted using straight dough, thick leaven and liquid leaven technologies. Samples made using the traditional yeast bread technology using pressed yeast were used as a control.

Wheat bread products were produced using liquid and thick leavens and straight dough in order to establish its effect on the formation of consumer and technological characteristics of the product. The dough was prepared using thick leaven (47–50% moisture) and liquid leaven (68–70% moisture) with 50 and 30% flour respectively. The dough was kneaded manually, then placed for fermentation in a thermostat at a temperature of 27–29°C, the total duration of fermentation was 180–240 minutes. After the dough was fermented, the dough was kneaded with the addition of the remaining flour and salt. Kneading was carried out under laboratory conditions in a farinograph mixer. It was placed for fermentation for 60–90 minutes, every 30 minutes after the start of fermentation it was kneaded by hand. During fermentation, the dough increased in volume and had a convex shape. The dough was also prepared in a straight way, where all the ingredients according to the recipe, including salt in the form of a solution, were mixed in a farinograph mixer until a dough with the necessary structural and mechanical properties was formed. The dough moisture content in all samples ranged from 43.6 to 44.2%.

In the control samples, which were prepared according to traditional technological recommendations, the dosage of pressed yeast was 1% to the weight of flour for leavened dough, and 3% for straight dough.

The readiness of the dough was assessed by achieving the normative titrated acidity and lifting force indicators and by the set of sensory characteristics, in accordance with the current technological regulations. Taking into account the results obtained, the parameters of the technological process were justified (**Table 4.6**) and a comparative assessment of the quality of semi-finished products (leaven and dough) was carried out.

Table 4.6 Parameters of the technological process for making leaven and dough

Indicators	Control			From liquid "wine" yeast		
	liquid leaven	thick leaven	straight dough	liquid leaven	thick leaven	straight dough
Leaven preparation						
Moisture content, %	70	50	–	68	47	–
Fermentation time, min	240	240	–	300	240	–
Lifting force, min	24	21	–	18	21	–
Final acidity, degrees	5.0	3.5	–	5.5	5.9	–
Dough preparation						
Moisture content, %	44.0	44.2	43.6	44.1	43.8	43.5
Fermentation time, min	60	60	180	90	90	240
Lifting force, min	16	14	13	7	11	18
Final acidity, degrees	3.8	3.5	3.1	3.9	4.3	4.2

After the fermentation stage, the dough was divided into loaves, shaped and sent to proof at a temperature of 34–36°C. In samples with "wine" yeast and though prepared with straight dough, the duration of proofing was within 60–90 minutes, with pressed yeast was 45–60 minutes. After the dough loaves increased in volume, they were moved to the baking chamber for baking. The baking duration at a temperature of 180–220°C for all samples was almost the same.

4.6 Sensory, physical and chemical quality assessment of bread products made by different dough preparation methods

Sensory, physical and chemical assessment of the quality of wheat bread products made with liquid and thick leavens and by the straight dough method was carried out in order to establish its effect on the formation of consumer and technological characteristics of the products. The research was carried out according to unified methods using standard instrumental and sensory approaches. Sensory properties were assessed according to a descriptive scale taking into account the shape, surface condition, crust color, crumb structure, aroma and taste. Physical and chemical parameters included moisture content, acidity, specific volume, porosity, shape stability and texture indicators. Comparative analysis was carried out 4–24 hours after baking in order to take into account the stabilization of the crumb structure.

Bread products made with liquid leaven were characterized by a more developed porous structure with thin-walled pores of predominantly rounded shape. The crumb had increased elasticity and uniform texture, which indicated intensive gas-forming processes at the fermentation stage. The crust was characterized by a uniform golden-brown color and a pronounced aroma, formed as a result of active fermentation and Maillard reactions. The products were characterized by a balanced taste with moderate acidity and without noticeable foreign flavors. During sensory evaluation, the samples prepared using liquid dough demonstrated a somewhat higher aromatic intensity compared with the other variants.

Bread produced with thick leaven showed a denser crumb with a finer internal structure. At the same time, the distribution of pores was less uniform. This feature can likely be explained by the lower hydration level of the finished product as well as by differences in the course of fermentation processes.

In addition, these samples formed a thicker crust with a more intense coloration, which may be related to the longer fermentation period and the associated biochemical transformations in the dough. The taste of such bread was perceived as richer, with more pronounced acidity and a more expressed enzymatic character.

Overall, the sensory characteristics suggest that the use of thick leaven contributes to the formation of a flavor profile closer to that traditionally associated with artisanal bread-making technologies.

A visual image of a cross-section of finished bread products prepared with pressed yeast is shown in **Fig. 4.4**, and with liquid wine yeast in **Fig. 4.5**.

Fig. 4.4 Cross-sectional view of bread products made from wheat flour with pressed yeast using different dough preparation methods: 1 – without leaven; 2 – with liquid leaven; 3 – with thick leaven

Fig. 4.5 Cross-sectional view of bread products made from wheat flour made with wine yeast using different dough preparation methods: 1 – without leaven; 2 – with liquid leaven; 3 – with thick leaven

Physical and chemical analysis (**Table 4.7**) showed that crumb moisture content in products made with liquid leaven was statistically higher compared to analogues made with thick leaven. The specific volume of bread made with liquid leaven exceeded the corresponding indicator in samples made with thick leaven, which correlated with the greater gas-holding capacity of the dough. Titrated acidity was higher in products made with thick leaven, which confirms the more intensive accumulation of organic acids during the fermentation process. The shape stability of products made with thick leaven was characterized by increased values, which is associated with a stronger gluten framework structure. Porosity and structural and mechanical properties were consistent with the results of sensory evaluation.

Table 4.7 Physical and chemical qualities of wheat bread made with pressed yeast (control) and with spontaneous starters from wine yeast

Indicators	Control			With sourdough		
	liquid leaven	thick leaven	straight dough	liquid leaven	thick leaven	straight dough
Moisture content, %	43.2	43.3	42.9	43.0	42.8	42.7
Acidity, degrees	2.9	2.7	2.2	3.0	3.2	3.1
Porosity, %	73	72	69	73	71	68
Specific volume, cm^3/100 g	3.17	3.06	2.95	3.20	3.09	2.85
Shape stability, H/D	0.58	0.56	0.56	0.50	0.49	0.47

The obtained data indicates that the method of dough preparation is a significant factor in shaping the quality of wheat bread products. A liquid leaven provides intensification of gas formation and the formation of a more developed porous structure. The porosity of bread is a decisive factor affecting its texture. A thick leaven contributes to the accumulation of acidity and the enhancement of the taste and aroma profile. The choice of a technological process allows to purposefully regulate the structural and sensory characteristics of the finished product.

The best sensory properties and physical and chemical indicators were characterized by products made with liquid leaven using liquid "wine" yeast. In terms of porosity and specific volume, bread made on semi-finished products of spontaneous fermentation was not inferior to the control sample made with traditional liquid leaven. Studies have established a significant improvement in the elasticity of the crumb of bread samples made on liquid and thick leavens with the addition of wine yeast compared to the control samples. However, an increase in the titrated acidity of the products by 0.6–0.9 degrees was established, and it slightly exceeds the normalized values for traditional bread made from premium wheat flour. This should be adjusted in the standards for bread products made using the technology under study. From the standpoint of artisanal bread baking, a differentiated approach to the use of leavens depending on the desired quality indicators is advisable. Thus, optimization of fermentation parameters opens up opportunities for increasing the stability and predictability of bread quality under different production models. It was found that the staling process of bread samples made with wine yeast sourdough proceeded more slowly than in control samples. Slower rates of freshness loss in samples with sourdough were also established by the indicator of elastic deformation of the bread crumb and by changes in its crumbliness.

Thus, the effectiveness of using wheat spontaneous sourdough with wine yeast has been established, as an example of ancient national traditions of dough preparation, which have been preserved in Ukrainian villages of southern Ukraine. It is promising as a comprehensive solution to bread baking problems related to improving quality and expanding the range of products.

At the same time, it was found that in order to revive the ancient national traditions of baking, their effective introduction and practical implementation at domestic enterprises, it is necessary to clarify and formulate the theoretical foundations of bread technologies using spontaneous sourdough, develop an informative base and practical recommendations for bread producers, which will provide for adaptation to local raw materials, common production models and equipment in the conditions of industrial bakeries and small, artisanal and craft bakeries. This requires combining the efforts of bakers with specialists in the fields of history, ethnography, agriculture, chemistry, biochemistry, microbiology, nutrition, restaurant management and others. Only under such conditions is it possible to realize the high potential of sourdough in solving the problems of the industry and the prospects for expanding the range of products that can be presented on the market, including under the popular lines "according to ancient, ethnic, authentic technologies", "living", "artisanal" bread, "for health", "with improved physiological properties".

4.7 Conclusion

A review of current data on the evolution of bread in the different regions of the world, an analysis of ancient and modern traditions of bread making in terms of choosing a development strategy for modern domestic enterprises of the bread and restaurant business, which is aimed at improving technologies and the range of bakery products, solving industry problems and improving product quality, was conducted. The work substantiates the high potential of wheat spontaneous starters authentic for Ukraine on wine yeast in solving bread baking problems and the feasibility of studying their technologies and properties.

Experimental studies have established that the parameters of sourdough preparation and their properties are significantly influenced by the recipe, chemical, and microbiological composition of the ingredients. It has been proven that due to the use of dried wine yeast and saccharized brew in the fermentation cycle, the sourdough acquires the necessary biotechnological properties within a day.

It was established that products made on liquid wine yeast have strong sensory characteristics, specific shades of taste and aroma, crust color, pore structure. In terms of porosity and specific volume, bread made with semi-finished products of spontaneous fermentation was not inferior to the control sample made with traditional liquid leaven. Studies have established a significant improvement in the elasticity of the crumb of bread samples made with the use of liquid and thick leavens on liquid wine yeast compared to the control samples.

All this gives grounds to assert the prospects of using spontaneous sourdough starters in the bread and restaurant business to improve technology and product range, and comprehensively improve its quality. However, it is noted that there is a need to continue research to create an information and regulatory base on national traditions, recipes, and product range in terms of historical periods and different regions, to formulate the theoretical foundations of bread technology using spontaneous starters, to develop measures to form the proper quality of products, and to adapt them to the working conditions of modern industrial and craft producers.

Conflict of interest

The authors declare no conflict of interest with respect to this paper, as well as the published research results, including financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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The study was conducted without financial support.

Data availability

The manuscript has no associated data.

Use of artificial intelligence statement

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

Authors' contributions

Nataliia Slobodyanyuk: Conceptualization, Formal analysis.
Oksana Tkachuk: Text writing, Information collection, Research, Analysis and systematization of results.
Tetiana Brovenko: Validation,Resources, Methodology, Research, Formal analysis.
Tetiana Lebedenko: Text writing conceptualization, Research, Validation, Formal analysis.
Halyna Tolok: Resources, Methodology.
Tamara Novichkova: Methodology, Formal analysis.

Petro Drozd: Resources, Methodology.
Mykola Gruntkovskyi: Resources, Methodology.

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