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Characteristics of producing ethyl alcohol

Charakterystyka wytwarzania alkoholu etylowego

Abstract

The paper presents the introduction to problems related to the distilling industry in Poland and its current situation. The theoretical issues related to the production of ethyl alcohol are discussed. The raw materials used and their impact on production efficiency, process steps and their conditions and quality requirements for alcoholic beverages based on ethanol are characterised. The main causes of the problem of distillery in Poland are seen in the import of cheap rectified and dehydrated spirits from other EU countries, which results in a fall in market prices that do not provide for reimbursement of production costs and increase of excise duty in 2014, which significantly contributed to the closure of the distillery. At present, there are around 100 of them in the country, most of which are made of distillates for bio ethanol production.

Keywords: ethyl alcohol, ethanol production, fermentation

Streszczenie

W pracy przedstawiono wprowadzanie do problematyki związanej z przemysłem gorzelniczym w Polsce oraz jego aktualną sytuację. Opisane zostały zagadnienia teoretyczne związane z procesem wytwarzania alkoholu etylowego. Scharakteryzowano stosowane surowce i ich wpływ na wydajność produkcji, etapy procesu wraz z ich warunkami oraz wymagania jakościowe napojów alkoholowych, otrzymywanych na bazie etanolu. Główne przyczyny problemów gorzelnictwa w Polsce upatruje się w imporcie taniego spirytusu rektyfikowanego i odwodnionego z innych krajów UE, co powoduje spadek cen rynkowych, które nie zapewniają zwrotu kosztów produkcji oraz podwyżki akcyzy w 2014 roku, która znacznie przyczyniła się do zamykania gorzelni. Aktualnie w kraju pozostało ich ok. 100, z których większość zajmuje się wytwarzaniem surówki do produkcji bioetanolu.

Słowa kluczowe: alkohol etylowy, produkcja etanolu, fermentacja

1. Introduction

Diluted solutions of ethyl alcohol obtained by fermentation were well-known to man in antiquity. Recent archaeological discoveries indicate that alcoholic beverages were produced during the Neolithic Age. The first ethanol distillation is attributed to the alchemist Geber of the VIII century. The description of the distillation apparatus and the way of obtaining alcohol from wine appeared in XIII century by prof. Arnold de Villeneuve of the University of Montpellier. In the XV century in Poland, herbs and flowers were extracted with alcohol, from which cosmetics and medicinal mixtures were made. An opinion on the beneficial effect of alcohol on human health has contributed to the increase of its consumption, production and development of craft distillery [1–3].

The intensive development of craft distillery in Poland took place in the XIX century, which was connected with the general development of the technique. Pistorius constructed the first distillation apparatus, a prototype of today's stripper columns, which allowed to produce high-percentage alcohol. Until 1830, the main raw material for the production of vodka in Poland was rye. In 1803, the method of producing potato alcohol was known, which allowed for about 7 times more alcohol than from rye, but only a few distilleries used this raw material. In 1866, the first excise tax was imposed, regulating the production of spirits in Polish territories. Before that, according to the statute of Jan Olbracht of 1546, every citizen of the country was free to sell and produce alcoholic beverages. In 1919, full control over the production and marketing of spirits was established in Poland. The State Spirit Monopoly was established, whose activity continued uninterrupted until 1939. It coordinated the production of spirits in the country, and also set the price of distillates for the individual provinces, as well as a production limit for distilleries. In this way, the State's Monopoly strictly regulated the production of spirits in the country, adjusting its size to the needs and possibilities of export. In the interwar period, there were about 1400 agricultural distilleries, which constituted an integral part of private property. In addition to the agricultural distilleries, 10 fruit distilleries, 5 molasses and 7 yeasts were in operation.

After World War II, in Poland, there were about 1200 agricultural distilleries good for commissioning and 15 industrial distilleries, adapted for the treatment of molasses. Nowadays, agricultural distilleries operate according to the demand reported from the fuel and spirits sector. In 1995, there were about 950 distilleries, and in 2011, their number was reduced to 173 [3–5].

2. Production of ethyl alcohol

2.1. Raw materials for the production of ethyl alcohol

The choice of raw material for ethanol production depends on the type and quantity of hydrocarbons fermented as well as their price. Their costs account for 76% of ethanol production costs. The yield of ethyl alcohol obtained from particular vegetable raw materials strongly depends on its sort (Table 1) [6].

Table 1. Efficiency of ethanol from individual vegetable raw materials [7]

Raw material	Rice	Corn	Wheat	Rye	Molasses	Oat	Potatoes	Apples
Yield, $dm^3 \cdot t^{-1}$	350–500	360–400	350–390	310–370	350	240	80–120	35–60

Raw materials for ethanol production are divided into two groups: straight -mono and -disaccharide sugars (e.g. glucose, fructose, sucrose) and polysaccharides (starch, glycogen). The first one of them undergoes direct fermentation, under the influence of some bacteria and yeast, the second are hydrolysed to fermentable sugars (-mono- and disaccharides). Simple sugars are present in vegetables, fruit, sugar cane, molasses and waste of food industry. Polysaccharides are found in potatoes, topinambur, manioc, chicory and waste of lignin-cellulose [6, 7].

Potatoes and cereals contain starches, which are their backup material for sourcing energy. This polysaccharide consists of glucose residues linked by a 1,4-α-glycosidic bond. Easy breakdown of starch has been used for centuries in the preparation of the mash for the production of ethyl alcohol. In traditional distillery craft, the source of enzymes for starch hydrolysis is malt (germinating grains, e.g. barley). In the germination process, enzymes of α-amylase and β-amylase are formed that break down the starches. The malt has now been replaced by enzyme preparations derived from such microorganisms as e.g. bacteria Bacillus subtilis or Aspergillus niger [8].

Molasses is a by-product of sugar production from sugar beet. It is a good raw material for ethanol because it contains a lot of carbohydrates, which undergo direct fermentation. Therefore, there is no need to use the evaporation stage (the process of starch release from the raw material) and the enzyme preparations in the technological process, which are necessary for the fermentation of starch raw materials [9].

2.1.1. Characteristics of yeast for distillery industry

The oldest known humanity biotechnology process is alcoholic fermentation with yeast share. Ethanol is produced by yeasts that live under anaerobic conditions and some bacteria species. The most commonly used species of yeast is Saccharomyces cerevisiae (Tab. 2). In the case of bacteria, important meaning for industry only have those that break down the sugars into ethyl alcohol such as e.g. Sarcina ventriculi [10].

Table 2. Yeast and bacterial species producing ethyl alcohol [10]

Yeast	Substrates	Species of bacteria	Substrates
Saccharomyces cerevisiae	glucose, fructose, galactose	*Zymomonas mobilis*	glucose, fructose, saccharose
Saccharomyces uvarum	saccharose, maltose, maltotriose	*Clostridium thermocellum*	glucose, cellobiose, cellulose
Saccharomyces diastaticus	glucose, maltose, starch	*Clostridium thermohydrosulphuricum*	glucose, xylose, cellobiose, starch
Saccharomyces rouxii	glucose, fructose, maltose, saccharose	*Thermoanaerobium brockii*	glucose, saccharose, cellobiose, starch
Schwanniomyces alluvis	dextrin, starch	*Thermobacterioides acetoethylicus*	glucose, saccharose, cellulose

Depending on the type of microorganism we use in the fermentation process, we can get different yields and reaction rates. The yield of ethanol produce from glucose for Z. mobilis and S. cerevisiae yeast is similar (Tab. 3). There are no significant differences between these microorganisms in the growth rate of biomass and ethanol production by yeasts and bacteria. The discrepancies between them appear with the ethanol production rate. The yeast produces ethanol at almost five times the speed, which is their main advantage. Also, in the case of glucose assimilation, the yeast is much faster than bacteria. As regards the type of fermentation process, it is best to use yeast for periodic fermentation because they are resistant to higher ethanol concentrations than bacteria. For continuous fermentation, it is better to use bacteria, because they are resistant to higher concentrations of ethanol in this type of process (Tab. 3) [10].

Table 3. Comparison of ethanol synthesis with bacteria (Z. mobilis) and yeast (S.cerevisiae) [10]

Kinetic parameter	Unit	*S. cerevisiae*	*Z. mobilis*
Max rate specific biomass growth	$1 \cdot h^{-1}$	0.41	0.43
Rate specific of assimilation of glucose	$(g_{microorg.} \cdot g_{glucose}) \cdot h^{-1}$	10.5	1.75
Rate specific ethanol production	$(g_{mikroorg.} \cdot g_{ethanol}) \cdot h^{-1}$	5.67	0.67
Yield of ethanol production on glucose	$g_{ethanol} \cdot g_{glucose}^{-1}$	0.47	0.43
Percentage yield	%	92	85
Max concentration of ethanol – in continuous fermentation – in batch fermentation	%	 do 5 do 20	 5.5–6.0 do 10

Yeasts of Saccharomyces cerevisiae are most commonly used in brewing and bakery craft. They can take different shapes depending on the age, the type of culture and the amount of food. These yeasts are larger in size than bacteria which are about 2–8 μm in width and 3–10 μm in length. Saccharomyces cerevisiae live in base, which contain simple sugars. They lead alcoholic fermentation mainly under anaerobic conditions [11]. Yeasts of this type ferment and assimilate most of the sugars. In the distillery craft a number of strains of Saccharomyces cerevisiae are used, which is associated mainly with their ability to rapidly alcohol ferment, resistance to alcohol concentration of 10–12% and high osmotic pressure. The most efficiently they fermented at 30–33°C. These yeasts have the ability to ferment glucose, fructose, sucrose, maltose, few strains are capable of fermenting raffinose, lactose and mannose [12].

Mixed cultures of yeasts are becoming popular, with individual strains having complementary properties each other or genetically modified to obtain the best possible properties. The used gamma rays for two types of Saccharomyces cerevisiae strains, Persian culture used in Tehran (PTCC 5269) and Armenian culture, strains resistant to high temperatures of 38–42°C and ethanol content up to 25% can be obtained. The thus microorganisms obtained allow the fermentation process to remain longer, without replacing yeast with new ones [12].

2.2. Preparation of ethyl alcohol

The stages of ethanol production vary, depending on the type of raw material used. In the case of cereal and potato distillery craft, it is necessary to distribute the polysaccharides present in the substrate in the evaporation and mashing process. This stage of alcohol production does not occur in the processing of fruit or molasses, which build from simple sugars. The remaining stages are the same for all raw materials and include the fermentation and distillation processes in which we receive distillate. In the final stage the distillate is purified in the process of rectification to spirit (Fig. 1) [13].

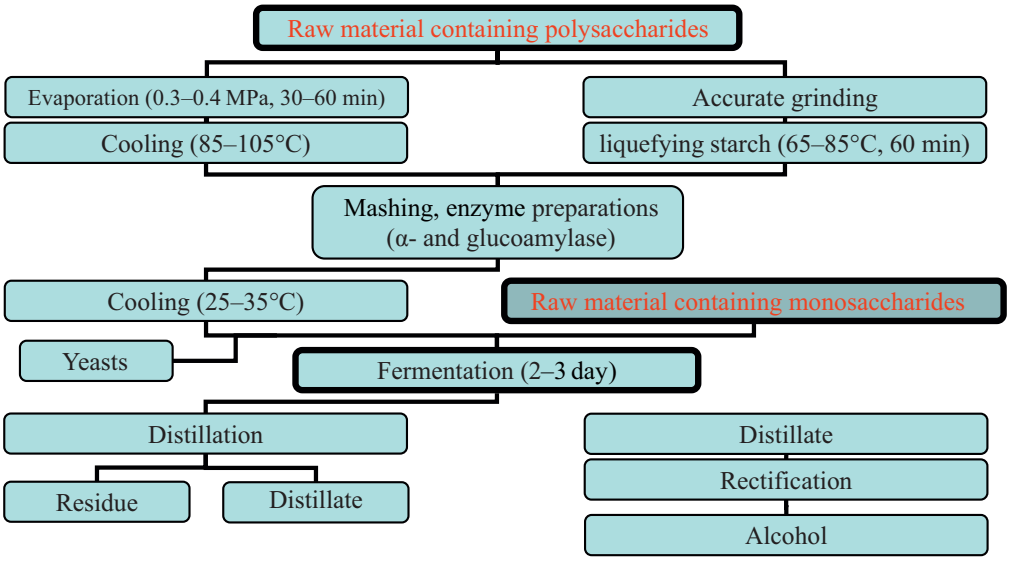

Fig. 1. Diagram of the process of making distillate and alcohol [13]

2.2.1. Preparation of the mash

Evaporation of raw material is the first step in the production of ethyl alcohol. Its purpose is to relax the intercellular substances, break the cell membranes and completely release and glue the starch. The amount of water used in this process must be approx. 4 times greater than the amount of starch that allows it to be liquefies. The evaporation process takes about an hour, at 120–140°C, at a pressure of 0.3–0.4 MPa. Liquified mash enzymatic preparations are used to reduce their viscosity and facilitate the saccharification of the starch. Enzymes break down chains of amylose, amylopectin and fermentable sugars, mainly to glucose [14].

The cold mashing process used by some distilleries involves the unpressurised release of starch. The raw material is finely crushed to about 1.7 mm, which facilitates the access of water to the starch grains. As a result, it is possible apply milder process conditions. The duration of cold mashing is approx. one hour at 65–85°C. Enzymatic preparations are also used in this process. The next step is the fermentation of the sweet mash with the use of distillery yeast [15].

The newest method of ethyl alcohol production is the simultaneous process of hydrolysis and fermentation of SSF (Simultaneous Saccharification and Fermentation), which allows for gradual release of glucose during fermentation. Starch is broken down by enzymes at temperatures below the value of the gelatinisation, significantly reducing energy consumption, the temperature throughout the process does not exceed 50–55°C [12].

2.2.2. Alcoholic fermentation

Alcoholic fermentation capacity demonstrated by the yeasts from the ascomycetes group. This process consists in the anaerobic decomposition of simple sugars into ethyl alcohol and carbon dioxide with a simultaneous release of energy. In fact, its course is more complex (Fig. 2). During fermentation, many by-products are formed, and the process itself depends on many factors: temperature, chemical composition of the base and pH of the environment. If oxygen has access to the base, yeast does not produce ethyl alcohol, only breathe oxygen and multiply. The concentration of ethyl alcohol (> 20%) produced by the fermentation process inhibits the yeast's activity [16].

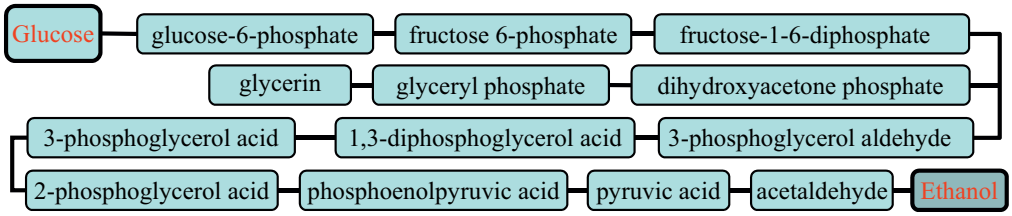

Fig. 2. Diagram of the glucose conversion to ethyl alcohol [11]

The alcoholic fermentation process can be represented by a relatively simple general equation (1). From one mole of glucose produces two moles of ethanol and carbon dioxide, the reaction proceeds with the release of energy of about 234.5 kJ. The microorganisms consume approximately 67 kJ to produce two moles of adenosine triphosphate (ATP) from adenosine diphosphate (ADP) with the participation of residuals of orthophosphoric acid (P_i) [17].

$$C_6H_{12}O_6 + 2ADP + 2P_i \rightarrow 2C_2H_5OH + 2ATP + 2CO_2 + 167.5\ kJ \quad (1)$$

In the first stage of fermentation, hydrolytic enzymes, sucrose and maltase break down sucrose and maltose (disaccharides) into simple sugars. Then the enzyme ATP (adenosine triphosphoric acid) is connect to the simple sugars and form glucose phosphate and fructose phosphate. In the next step, fructose phosphate, after the subsequent addition of the phosphate acid, is broken up into two triose: phosphoglycerol aldehyde and phosphorodihydroacetone. These sugars have the same summary formula but different structure and properties. Under the influence of the isomerase enzyme, the ketone is converted into an aldehyde which is then oxidised to phosphoglyceric acid. Part of the aldehyde, under the action of dehydrogenase, changes into glycerol phosphate, which then turns into glycerol. A large amount of aldehyde

molecules is converted to phosphoglyceric acid, which is further converted to phosphorpyruvic acid by donating part of phosphate to the enzyme adenosine diphosphate acid [4, 10, 11].

The initial fermentation step is identical like glycolysis of glucose into pyruvate (2), which could be converted into acetyl coenzyme A (acetylCoA) or oxaloacetate. In case of oxygen deficiency, the yeast metabolises pyruvate to ethanol [17].

$$C_6H_{12}O_6 + 2P_i + 2ADP + 2\,NAD^+ \rightarrow 2CH_3COCOO^- + 2ATP + 2NADH + 2H^+ \qquad (2)$$

As a result of non-oxidative decarboxylation, pyruvic acid is transformed into acetaldehyde (3). The reaction takes place under the influence of two pyruvate decarboxylase enzymes and thiamine pyrophosphate, which separate the carboxylic group in the form of CO_2 from the acid [17, 18].

$$2CH_3COCOOH \rightarrow 2CH_3\,CHO + 2CO_2 \qquad (3)$$

In the last step, the acetaldehyde is reduced to ethanol in the presence of alcohol dehydrogenase (4). During the oxidation of 3-phosphoglyceric aldehyde to 1,3-diphosphoglyceric acid is formed dinucleotide (NADH), which is a hydrogen donor. The main products of the process are ethyl alcohol and carbon dioxide [17, 18].

$$2CH_3CHO + 2\,NADH + 2H^+ \rightarrow 2CH_3CH_2OH + 2NAD^+ \qquad (4)$$

A lot of byproducts are formed in the alcoholic fermentation process, which can improve the taste of the final product or significantly worsen it. Their presence and amount in alcoholic drinks depend on the type and quality of raw materials, methods and conditions of the technology used. The storage of the obtained alcohol solution is also important for him quality. The byproducts of the fermentation process include aldehydes, esters, methanol, glycerin, organic acids and higher alcohols [19].

Carbonyl compounds such as methanal, ethanal, propanal, butanal, pentanal, hexanal, 2-methylpropanal, acetone, glyoxal and furfural worsen the organoleptic properties of alcoholic beverages. Their source is fat decompose reactions. In controlling the synthesis of aldehydes, the most important role is played by the temperature and pH of the fermentation environment [20, 21]. The agricultural distillates from molasses may have several times higher concentrations of acetaldehyde in comparison with cereal distillates. Part of the hydrocarbons can be converted by bacteria to aldehydes. In the final product, as a result of condensation of aldehydes with alcohols, they may appear in a small amount of acetals [22]. In higher concentrations of acetals, the smell of the beverage significantly worsens [19, 24].

Methyl alcohol is formed from pectin by the decomposition into methanol via pectic acid. As a result of the enzymatic hydrolysis of the polygalacturonic acid methyl ester, free carboxyl groups and methanol are formed [4, 23]. Pectin is a mixture of carbohydrates and is usually found in generative organs of plants (fruits, seeds). Therefore, the greatest amount of methanol will be composed of spirits derived from fruits, mainly apples and plums. Higher

alcohols adversely affect the taste of alcoholic beverages. They are produced in the amino acid dezamination process (isoleucine, leucine and valine) [4, 10, 11]. They are characterised by a higher boiling point than ethanol, which is why they can be removed relatively easily from the product. The following fermentation products appear in the largest concentrations: propanol, butanol, pentanol and 3-methylbutanol. Their formation depends on the type of yeast and raw material used and the presence of oxygen, nitrogen and sulphur in the solution. As in the case of esters, a low content of fusels in an alcoholic beverage may have a beneficial effect on its taste [4, 19, 23].

Esters are formed from the combination of activated fatty acids and alcohols formed during the fermentation process. Despite their presence in trace amounts in final products, they give them a characteristic smell [19]. The synthesis of esters can be controlled to some extent by the change conditions run of the fermentation process: hydrostatic pressure, reactor size, nitrogen level, wort oxygenation and temperature, and selection of raw materials. The influence of yeast race on ester production and their relation to each other is extremely important. Proper selection of yeast may increase or decrease nearly five times the amount of esters in the final product [24].

Sulphur compounds and organic acids may also be present in the fermentation product. In drinks, most common are methanethiol, dimethyl sulphide, dimethyl disulphide, dimethyl trisulfide, methyl thioesters and thiols, which are formed from the reaction of yeast metabolism or non-enzymatic reactions [25, 26]. Acetic, lactic and butyric acids may be produced (as a byproduct) by some yeast. The increase in temperature and pH of the fermentation environment is conducive to the development of microflora of bacteria responsible for the synthesis of organic acids. Their excessive amount and reduced pH, the overall efficiency of the fermentation process may be reduced [19,27].

The raw spirit obtained from the fermentation process is further purified. Depending on the degree of purity of the final product, ordinary, selective, luxury and neutral spirits are distinguished [4, 10, 11].

2.3. Separation of ethyl alcohol

2.3.1. Distillation

Ethyl alcohol can be extracted from the fermentation product using a classic distillation process that involves evaporation of the liquid and condensation of the resulting vapour. The mash is heated to about 78.3°C, where the ethanol is evaporated. Vapours are condensed by lowering their temperature. The raw spirit obtained after the distillation process is a mixture of many components, as the other compounds contained in the feed evaporates together with the ethanol. Separation of these substances from ethyl alcohol can be achieved using the rectification process. Ethyl alcohol forms azeotropic mixture with water, which cannot be separated by straight distillation [4]. In agricultural distillery, multiple straight distillations are carried out, producing 65–88% of crude spirit, which also includes volatile fermentation products [3].

Straight distillation is divided into equilibrium, periodic and continuous distillation. Equilibrium distillation is runs continuous and is mainly used to separate low volatility substances from high volatility substances. Periodic distillation is used for the production of special alcoholic beverages e.g. fruit vodkas. In the continuous distillation, due to the short residence time of the substance in the elevated temperature zone, the decomposition and polymerisation of the particles are avoided [28–30].

2.3.2. Rectification

Rectification is a separation process that uses the difference in volatility of individual components of liquid mixtures. The separation occurs in a column, when it flows countercurrent and without diaphragm flows down the liquid stream, and the vapour to top of the column. A higher temperature is at the bottom of the column, while the lower one is at the top. The steam passing through the column is enriched in a more volatile component and the liquid in the less volatile component has a higher boiling point [31].

The rectification can be carried out both periodically and continuously. The most common way is a continuous process, and periodic rectification is used to separate small amounts of mixtures. In the continuous process, the raw material is fed continuously to the column powered shelf, which is divided into the reinforcement and the stripping part. Continuous distillate and depleted liquid of constant composition are also obtained [29].

Periodic rectification consists of a one-time filling of the boiler with a liquid mixture, which is heated to the boil. Further distillate fractions are collected at the top of the column from the condenser. As a result, we get fractional mixtures that differ in condensing temperatures. The rectification process produces purified spirits that contain more than 96% ethyl alcohol but less than 97.2%. Hydro-selection or molecular sieves are used to obtain 100% of the spirit.

3. Quality requirements

In the process of alcoholic fermentation, in addition to ethyl alcohol, other compounds are formed, which give the spirits a characteristic flavour and aroma as well as affect their quality. Raw spirit should meet the requirements set out in Table 4 in accordance with the agricultural distillery quality standard [32].

The standard of the quality of rectified alcohol divides it into three species: luxury, perfect and ordinary (Table 5). In order to obtain pure vodkas, the spirit with demineralised water should be mixed in the characteristic proportions for the specific product. Species of vodka also include juices, macerates, distillates, dyes, sugar syrups and other flavours. The requirements set by the quality standard for pure spirits are given in tables 6 and 7 quality requirements for the species of vodkas [13, 33–35].

Table 4. Requirements for the quality of agricultural distillate [32]

Features	Agricultural distillate			
	molasses	cereal	potato	fruit
Transparency	transparent, without sludge and turbidity, mechanical impurities are allowed, drooping to the bottom after 2 hours			
Colour	colourless, yellowish or greenish shades are allowed			colourless, yellowish shade is allowed
Smell and taste	specific, characteristic of the raw material used, without extraneous odours and odours			
Power, % vol	≥ 88			≥ 65 and ≤ 86
Fusels[1], g*dm^{-3} 100%	*	≤ 5.0 in spirits for the production of okowit, in others *	*	≤ 5.0
Aldehydes[2], g*dm^{-3} 100%	≤ 0.3	≤ 0.1		≤ 0.2
Molasses alcohol, g*cm^{-3} 100%	*	≤ 0.08 in spirits for the production of okowit, in others *	*	≤ 0.8
Acids[3], g*dm^{-3} 100%	≤ 0.1	≤ 0.08		≤ 0.2
Hydrogen cyanide, mg*dm^{-3} 100%	*			≤ 0.3 in stone's fruit distillate, in others *
Dry residue after evaporation, g*dm^{-3} 100%	< 0.08	*		
Presence of furfural	unacceptable in the production of vinegar, in others *			
Pyridine, g*dm^{-3} 100%	< 0.02 in the distillate for the production of vinegar, in others*			

* is not normalised

[1)] in calculated on a mixture of isoamyl and isobutyl alcohol

[2)] in calculated on the acetaldehyde

[3)] in calculated on acetic acid

Table 5. Alcohol quality requirements [33]

Features	Rectified alcohol		
	ordinary	perfect	luxury
Ethanol, % vol	≤ 96	≤ 96.5	
Fusels [1], g*dm^{-3}100%	≤ 0.005	≤ 0.002	≤ 0.001
Aldehydes [2], g*dm^{-3}100%			
Esters [3], g*dm^{-3}100%	≤ 0.05	≤ 0.03	
Acids[4], g*dm^{-3}100%	≤ 0.0020	≤ 0.015	
Methyl alcohol, g*100 cm^{-3}100%	≤ 0.05		≤ 0.03
Lang's attempt, min	≥ 18	≥ 20	
Dry residue, g* dm^{-3}100%	≤ 0.015	≤ 0.010	
Furfural	unacceptable		
Volatile nitrogen base [5], g* dm^{-3}100%	< 0.001		

[1)] in calculated on isobutyl alcohol
[2)] in calculated on the acetaldehyde
[3)] in calculated on ethyl acetate
[4)] in calculated on acetic acid
[5)] in calculated on nitrogen

Table 6. Quality requirements of pure vodkas [24]

Vodkas, %vol		Aldehydes[1]	Fusels [2]	Acidity	Dry residue	Methanol, g*100 cm^3 100%
no more than, g*dm^{-3} 100%						
Ordinary	38–70	0.008	0.005	*	*	≤ 0.1
Perfect		0.004	0.003	*	0.035	≤ 0.05
Luxury		0.003	0.002	*		≤ 0.03
Mixed		like for pure vodkas, made from a lower alcohol quality				

* is not normalised
[1)] in calculated on the acetaldehyde
[2)] in calculated on amyl alcohol
[3)] in calculated on acetic acid

Table 7. Quality requirements for species vodkas [35]

Species products	Power, %vol	Extract, g*dm^{-3}	Fusels [1], g*dm^{-3} 100%	Methanol, g*100 cm^{-3} 100%	Hydrogen cyanide, mg*dm^{-3}
Dry regular	30–50	do 50	≤ 1.5	≤ 0.25	≤ 3
Dry natural	30–75		≤ 5	≤ 0.4 (slivovitz –0.8)	
Dry natural mixed			≤ 4	≤ 0.4	
Semi-dry	30–45	51–120	≤ 1.5	≤ 0.25	
Semi-sweet		121–220			
Sweet		221–330			
Liqueur	25–45	> 330			
Creams	18–25	> 400	*		
Cocktails		do 400	≤ 1.5		
Aperitifs	18-35				

* is not normalised

[1)] in calculated on amyl alcohol

4. Summary

- Current problems of agricultural distillery craft in Poland include the import of cheap rectified and dehydrated spirits from other EU countries, which causes a dramatic drop in market prices that do not ensure the return of production costs.
- The increase in excise duty in 2014 has contributed to the closure of the distillery craft; at present, there are about 100 (95% of small and medium-sized companies) in the country, most of which are producing distillate for bioethanol production.
- In most cases, raw materials containing starches, such as cereals and potatoes, are used in ethanol production. Despite the evaporation and mashing stages, the yield of ethyl alcohol is higher.
- Bacteria and yeast can be used in the fermentation process. They have the same efficiency of ethanol production from glucose but vary in speed. Yeasts allow for five times faster fermentation.
- Saccharomyces cerevisiae is the most widely used yeast species in the distillery industry. Mixed or genetically modified strains that are resistant to up to 25% vol. are becoming more and more popular.

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