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## **FORMATION AND DEVELOPMENT OF THE ALCOHOL INDUSTRY IN UKRAINE IN THE CONTEXT OF THEORETICAL AND METHODOLOGICAL FACTORS**

*The author has set the goal to generalize the theoretical and methodological foundations of the formation of the alcohol industry of Ukraine, which have formulated in the works of foreign and domestic scientists in the second half of the 18<sup>th</sup> – early 20<sup>th</sup> centuries. The characteristic of the first devices of the distillation action, which were most widely used in the production of alcohol of the period under study, is given. It has shown that in the 17<sup>th</sup> – 18<sup>th</sup> century the methods of distillation were sufficiently developed, which made it possible to obtain alcohol for industrial production. Despite the fact that the chemical equation of alcoholic fermentation was discovered at the end of the 18<sup>th</sup> – at the beginning of the 19<sup>th</sup> century, until the second half of the 19<sup>th</sup> century there was not science-based technology for the process of alcohol production. It has proved that the forming of the alcohol industry was preceded by the development of the theory of distillation and fermentation. The main positions of the mechanistic, microbiological, physico-chemical, physiological theories of fermentation, which have formulated in the second half of the 19<sup>th</sup> century, have generalized. Their founders are domestic and foreign scientists Zh.-B. Dumas, E. Peligo, M. Bertlo, A.M. Butlerov, A. Lavoisier, J. Lussac, S. Canarian de Latour, T. Schwann, F. Kuttsing, J. Libich, L. Paster, M.M. Manaseina, E. Buhner, L.A. Ivanov, A.I. Lebedev, S.P. Kostychev, Ya.O. Parnas, K. Neyberg, G. Embden, O. Meyerhof and others.*

**Key words:** *alcohol industry, alcohol, fermentation, distillation, enzymes, methanol.*

# СТАНОВЛЕННЯ ТА РОЗВИТОК СПИРТОВОЇ ПРОМИСЛОВОСТІ В УКРАЇНІ В КОНТЕКСТІ ТЕОРЕТИЧНИХ І МЕТОДОЛОГІЧНИХ ЧИННИКІВ

*Автор поставив за мету узагальнити теоретичні та методологічні основи становлення спиртової галузі України, які були сформульовані в роботах зарубіжних та вітчизняних учених у другій половині XIX – на початку XX ст. Наведена характеристика перших пристроїв дистиляційної дії, які найбільш широко використовувалися у виробництві алкоголю досліджуваного періоду. Показано, що в XVII–XVIII ст. методи дистиляції були достатньо розвиненими, що дозволило отримувати алкоголь для промислового виробництва. Незважаючи на те, що хімічне рівняння алкогольного бродіння було розроблене наприкінці XVIII – на початку XIX ст., до другої половини XIX ст. не існувало науково обґрунтованої технології для виробництва алкогольної продукції. Доведено, що формуванню алкогольної промисловості передувала розробка теорії перегонки та бродіння. Узагальнено основні положення механічної, мікробіологічної, фізико-хімічної, фізіологічної теорій бродіння, які були сформульовані у другій половині XIX ст. Їх фундаторами є вітчизняні і зарубіжні вчені: Ж.-Б. Дюма, Е. Пеліго, М. Бертло, А.М. Бутлеров, А. Лавуазьє, Ж. Люссак, Ш. Каньяр де Латур, Т. Шванн, Ф. Кютцінг, Ю. Лібіх, Л. Пастер, М.М. Манасеїна, Е. Бухнер, Л.А. Іванов, А.І. Лебедев, С.П. Костичев, Я.О. Парнас, К. Нейберг, Г. Ембден, О. Мейергоф та інші.*

**Ключові слова:** *спиртова промисловість, спирт, ферментація, дистиляція, ферменти, метанол.*

# СТАНОВЛЕНИЕ И РАЗВИТИЕ СПИРТОВОЙ ПРОМЫШЛЕННОСТИ В УКРАИНЕ В КОНТЕКСТЕ ТЕОРЕТИЧЕСКИХ И МЕТОДОЛОГИЧЕСКИХ ФАКТОРОВ

*Автор поставил цель обобщить теоретические и методологические основы становления спиртовой отрасли Украины, которые были сформулированы в работах зарубежных и отечественных ученых во второй половине XIX – в начале XX ст. Приведена характеристика первого оборудования дистиляционного действия, которое наиболее широко использовалось в производстве алкоголя исследуемого периода. Показано, что в XVII–XVIII ст. методы дистиляции были достаточно развитыми, что позволяло получать алкоголь для промышленного производства. Несмотря на то, что химическое уравнение алкогольного брожения было разработано в конце XVIII – начале XIX ст., до второй половины XIX ст. не существовало научно обоснованной технологии для производства алкогольной продукции. Доказано, что формированию алкогольной промышленности предшествовала разработка теории перегонки и брожения. Обобщены основные положения механической, микробиологической, физико-химической, физиологической*

*теории брожения, которые были сформулированы во второй половине XIX ст. Их фундаторами являются отечественные и зарубежные ученые: Ж.-Б. Дюма, Э. Пелиго, М. Бертло, А.М. Бутлеров, А. Лавуазье, Ж. Люссак, Ш. Каньяр де Латур, Т. Шванн, Ф. Кютцинг, Ю. Либих, Л. Пастер, М.М. Манасеина, Е. Бухнер, Л.А. Иванов, А.И. Лебедев, С.П. Костычев, Я.А. Парнас, К. Нейберг, Г. Эмбден, А. Мейергоф и другие.*

**Ключевые слова:** *спиртовая промышленность, спирт, ферментация, дистилляция, ферменты, метанол.*

Alcohol industry of Ukraine provides products for domestic market and the foreign countries during some decades. Alcohol branch has an important role in the efficient functioning of the pharmaceutical and food industries, one of the most profitable in Ukraine. Alcohol industry in addition to the main alcohol product produces about 30 some types of products, namely: canned fruits and vegetables, rye malt, brewing malt, kvass concentrate, mineral water, low alcohol beverages, confectionery, alcoholic vinegar, hops extract, wine, solvents and the like. The Ukrainian alcohol branch satisfies the domestic needs of the state in alcohol for the manufacture of alcoholic beverages, using only 30–35% of the total capacity [1].

Further development of the industry is based on the consideration of advanced foreign and domestic historical experience, the development of strategic initiatives, the formation of new needs for the fuller use of productive capacity. Separate aspects of the formation and development of the alcohol industry in Ukraine have been partially reflected in the scientific works of V.G. Pikhov [10], P.V. Rudnitsky [11], L.G. Mel'nik [7], M.M. Moskalyuk [8], O.O. Nesterenko [9], our previous publications [1–3]. However, until now, the theoretical and methodological foundations of the formation and development of the alcohol industry, based on the works of foreign and domestic scientists, have not generalized. In view of this, the purpose of this research is to highlight the preconditions for the formation of the theory of distillation, which formed the basis for the development of scientific technologies for the production of alcohol. The research is based on the application of general scientific and historical methods, source study analysis.

Distillation (*lat. Distillatio – dripping*) – distillation, evaporation of the liquid, followed by cooling and condensation of vapors. Distillation is considered primarily

as a technological process of separation and refining of multicomponent substances - among other processes with phase transformation and mass transfer: sublimation, crystallization, liquid extraction, and some others. There is a distillation with condensation of steam into a liquid (in which the resulting distillate has an average composition due to mixing) and distillation with condensation of steam in the solid phase (in which in the condensate a concentration of components occurs). The product of distillation is a distillate or residue (or both), depending on the substance to be distilled and the purpose of the process. The main parts of the distillation device are a heated container (cube) for the liquid to be distilled, a cooled condenser (refrigerator) and a heated steam line [5].

The history of distillation began in the era of antiquity. The man first distilled the resin, then gold, silver, lead, etc. For centuries, the skill of distillation was the most revered of all sciences and arts. Who owned it, believed that he was only two steps away from world domination and immortality. In all likelihood, the first alcoholic beverage made by man was juice, squeezed out of fruit, most likely from grapes, which naturally wandered at ordinary temperature. Probably, simultaneously with wine the technology of manufacturing of beer has been developed. It is known that the ancient Egyptians made this drink from fermented infusion of barley. Our ancient ancestors did not understand the nature of fermentation. It seemed to them a sacred process connected with the influence of the gods.

As for the art of distillation, it could have originated in China, but there is not enough precise data to support this hypothesis. Therefore, the role of the cradle of distillation is borne by Egypt. As evidence, it is based on the murals painted by the Greek philosopher Zosimus. Zosim, born in Egypt, saw on the walls of the temple of Memphis among the hieroglyphics drawings of distillers. Even Zosima, who lived in the III century AD, these images seemed very ancient. The philosopher redrawn what he saw, thanks to which the Egyptian images have reached our days [11].

The man observed nature, noting how under the action of the sun water vapor forms, settling out later under the influence of cold. This cycle of substances in nature can be considered a huge distillation apparatus located above our head and

condensing moisture under our feet. This opinion was held by the Greek philosopher Aristotle (384–322 BC). He wrote in his work «Meteorology» the following: «Sea water becomes potable due to evaporation. This can be subjected to any moisture. After turning into vapors, it becomes liquid again».

It can be assumed that, trying to reproduce in miniature the water cycle in nature, our ancestors created the first very primitive distilling apparatus and invented distillation. However, the distillation of water was not of much interest, because after distilling water, you can get only water. Therefore, ancient people turned to distilling other liquids. But it was not alcoholic beverages yet.

Apparently, the first object of distillation after the water was cedar tar. In ancient Egypt, it has distilled, receiving cedar oil, which served, in particular, for embalming the dead. The Greek historian Herodotus (5<sup>th</sup> century BC) and the Sicilian historian Diodorus tell how corpses mummified with the help of cedar oil in ancient Egypt. Alcohol distillation in China was known during the Han dynasty (1–2 century), but archeological excavations indicate that alcohol distillation was widely spread during the Jin and Song dynasties (10<sup>th</sup>–13<sup>th</sup> century) [11].

Distilled water has been known since 200 AD, when Alexander Afrodisius described the process of its manufacture. Arab scholars Jabir ibn Hayyan (Geber), Al-Kindi (Alkindus), Persian scientist Muhammad ibn Zakariya Al-Razi used distillation in their alchemical experiments. In the XI century, Avicenna mentions distillation as a method of obtaining essential oils. Among the inventions of the "father of chemistry", Jabir ibn Hayyan was a self-made device for the production of alcohol. Alcohol distillation in China was known during the Han dynasty (I-II century), but archeological excavations indicate that alcohol distillation was widely spread during the Jin and Song dynasties (10<sup>th</sup>–13<sup>th</sup> century).

The literature is often silent about the huge role of alchemy in the progress and development of our civilization. Nevertheless, it was the most important science in the period from the 10<sup>th</sup> to about the 17<sup>th</sup> century. In the second half of the Middle Ages, ancient manuscripts seized the imagination of some thinkers. Some scientists, monks and healers began to study, reflect and conduct experiments, having achieved

amazing progress in science and, in particular, in distillation. The focus of alchemical research was the philosopher's stone. For all alchemists, it was a substance, that could turn cheap metal into gold and silver and immediately bring wealth. To obtain a philosophical stone – the ultimate goal of the alchemists – it was necessary to perform 12 delicate operations: burning, freezing, dissolving, digesting, distillation, sublimation, separation, incineration, fermentation, etc. Of these operations, dissolution, fermentation and especially distillation make it possible today famous alcoholic beverages [10].

After the end of the Middle Ages, the ideas of alchemists for a long time influenced the scientific minds of many European countries. Ally Peter I., Jacob Bruce was looking for an elixir of longevity and tried to prepare «living» and «dead» water. Moise Charas, an apothecary of Louis XIV, following the example of the ancient alchemists, subjected to various kinds of distillation. He considered distillate of human skulls to be the best medicine and said that two or three heads of healthy men who died a violent death and a ceramic distillery should use. By the way, a little later at the court of Queen Elizabeth they were well acquainted with his theory.

In Europe, distillation of alcohol known in the XIIth century, according to the work of physicians Salerna medical school. In 1500, the German alchemist Jerome Braunschweig published «Liber de arte destillandi» (The Book of the Art of Distillation). This was the first book devoted to the issue of distillation. In 1651, scientist John French published «The Art of Distillation» – a practical guide to distilling alcohol. The development of distillation technology made it possible to mass produce strong spirits. Various types of drinks known under the term lat. aqua vitae – the «water of life». Then came names Gaelic whiskey, French cognac and, perhaps, vodka [4].

In the early New Time (1500–1800) Protestant leaders such as Martin Luther, Jean Calvin, leaders of the Anglican Church and even the Puritans believed that alcohol is God's gift and created for the enjoyment and maintenance of human health, in the same time drunkenness has considered as a sin. Until the beginning of the 18<sup>th</sup>

century, the attitude to drinking was positive with moderate consumption, drunkenness was condemned.

Despite the existing ideal of moderation, the consumption of alcohol at this time was generally high. In the 16<sup>th</sup> century, the consumption of alcoholic beverages reached 100 liters per person per year. In Valladolid, Spain and Poland, peasants consumed up to three liters of beer per day. In Coventry, England, the average amount of beer and ale consumed was about 17 liters per person per week. Swedes consumed beer 40 times more than now. English sailors received a gallon of beer per day, while soldiers received two thirds of a gallon (a gallon is a measure of volume in the English system of measures, corresponding to 3.79 to 4.55 liters, depending on the country of use). In Denmark, the usual consumption of beer was one gallon per day for an adult. It is important to note that modern beer (3–5% alcohol) is much stronger than beer in the past (about 1% alcohol) [5].

Most of the wines produced in Northern Europe at that time were light-flowing, light in color and with low alcohol levels. Such wines could not be maintained and eventually became over-flavored. Wine producers did not consider it necessary to bear the cost of aging wine. By the 16<sup>th</sup> century, aged wines were made only in the Mediterranean countries. In the 17<sup>th</sup> century, two events occurred that fundamentally changed the wine industry in the production of aged wines. The first – the use of cork and glass bottles, which allowed to store wine in a practically sealed environment; the second – the growing popularity of fortified wines, such as port wine, madeira and sherry. The addition of alcohol has been used as a preservative, allowing wines to withstand long sea voyages to England, America.

The most widespread rotary device of that time was Alambique Sinezius, which consisted of a reeded cube, an air reflux condenser and a refrigerator with two nozzles for water supply and drainage. The raw material was heated in a cube by any source of heat, alcohol pairs climbed up the cube, then through the tube came into the refrigerator, where they condensed in the coil under the influence of water. In copper distillates, paints, medicines and aromatic essences were made, and from the 16<sup>th</sup>

century alcohol. As a raw material, the latter used a variety of products (grape, honey, grain, corn, potatoes) [6].

The process of obtaining alcohol was discovered in different regions of the globe almost simultaneously. In Europe the first distillation of alcohol-free liquid was made by the Italian monk-chemist Valentine. Alchemists of Provence (France) adapted the Arabian-made pouring cube to convert the grape wort into alcohol. About the construction of distilleries in the Kiev Rus was mentioned in the Byzantine Chronicle in 1174. In the Russian Empire the vodka appeared at the end of the 14<sup>th</sup> century. In 1386 the Genoese Embassy brought the first vodka to Moscow (aqua vitae – «live water»), introducing it to Prince Dmitry Donskoy. In 1429, Aqua Vita was again brought to Moscow by foreigners, this time as a universal medicine, but they considered it necessary to breed with water. The idea of breeding alcohol served as an impetus for the production of Russian vodka [6].

In 1334 the alchemist from Provence, Arno de Wilgher (France), first has received wine alcohol from grape and in 1360 some French and Italian monasteries produced wine alcohol. In the 16<sup>th</sup> century «Aqua Vita» penetrates practically all countries of Europe. Between alcoholic beverages of different countries are beginning to manifest differences, which eventually become more significant. In the 17<sup>th</sup> century the distillation methods were already well developed, that gave the opportunity to drink alcohol in large quantities. This «medical» era is over and the era of trade began.

18<sup>th</sup> century did not bring particular advances in the process of distillation, but in the first half of the 19<sup>th</sup> century distillation technology has undergone rapid development. Instead of the traditional coil coil, the use of rather complicated structures from so-called rectifiers and refluxers, which allowed the output of a higher strength product to be used. Along with their improvements, the consecutive connection of two cubes was used. A rotating machine of this type – the so-called Pistorius machine – was widely used in Germany and then in Russia [12]. In the beginning 19<sup>th</sup> century E. Adam has invented a rotary device, which allowed to get eight heats per day, instead of two conventional ones, to save fuel, water and human



labor, as well as to obtain alcohol with a more pleasant taste. In 1813, a plate of dismembering apparatus appeared. In 1817 Pistorius patented an improved reagent.

In 1826, the Scottish R. Stein originated the idea of creating a permanent distillation machine, which is being implemented by an Irishman of French origin A. Coffey. In 1831 he patented a revolutionary rotary machine, called patent still or coffey still. The new device was 15–20 times faster than traditional alabama, more economical and gave a cleaner and stronger alcohol. The invention was used not only for the production of whiskeys, but also for many other beverages, including vodka, gin and white rum. The technology of distillation became so perfect that alcohol was practically «absolutely» pure [12].

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In 1867 the Belgian apparatus of Saval appeared allowed to receive alcohol from a continuous cycle up to 96%. In 1867 E. Sorel invented a cubic distillation apparatus of periodic action, and in 1881 E. Barbere – a continuous distillation apparatus. It should be noted that E. Sorel and E. Barbe in France laid the foundations of the theory and method of purifying alcohol from impurities. In 1876 the Russian engineers Nedoshivin and Novitsky perfected the alcohol counter of Siemens-Halske for the volume accounting of the amount of alcohol. However, until the second half of the 19<sup>th</sup> century the methods of obtaining alcohol were primitive, scientific technology did not exist at all. In 1660, the English chemist R. Boyle first received dehydrated ethyl alcohol, and also discovered some of his physical and chemical properties, in particular, showing the ability of ethanol to be high-temperature fuel for burners. Absolute (anhydrous) ethyl alcohol has obtained in 1796 by the Russian chemist T.E. Lovitz [7].

The first research of methyl alcohol was conducted in 1834 by French chemists J.-B. Dyum and E. Peligo, who called it «methyl or wood alcohol», since it was found in products of dry distillation of wood. The synthesis of methanol from methyl chloride was carried out by the French chemist M. Berthelot in 1857, which was first discovered isopropyl alcohol in 1855 synthesized by the action on propyl aqueous sulfuric acid. Tertiary alcohol was first synthesized by the famous Russian scientist A.M. Butlerov in 1863, laying the groundwork for a series of experiments in this direction. The discovery of starch malation malt by K.S. Kirchhoff in the Russian Empire in 1814, as well as the theory of the formation of intermediate compounds between the substrate and the catalyst by A.I. Khodnev, the teaching of A.I. Oparin and A.L. Kuransov about the enzymes of plant origin and its role in the living cell, gave rise to the scientific basis for the enzymatic catalysis of starch [8].

The chemical equation of alcohol fermentation is given by the French chemists A. Lavoisier (1789) and J. Lussacom (1815). In the first half of the 19<sup>th</sup> century French botanist C. Canier de Latour, studying the precipitate, formed as a result of alcohol fermentation, found living microorganisms in it. German scientists T.Schwann and F. Kuttsing, studying independently of each other the film, formed in

the course of vinegar fermentation, and the sediment, that occurs in the process of alcohol fermentation, also found microorganisms. They have concluded that the processes of vinegar and alcohol fermentation are a function of microbes. At this time, the work of S. Canary de Latour (1837) on the biological nature of the fermentation process was published. However, this conclusion was not found to be appropriately recognized, since at that time the theory of the physical and chemical nature of fermentation, formulated by Y. Lybich, was very popular [4].

Separate laws of fermentation were discovered by French chemist and microbiologist L. Pasteur. The scientist began his 20-year study in 1856. In 1861, he has proved that the formation of alcohol, glycerin and amber acid during fermentation can occur only at the presence of microorganisms. In 1862 the Paris Academy of Sciences awarded L. Pasteur the prize for solving the spontaneous generation of a living organism. The scientist has shown that fermentation is negatively affected by oxygen, since bacteria that carry fermentation can develop only in an oxygen-free environment. These facts allowed him to divide all organisms into aerobic (grow in the presence of oxygen) and anaerobic (without it). L. Pasteur found that the types of fermentation, in the process of which produce different products, are caused by certain types of microorganisms. Thus, the agents of alcohol fermentation (conversion of sugar to alcohol) are yeast, lactate fermentation agents (conversion of sugar to lactic acid) – rod-shaped bacteria [12].

The possibility of cell-free alcohol fermentation for the first time was indicated by the Russian physicist-biochemist M.M. Manaseina in 1871, who was an internship at the Polytechnic Institute in Vienna at Y. Wiesner, where she studied the process of alcohol fermentation. Scientist discovered that fermentation occurs under the influence of special substances that can be isolated from yeast cells [9]. These results refuted the «physiological» theory of fermentation of L. Pasteur and testified to the benefit of «chemical», which was followed by C. Bernard, J. Liebig and M. Burtlo [9]. It took more than a quarter of a century before these results were completely confirmed by the German chemist E. Buhner.

In accordance with the mechanistic theory of fermentation, yeast constantly decompose to a liquid state, creates a chemical tension, which causes the molecules of sugar to decompose. Accordingly, alcohol fermentation is a complex but, in general, ordinary chemical reaction. Proponents of the mechanistic theory have shown that substances found in living cells can be synthesized, but no one has been able to isolate a substance that promotes fermentation. Subsequently E. Buhner put forward the hypothesis that such an active substance is an enzyme. His discovery meant that fermentation occurs as the result of the chemical activity of the enzyme both inside and outside the yeast cell. Published in 1897 E. Buhner's work «On alcohol fermentation without the participation of yeast cells» caused a discussion among his colleagues-scientists. In 1902 in another article, he described the results of research on the chemical influence of yeast on milk sugar. In 1907 E. Buhner was awarded the Nobel Prize in Chemistry «for his research work on biological chemistry and the discovery of extracellular fermentation» [11].

The formation of the theory of fermentation was facilitated by the creative search of the domestic scientists. So, the Russian chemist L.A. Ivanov in 1905 found that added phosphate to yeast juice increased the rate of fermentation several times. Research of domestic biochemist A.I. Lebedev, S.P. Kostychev, I.A. Parnassus and German biochemists K. Neyberha, G. Embden, O. Meyerhof confirmed that phosphoric acid is involved in crucial stages of alcoholic fermentation. As a result, it was proved that this type of fermentation has the most economic significance.

Thus, the theoretical and methodological foundations of becoming alcohol industry formed in the second half of 19<sup>th</sup> – early 20<sup>th</sup> century, initiated by the discovery of process of distillation and fermentation theory. The process of obtaining alcohol was invented in the 16<sup>th</sup> century in different regions of the world practically simultaneously. In the 17<sup>th</sup> – 18<sup>th</sup> centuries the distillation methods were quite developed, that gave the opportunity to receive alcohol for industrial purposes. The chemical equation of alcohol fermentation was given by French chemists at the end of the 17<sup>th</sup> – to the beginning of the 18<sup>th</sup> century. However, the methods of obtaining alcohol were primitive until the second half of the 19<sup>th</sup> century, there was no

scientific technology of the fermentation process. In the second half of the 19<sup>th</sup> century mechanistic, microbiological, physico-chemical, physiological were formulated, to the its development made efforts: Zh.-B. Dumas, E. Peligo, M. Bertlo, A. M. Butlerov, Lavoisier, Zh. Lyussak, Sh. Kanyar de Latour, T. Schwann, F. Kyuttsinh, Yu. Liebig, L. Paster, N.M. Manaseina, E. Buhner, L.A. Ivanov, A.I. Lebedev, S.P. Kostychev, Ya.O. Parnas, K. Neyberg, G. Embden, O. Meyerhof and other scientists.

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