Main directions of application of active carbons in alcoholic beverage production

Tatiana Shendrik[1], Leonid Levandovskyi[2], Anatolii Kuts[3], Vitalii Prybylskyi[3], Olena Grabovska[3]

1 – L.M. Litvinenko Institute of Physical–Organic Chemistry and Coal Chemistry of the National Academy of Sciences of Ukraine, Kyiv, Ukraine
2 – Kyiv National University of Trade and Economics, Kyiv, Ukraine
3 – National University of Food Technologies, Kyiv, Ukraine

Keywords:

Active coal
Alcohol
Vodka
Purification

Article history:

Received 19.11.2018
Received in revised form 24.04.2019
Accepted 30.05.2019

Corresponding author:

Tatiana Shendrik
E-mail: shendriktg@gmail.com

DOI: 10.24263/2310-1008-2019-7-1-12

Abstract

Introduction. The purpose of the publication is to assess the quality and to usage of natural charcoal of activated charcoal by physical and chemical indicators for alcoholic beverage production – for the purification of water-alcohol mixtures from impurities in the technology of vodka.

Materials and methods. Activated charcoal – as a raw material for the purification of water-alcohol mixtures in the technology of vodkas. Methods of research: adsorption activity by iodine; adsorption activity by acetic acid; adsorption activity by methylene blue; total volume of pores in water; bulk density of activated carbon; fractional composition; mass of ash; bulk iron; bulk moisture content; abrasion strength.

Results and discussion. Activated charcoal of plant origin BAU-A, BAU-A-LVZ, BAU-A-Ag, MeKS, KAU-A, KDS-A according to the complex of indicators does not fully meet the high requirements of alcoholic beverage production. The active charcoal grades BAU-A have the standard values of indicators: adsorption activity by iodine – 62%; adsorption activity by acetic acid – 64 ml; adsorption activity by methylene blue – 129 mg/g; total pore volume by water – 1.72 cm^3/g; bulk density – 215 g/dm^3; mass fraction of the balance on a sieve with a linen: № 36 – 1.6%; № 10 – 98%; on the pallet – 0.4%; mass of ash – 4.7%; mass fraction of water soluble ash – 1.64%; mass fraction of iron – 0,12%; mass moisture content – 3.8%; abrasion resistance – 52.8%. To expand the range of values of indicators, it is necessary to create different combinations based on the BAU-A grades of coal or their modifications BAU-A-LVZ, BAU-A-Ag together with activated charcoal stone (MeKS), coconut (KAU-A) and anthracite (KDS-A). Activated charcoal of the mark MeKS in relation to BAU-A has higher values: adsorption activity by iodine by 32%; adsorption activity by acetic acid by 45.3%; adsorption activity by methylene blue at 52.7%; bulk density at 62.4%; tensile strength at 37.3%. In relation to BAU-A, activated charcoal MeKS has lower values: the total volume of pore water by -9.6%; mass of the remainder on a sieve with a linen: № 36 on -1.5%; № 10 at -7.6%; on a pallet of 9.1%; mass of ash at -1.1%; a mass of water-soluble ash -0.4%; bulk of iron by 0.1%; mass moisture content -0.6%. At the same time low indicators of one activated carbon can be offset by high indicators of other coal.

Conclusion. Creation of combined activated charcoal with optimized parameters (increased durability, high adsorption and catalytic properties, developed porous structure) will allow to meet the high requirements of alcoholic beverage production and to more actively absorb organic impurities, improving the organoleptic parameters of vodkas.

Introduction

The search for new active carbons used for alcoholic beverage production is associated with a number of difficulties. Until recently, this issue was resolved intuitively, based on the experience of manufacturers of active carbons, as well as distillers production technologists. This is due to the high complexity of the process of obtaining active carbons, as well as the subsequent process of cleaning the sorting with active carbon. These processes are characterized by an abundance and variety of various internal links between active carbon and the water-alcohol mixture.

Therefore, the *purpose* of the publication is to assess the quality and to usage of natural charcoal of activated charcoal by physical and chemical indicators for alcoholic beverage production – for the purification of water-alcohol mixtures from impurities in the technology of vodka.

Analysis of recent researchs and publications

In order to select the optimal technological process of sorting with active carbon, it is necessary to compare the various modes of the technological process. It is necessary to take into account and analyze the effect of a large number of factors on the parameters of the process. All this should be done in a limited time frame for developing the technological process. Therefore, it is have to choose the best options of the technological process, as well as the best conditions (modes) of its implementation.

Naturally, such a state of affairs cannot satisfy the rapidly growing and increasingly complex alcoholic beverage production. The emergence of new adsorbents (López-Garzón et al, 1999; Tzvetkov et al, 2016; Kwiatkowski et al, 2017; Marsh, Rodriguez-Reinoso, 2006; Acikyildiz et al, 2014; Rivera-Utrilla et al, 2011) [1-6] for the distillery production (Kuzmin et al, 2017; Kuzmin et al, 2015, 2017) [7-10] causes significant changes in the optimization of the technological process of sorting with active carbon (Muhin et al, 2003; Muhin et al, 2004) [11, 12].

At present, the main types of active carbons can be distinguished in the alcoholic beverage industry (Petrov et al, 2004; Mank, Melnik, 2007) [13, 14]. They are made from materials that contain complex organic compounds that can form a solid carbon residue under certain conditions. Classification of sorbents (activated carbons by nature of origin for alcoholic beverage production (Figure 1): *natural origin* (crushed active wood BAU-A; modified BAU-A activated carbons for alcoholic beverage production; modified activated carbons by metal ions; active carbons from fruit stones, nutshells; active carbons from various organic wastes, active carbons from fossil coals, natural minerals); and *synthetic origin* (silica gel).

Charcoal activated wood crushed BAU-A

The classical technology of using traditional active carbons of the BAU-A brand in alcoholic beverage production is typical for 80% of alcoholic beverage enterprises in Ukraine, which are used at the stage of processing water-alcohol mixtures with active carbon.

Charcoal activated wood crushed brand BAU-A refers to the active coal gas type, which is made from (birch wood) charcoal brand A, followed by treatment with water vapor at a temperature of 800-950°C, with preliminary or subsequent crushing (Petrov et al, 2004; Portnoj, 2004) [13, 15]. The quality of BAU-A coal depends on the quality of the initial wood or carbonizate, as well as the technological parameters in the process of wood carbonization and subsequent activation (Petrov et al, 2004) [13].

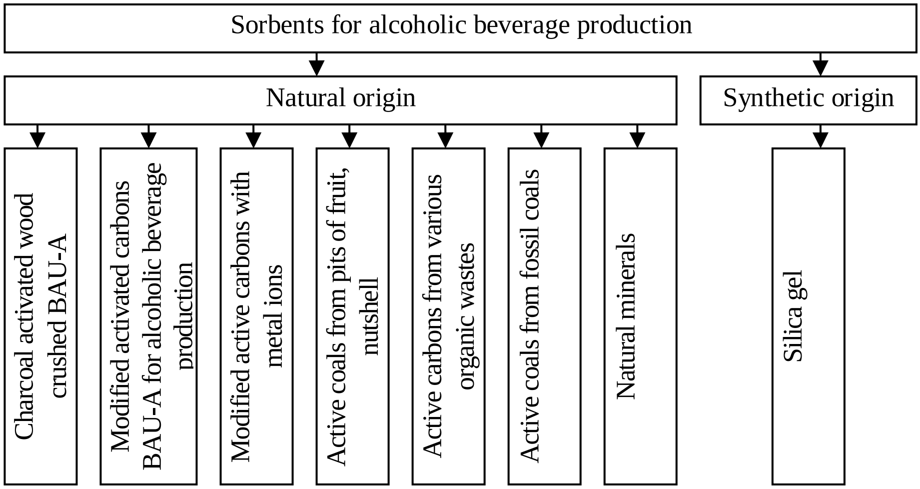

Figure 1. Classification of sorbents for alcoholic beverage production

Requirements of the normative documentation for activated carbon BAU-A: appearance – black grains without mechanical impurities; adsorption activity by iodine – at least 60%; total pore volume of water is at least 1.6 cm^3/g; bulk density – not more than 240 g/dm^3; fractional composition, mass fraction of the residue on the sieve with the web: № 36 – not more than 2.5%, № 10 – not less than 95.5%, on the pallet – not more than 2.0%; mass part of ash – no more than 6%; mass of moisture – no more than 10%; abrasion resistance (%) – not regulated.

The advantages of coal BAU-A:

- high specific surface area of the porous space (500-800 m^2/g), due to which adsorption of organic impurities from the solution and catalytic processes of formation of new substances take place (Petrov et al, 2004) [13];
- treatment of aqueous-alcoholic solutions with active carbon is accompanied by a course of redox reactions and a multicomponent adsorption process of ethyl alcohol microimpurities (Portnoj, 2004) [15];
- high organoleptic characteristics of water-alcohol mixtures (vodka) after treatment with active carbon.

Disadvantages of BAU-A coal:

- high alkalinity of the surface of active carbon (pH of active carbons after vapor-gas activation – 9–11) (Petrov et al, 2004) [13];
- the presence of mineral impurities in the structure of active carbon (water soluble ash) – 0.5–0.7% by weight (Petrov et al, 2004) [13];
- low mechanical strength 37–42%, which leads to significant losses of coal in the process of working coal columns (Muhin et al, 2003; Muhin et al, 2004) [11, 12];
- the presence of powdered particles of activated carbon, which requires the installation of additional filtration systems after coal columns and increases the consumption rate of coal (Petrov et al, 2004) [13];
- low values of the bulk density of activated carbon up to 240 g/dm^3 reduce its mechanical strength;
- large range of granulation of active carbon. With the dynamic method, it is self-sorted: large-sized coal grains are located in the middle of the coal column, smaller grains are thrown to the

periphery, as a result of which the water-alcohol mixture moves across the cross-section of the coal column differently;
- replacement of birch or beech raw coal with a mixture of soft wood, and therefore increases the consumption of active carbon for the treatment of water-alcohol mixtures;
- a small amount of micropore space, which characterizes the low absorption capacity in comparison with other coals of gas type.

The above indicators of active carbon BAU-A do not fully meet the requirements of alcoholic beverage production (Petrov et al, 2004) [13].

Therefore, we need an additional analysis of active carbon according to the following indicators:
- abrasion resistance up to a value of 70% (Petrov et al, 2004; Portnoj, 2004) [13, 15];
- adsorption activity according to the method of Schulman and Babkova (Petrov et al, 2004; Portnoj, 2004) [13, 15];
- adsorption activity by acetic acid (Oshmyan method) to a value of 70–110 cm^3 (Petrov et al, 2004; Portnoj, 2004) [13, 15], which characterizes the catalytic properties of activated carbon (Petrov et al, 2004) [13].

Modified activated carbons BAU-A for alcoholic beverage production

Wood activated charcoal brand BAU-LV was developed specifically for alcoholic beverage production and is characterized by specific normalized indicators: abrasion resistance, adsorption activity by acetic acid (Petrov et al, 2004) [13].

Requirements of regulatory documentation for activated carbon brand BAU-LV: appearance – black grain without mechanical impurities; adsorption activity by iodine – at least 65%; total pore volume of water is at least 1.6 cm^3/g; bulk density – not more than 240 g/dm^3; fractional composition, mass fraction of the residue on the sieve with the web: № 36 – no more than 2.5%, № 10 – not less than 96.5%, on the pallet – not more than 1.0%; mass part of ash – no more than 6%; mass of moisture – no more than 10%; abrasion resistance – at least 45%; adsorption activity by acetic acid – not less than 70 ml.

Charcoal active wood shredded brand BAU-A-LVZ. Requirements of regulatory documentation for activated carbon BAU-A-LVZ: appearance – black grain without mechanical impurities; adsorption activity by iodine – not less than 65–70%; total pore volume of water is at least 1.6 cm^3/g; bulk density – not more than 240 g/dm^3; fractional composition, mass fraction of the residue on the sieve with the web: № 36 – not more than 2.5%, № 10 – not less than 95.5%, on the pallet – not more than 2.0%; mass of ash – no more than 3%; mass of moisture – no more than 10%; adsorption activity by acetic acid – not less than 70 ml; abrasion resistance – at least 60%.

Modified active carbons with metal ions

To enhance the catalytic component of the sorting treatment process, active carbons are applied with additives that accelerate the chemical reactions taking place and are catalysts for this process (Petrov et al, 2004) [13]. In addition to the acquisition of catalytic activity by such carbon materials, the possibility of a significant increase in the capacity and selectivity of carbon sorbents when modifying them with metal ions in sorption processes has been established (Zhabkina et al, 2005) [16]. The highest sorption for activated carbons is observed for silver ions (Petrov et al, 2004; Zhabkina et al, 2005) [13, 16], gold, metals of the platinum group, where direct interaction with the matrix of coal occurs, which leads to the formation of surface complexes or reduction (Zhabkina et al, 2005) [16]. This makes it possible to obtain drinks with qualitatively new or better organoleptic and physicochemical parameters (Zhabkina et al, 2005) [16].

Requirements of normative documents for active impregnated grade A coal: silver content –

0.08–0.11%; bulk density is fixed; fractional composition, mass fraction of the residue on the sieve with a hole diameter: 3.6 mm – not more than 2.5%, 1.0 mm – not standardized, 0.5 mm – not more than 3.0%; on the pallet – 2,0%; mass of water – no more than 15%.

Requirements of regulatory documents for impregnated active grade B grade coal: silver content – 0.06–0.08%; bulk density is fixed; fractional composition, mass fraction of the residue on the sieve with a hole diameter: 3.6 mm – not more than 2.5%, 1.0 mm – not standardized, 0.5 mm – not more than 3.0%; on the pallet – 2,0%; mass of water – no more than 10%.

Requirements of the normative documentation for active BAU-A-Ag silver impregnated coal: silver content – 0.08–0.11%; bulk density – not more than 240 g/dm^3; grain size: >3.6 mm – not more than 2.5%, <3.6…1.0 mm – not standardized, <1.0 mm – not more than 2.0%; mass of moisture – no more than 10%.

Impregnation of activated carbons with metal ions has several disadvantages, the main of which is the gradual leaching of silver from the surface of the coal (Zhabkina et al, 2005) [16].

Active coals from pits of fruit, nutshells

The use of active carbons obtained from fruit pits, nutshell (cedar, walnut, coconut), leads to the optimal technological processing modes of sorting, which are significantly different from the modes of using traditional BAU-A (Petrov et al, 2004) [13].

Obtaining active carbon from the seeds of fruit of fruit trees (apricot, peach) of the MeKS brand is carried out by their carbonization (pyrolysis at 450–550 °C), crushing to the required particle size and subsequent activation (Muhin et al, 2003) [11].

The production of active carbon from coconut shell carbonisate is performed by the vapor-gas activation method at a temperature of 850–870 °C and a consumption of water vapor 5–10 kg per 1 kg of coal (Muhin et al, 2003) [11].

To clean the water-alcohol solutions in the distillery production, the active coal KAU-2 is used – the product of treatment of a coconut shell at high temperature. According to physico-chemical parameters of coal, activated KAU-2 should be without mechanical impurities and correspond to the following indicators: appearance – coarse-grained, black without mechanical impurities; adsorption activity by methylene blue – not less than 270 mg/g; mass fraction of water – no more than 10%; bulk density (g/dm) – is not standardized; fractional composition: particles in the size from 3.6 to 5.0 mm – no more than 2.5%; particles in the size from 1.0 to 3.6 mm – not less than 96,5%; particle size less than 1.0 mm – not more than 1.0%; mass fraction of ash - not more than 10%; durability at abrasion – not less than 72%.

Active carbons from various organic wastes

Activated charcoal is obtained from materials that form a solid carbon residue. Among them stand out: wood – 36%, coal – 28%, brown coal – 14%, peat – 10%, shell coconut – 10%, organic materials and waste – 2% (Kuzmin et al, 2017) [7]. Only 2% of organic material and waste are used to produce activated carbon. Therefore, there are actual searches for alternative materials with the use of existing technologies in the food industry, the waste of which can be used for the production of adsorbents (Kuzmin et al, 2017) [7].

The proposed method of production of activated charcoal from pyrolyzed wood waste, which is formed after the smelting of food products, followed by carbonization of non-isothermal heating and activation at lower temperatures to 500–700 ºC in the presence of H_3PO_4. This allows to obtain sorbents with a large yield factor of 80–90% and fractional composition of particles in the size of 1,0-3,6 mm (Kuzmin et al, 2017) [7]. Parameters of the porous structure of activated carbon from pyrolyzed wood waste (Kuzmin et al, 2017)

[7]: total pore volume V_{Σ}=0.187 cm^3/g (100%); Volume of macropores V_{ma}=0.047 cm^3/g (25%); volume of mesopores V_{me}=0.049 cm^3/g (26%); volume of micropores V_{mi}=0.091 cm^3/g (49%).

The method of production of activated carbon from wood carbonisation is proposed, which includes mixing of carbonaceous raw materials with potassium hydroxide KOH at an activation temperature of 600–800 °C, with a yield factor of 70–80% and a fractional composition of particles in the size of 1,0-3,6 mm. Parameters of the porous structure of activated carbon from pyrolyzed wood waste (Kuzmin et al, 2017) [9]: total pore volume V_{Σ}=0.421 cm^3/g (100%); volume of macropores V_{ma}=0.034 cm^3/g (8.08%); volume of mesopores V_{me}=0.091 cm^3/g (21.61%); volume of micropores V_{mi}=0.296 cm^3/g (70.31%).

Active coals from fossil coals

The production of activated carbons from anthracite brand KDS-A is carried out by the vapor-gas activation method at a temperature of 850–870 °C and a consumption of water vapor of 5…10 kg per 1 kg of coal (Muhin et al, 2003) [11].

It is promising to obtain activated charcoal from brown coal at an activation temperature of 600 ºC; activating agent – KOH; exit rate 40.0%; total pore volume V_{Σ}=0,500 cm^3/g (100%); volume of macropores V_{ma}=0,040 cm^3/g (8%); volume of mesopores V_{me}=0.220 cm^3/g (44%); volume of micropores V_{mi}=0.240 cm^3/g (48%) (Tamarkina et al, 2011) [17].

Natural minerals

Clay minerals have a very high adsorption capacity, together with their high dispersion and extremely developed surface (Sokolov, 1996) [18]. Five main types of microstructures of clay rocks were identified – cellular, skeletal, matrix, turbulent and laminar, which affects their properties during use (Osipov et al, 1989; Grabovska-Ol'shevska et al, 1984) [19, 20].

For the selection of effective sorbents in the distillery production (Mank, Melnik, 2007) [14], natural dispersed minerals are considered: mordenite, clinoptilolite, Cherkassky montmorillonite, saponite, glauconite, hydromica, palygorskite. The presented minerals actively adsorb higher alcohols, reducing their initial content by 3-4 times (Mank, Melnik, 2007) [14].

Each adsorbent has its own advantages in improving the quality of sorting. Therefore, it is advisable to use the combined compositions of sorbents, consisting of a mixture of several natural minerals for the adsorption of impurities (Mank, Melnik, 2007; Melnik et al, 2014; Mank, Melnik, 2004) [14, 21, 22].

Advantages:

– by a number of attributes, zeolites belong to molecular sieves, natural sodalite from a wet mixture of gases adsorbs only water, and the same aluminosilicates, to a greater or lesser extent, absorb all components of complex mixtures (Kubasov, 1998) [23];

– zeolites containing a significant number of cations, are able to effectively and selectively extract various ions from solutions, to ensure their concentration. These qualities determine the widespread use of zeolites as ion exchangers (Kubasov, 1998) [23].

Disadvantages:

– low absorption capacity (adsorption volume) (Kubasov, 1998) [23];

– adsorption occurs mainly, only small molecules – water, oxygen (Kubasov, 1998) [23];

– zeolite, which consists of compounds of aluminum and lead, is dangerous to human health (Kurtov et al, 2003) [24].

Silica gel

When methanol is adsorbed on silica gel, the vapors of this alcohol are sorbed on the surface of the silica gel irreversibly – they cannot be pumped out even in vacuum. During adsorption, a chemical reaction occurs between the silanol groups of the surface and methanol (Braun et al, 1985) [25]. With prolonged contact with coal, the content of aldehydes increases in sorting, therefore, with a dynamic treatment method, it is recommended to lay a layer of silica gel in the columns, which is the best aldehyde adsorbent than active carbon.

Materials and methods

The object of the study was active carbons of various types: crushed activated wood charcoal BAU-A; charcoal activated wood crushed BAU-A-LVZ; BAU-A silver impregnated active carbon (BAU-A-Ag); active stone coal (MeKS); coconut activated carbon (KAU-2); anthracite active coal (KDS-A).

The research methods are based on the research methods of active carbons by physicochemical parameters: adsorption activity by iodine; adsorption activity by acetic acid; total pore volume by water; bulk density; fractional composition; mass of ash; bulk iron; mass of moisture; abrasion resistance.

The method for determining the mass fraction of moisture is based on the drying of a sample of coal in a drying cabinet to a constant mass at 105 °C, followed by weighing of the dried sample.

The method for determining the mass fraction of ash is based on determining the unburnt balance of coal after burning it in a muffle furnace at a temperature of 600-650 °C.

The method for determining the mass of 1 dm^3 of activated carbon is based on the pre-drying of activated charcoal to a constant mass. The dried charcoal is placed in a pre-weighed cylinder with a capacity of 100 cm^3 and weighed with an error of up to 0.01 g.

Method of determination of grains. Weighing 100 g of charcoal is sprayed on sieves with rounded eyes in diameter of 5.0; 3.6 and 1.0 mm. The residues are weighed on the fractions and determine the mass of each fraction as a percentage of the weight of dry coal.

Methods of determination of activity of activated carbon. The activity of coal used to clean water-alcohol mixtures is determined by several methods:

- Titerometric method, which is based on the determination of adsorption of acetic acid (according to Oshmyan): the amount of acetic acid adsorbed by coal is directly dependent on the activity of coal;
- Iodometric method, which is based on titerometric determination of the amount of iodine by the difference of the initial amount of iodine taken for analysis and which is not absorbed by coal.

Determination of the total pore volume by water. The method is based on the determination of the mass of water, which filled all pores when the boiling water wasused in the water after the removal of excess water from the surface of the grains.

Results and discussions

As a result of experimental studies of active carbons for alcoholic beverage production, the following characteristics were obtained:

Active carbon of BAU-A: adsorption activity by iodine – 62%; adsorption activity by acetic acid – 64 ml; adsorption activity by methylene blue – 129 mg/g; total pore volume of water – 1.72

cm^3/g; bulk density – 215 g/dm^3; fractional composition, mass fraction of the residue on the sieve with canvas: № 36 – 1.6%; № 10 – 98.0%; on the pallet – 0.4%; mass of ash – 4.70%; mass fraction of water-soluble ash – 1.64%; mass fraction of iron – 0.12%; mass of moisture – 3.8%; abrasion resistance – 52.8%.

Active carbon of BAU-A-LVZ: adsorption activity by iodine – 69%; adsorption activity by acetic acid – 73 ml; adsorption activity by methylene blue – 141 mg/g; total pore volume of water – 1.91 cm^3/g; bulk density – 221 g/dm^3; fractional composition, mass fraction of the residue on the sieve with cloth: № 36 – 1.4%; № 10 – 97.6%; on the pallet – 1.0%; mass of ash – 4.95%; the mass part of water-soluble ash is 1.87%; mass fraction of iron – 0.13%; mass fraction of moisture – 4.1%; abrasion resistance – 59.6%.

Active carbon of BAU-A-Ag: adsorption activity by iodine – 73%; adsorption activity by acetic acid – 82 ml; adsorption activity by methylene blue – 169 mg/g; total pore volume of water – 2.0 cm^3/g; bulk density – 228 g/dm^3; fractional composition, mass fraction of the residue on the sieve with canvas: № 36 – 2.1%; № 10 – 96.6%; on the pallet – 1.3%; mass fraction of ash – 5.12%; mass fraction of water-soluble ash – 1.95%; mass fraction of iron – 0.15%; mass of moisture – 4.5%; abrasion resistance – 63.1%.

Active carbon of MeKS: adsorption activity by iodine – 94%; adsorption activity by acetic acid – 117 ml; adsorption activity by methylene blue – 273 mg/g; total pore volume of water – 1.57 cm^3/g; bulk density – 572 g/dm^3; fractional composition, the mass fraction of the residue on the sieve with canvas: № 36 – 0.1%; № 10 – 90.4%; on a pallet – 9.5%; mass fraction of ash – 3.61%; mass fraction of water soluble ash – 1.27%; mass fraction of iron – 0.19%; mass of moisture – 3.2%; abrasion resistance – 90.1%.

Active carbon of KAU-2: adsorption activity by iodine – 82%; adsorption activity by acetic acid – 67 ml; adsorption activity by methylene blue – 265 mg/g; total pore volume of water – 1.23 cm^3/g; bulk density – 524 g/dm^3; fractional composition, mass fraction of the residue on the sieve with cloth: № 36 – 0.2%; № 10 – 96.3%; on a pallet – 3.5%; mass of ash – 3.26%; mass fraction of water-soluble ash – 1.04%; mass fraction of iron – 0.13%; mass fraction of moisture – 2.1%; abrasion resistance – 86.7%.

Active carbon of KDS-A: adsorption activity by iodine – 51%; adsorption activity by acetic acid – 62 ml; adsorption activity by methylene blue – 117 mg/g; total pore volume of water – 1.43 cm^3/g; bulk density – 691 g/dm^3; fractional composition, the mass fraction of the residue on the sieve with canvas: № 36 – 0.1%; № 10 – 97.2%; on a pallet – 2.7%; mass of ash – 2.4%; mass fraction of water-soluble ash – 0.78%; mass fraction of iron – 0.10%; mass of moisture – 2.9%; abrasion resistance – 79.3%.

BAU-A coal is a standard activated carbon for alcoholic beverage production. The «dynamic method» of cleaning water-alcohol mixtures with activated carbon from impurities is the classic technology of vodka. In the further analysis, we will use the characteristics of the BAU-A active carbon as basic for further analysis and comparison with other active carbons.

BAU-A coal has an adsorption activity by iodine of 62% (Figure 2). The BAU-A active carbon group specially modified for alcoholic beverage production - BAU-A-LVZ and BAU-A-Ag has adsorption activity by iodine of 69% and 73%, respectively. These coal has an adsorption activity by iodine of 7% and 11% more than the base BAU-A. At the same time, the stone active carbon (MeKS) and coconut active carbon (KAU-2) have a high adsorption activity by iodine by 32% and 20%. The first conclusion can be made that stone coal (MeKS) has better sorption characteristics than other coals. Low adsorption activity by iodine showed active carbon from fossil coal grade KDS-A (-11%).

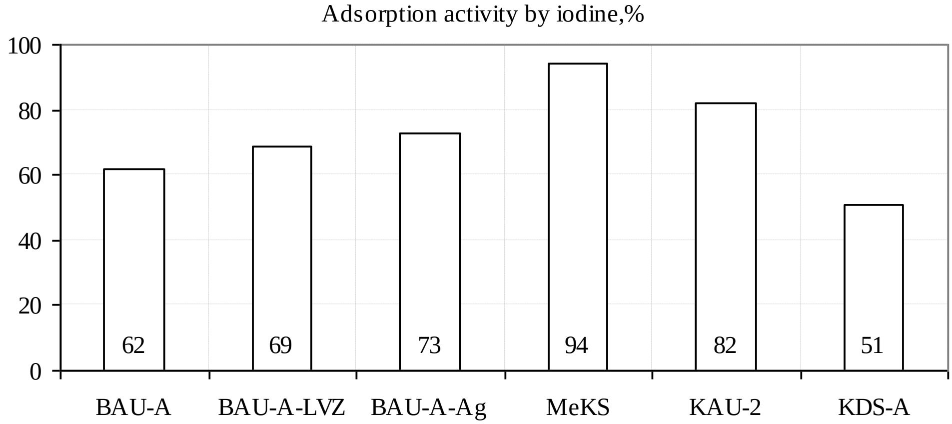

Figure 2. Dependence of adsorption activity by iodine on the type of active carbon

The volume of acetic acid adsorbed by coal is directly dependent on the adsorption activity of coal. BAU-A coal has 64 ml adsorption activity by acetic acid (Figure 3). Modified active carbons BAU-A-LVZ and BAU-A-Ag have 73 ml and 82 ml adsorption activity by acetic acid, which is 12.3% and 22.0% more than standard BAU-A active carbon. At the same time, the stone coal brand MeKS is 45.3% more adsorbing acetic acid and has a greater sorption activity for acetic acid among all active carbons (117 ml). Coconut active carbon brand KAU-2 has a standard adsorption activity by acetic acid – 67 ml. Active carbon from fossil coal has the lowest value of adsorption activity by acetic acid (62 ml).

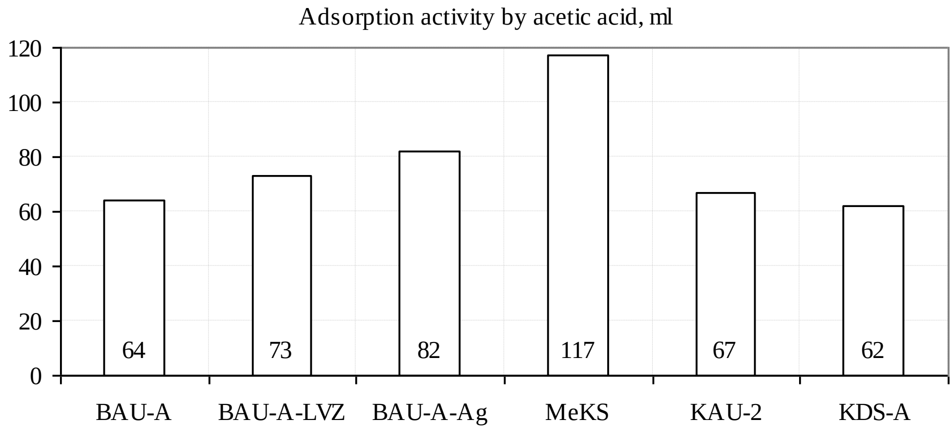

Figure 3. Dependence of adsorption activity by acetic acid on the type of active carbon

BAU-A coal has adsorption activity by methylene blue – 129 mg/g (Figure 4). Modified active carbons BAU-A-LVZ and BAU-A-Ag have 141 mg/g and 169 mg/g adsorption activity by methylene blue, which is 8.5% and 23.7% more than standard BAU-A active carbon. At the same time, MeKS stone coal, by 52.7%, adsorbs methylene blue more and has a large sorption activity for methylene blue among all active carbons (273 mg/g). Coconut active carbon KAU-2 has sorption activity for methylene blue – 265 mg/g. Active carbon from fossil coal (KDS-A) has the lowest value of adsorption activity by acetic acid (117 mg/g).

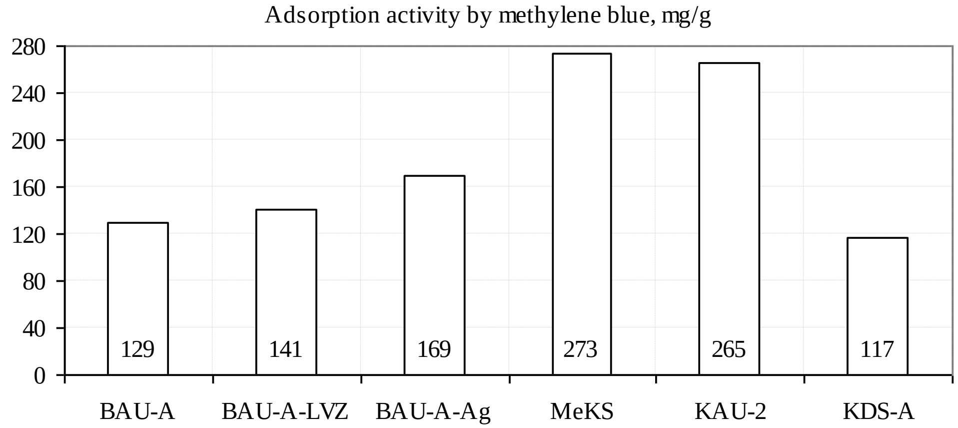

Figure 4. Dependence of adsorption activity by methylene blue on the type of active carbon

BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a larger total pore volume of water of 1.72–2.00 cm^3/g than stone fruit (1.57 cm^3/g), coconut (1.23 cm^3/g), active carbon from fossil coal (1.43 cm^3/g) (Figure 5). This means that BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a larger volume of sorbing pores and a greater absorption capacity for organic impurities.

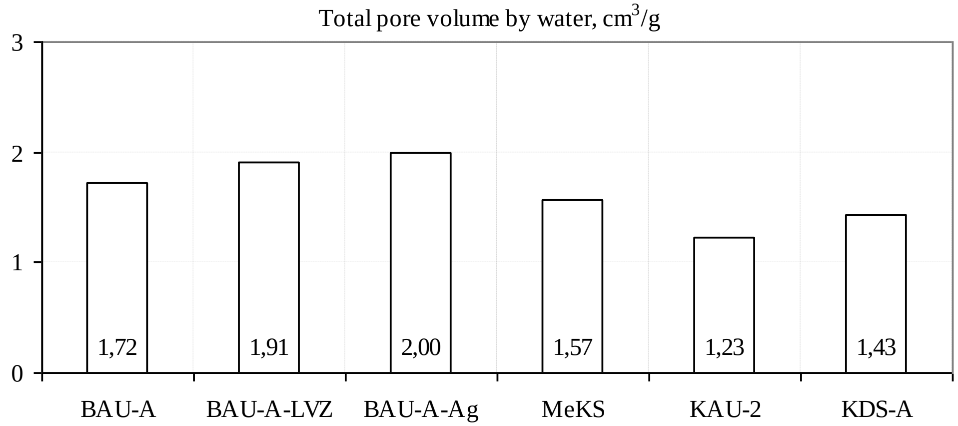

Figure 5. Dependence of the total pore volume of water on the type of active carbon

Bulk density of coals of stone MeKS (572 g/dm^3), coconut KAU-2 (524 g/dm^3), active carbon from fossil KDS-A coal (691 g/dm^3) is more than 2 times higher than the bulk density of the group of BAU-A coal (215-228 g/dm^3) (Figure 6). This will increase the speed of filtering sorts with the same cleaning efficiency.

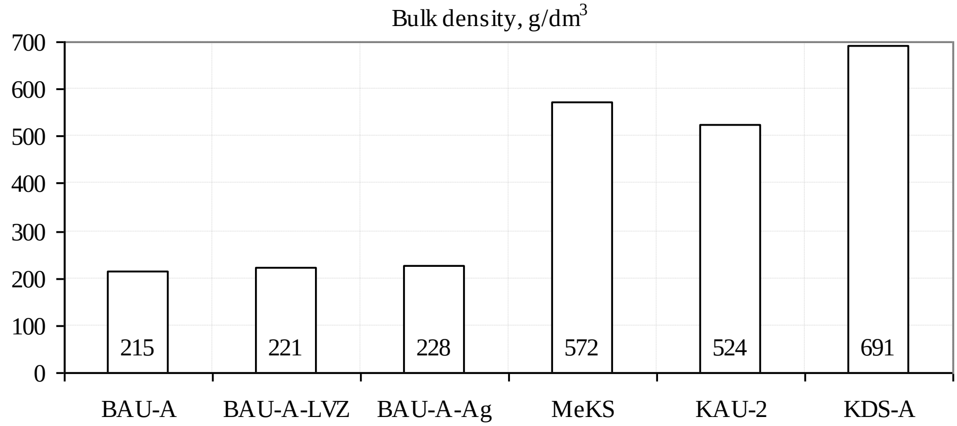

Figure 6. Dependence of bulk density on the type of active carbon

BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a mass fraction of ash of 4.70–5.12%, which is more than that of stone fruit (3.61%), coconut (3.26%) and active coal from fossil coal (2.40%). It can be concluded that the BAU-A, BAU-A-LVZ, BAU-A-Ag coals are less pure adsorbents, since they contain a larger amount of ash, as well as a water-soluble part of the ash (Figure 7).

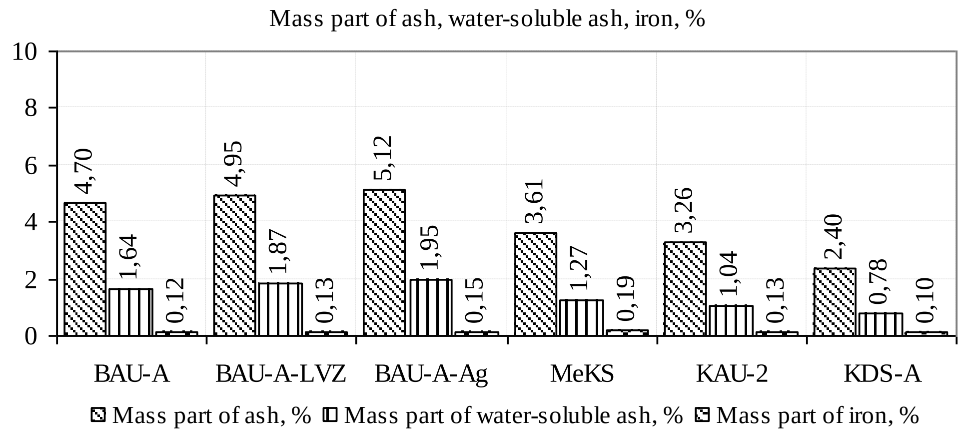

Figure 7. Dependence of the mass part of ash, water-soluble ash, the mass of iron on the type of active carbon

BAU-A, BAU-A-LVZ, BAU-A-Ag coals have a mass fraction of iron of 0.12–0.15%, which is less than stone fruit (0.19%). Coconut active coal (0.13%) and active coal from fossil coal (0.10%) have a mass fraction of iron comparable to BAU-A grade coal (Figure 7).

The abrasion resistance of the active carbons of the BAU-A group (52.8–63.1%) is lower than that of the stone stones (90.1%), coconut (86.7%) and active coal from fossil coal (79.3%), which allows reducing the consumption rate of active carbons (Figure 8).

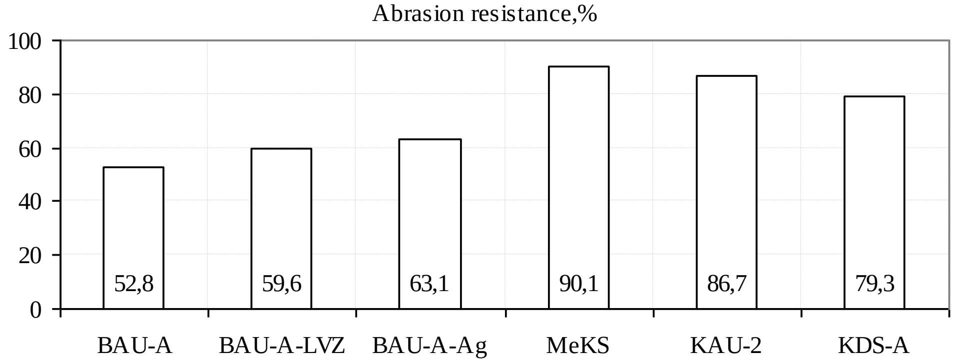

Figure 8. Dependence of abrasion resistance on the type of active carbon

The fractional composition of activated carbons of the BAU-A group more meets the requirements of the distillery production than that of stone stone (MeKS), coconut (KAU-A) and active coal from fossil coal (KDS-A), which allows reducing the consumption rate of active carbons (Figure 9-10).

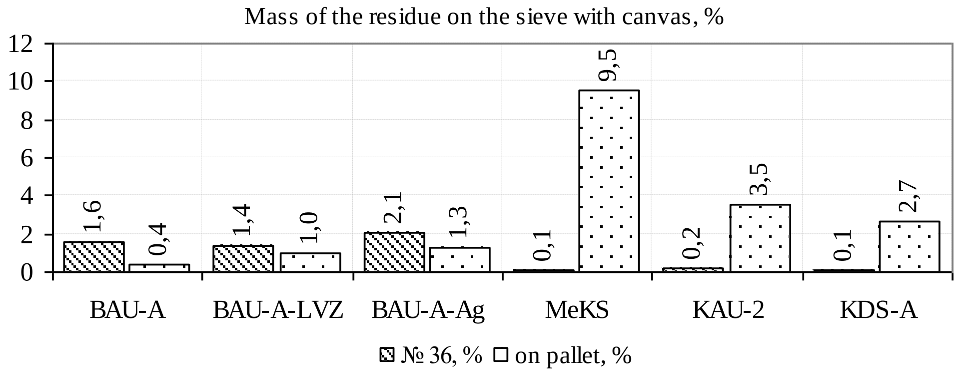

Figure 9. Dependence of fractional composition on the type of active carbon

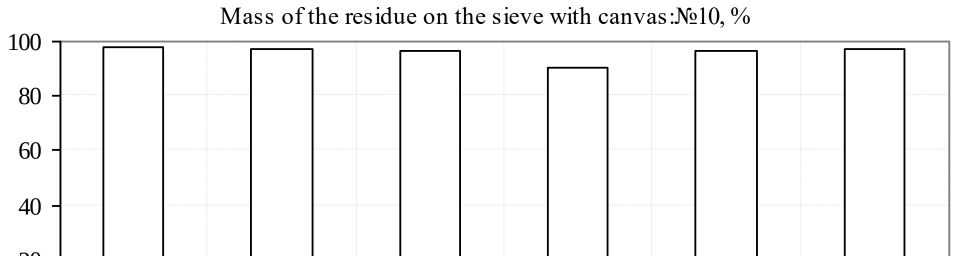

Figure 10. Dependence of fractional composition on the type of active carbon

Conclusions

As a result of the research, we can conclude that there is not a single one of the reviewed active carbons that would satisfy the increased requirements of alcoholic beverage production. To do this, it is necessary to create various combinations on the basis of BAU-A grade coal or its BAU-A-LVZ, BAU-A-Ag coal together with stone fruit (MeKS), coconut (KAU-A) and active carbon from fossil coal (KDS-A). The low performance of some active carbons will be compensated by the high performance of other carbons. Low values of abrasion resistance of active coals of the BAU-A group (52.8–63.1%) can be compensated for by the stone stones (90.1%), coconut (86.7%) or active coal from fossil coal (79.3%), which can be used in the frontal layer of coal columns. Combined coal will increase the strength to withstand the pressure of the liquid in the coal columns when the coal particles rub against each other. Combined active carbons will have adapted sorption and catalytic performance. The developed porous structure will make it possible to extract from the aqueous-alcoholic solutions and retain organic impurities in the volume of sorbent pores. This will improve the tasting properties of vodka.

References

1. López-Garzón F.J., Fernandez-Morales I., Moreno-Castilla C., Domingo-García M. (1999), Carbon materials as adsorbents for vapour pollutants, *Studies in Surface Science and Catalysis*, 120(B), pp. 397–433.
2. George Tzvetkov, Simona Mihaylova, Katerina Stoitchkova, Peter Tzvetkov, Tony Spassov (2016), Mechanochemical and chemical activation of lignocellulosic material to prepare powdered activated carbons for adsorption applications, *Powder Technology*, 299, pp. 41–50.
3. Miroslaw Kwiatkowski, Vanessa Fierro, Alain Celzard (2017), Numerical studies of the effects of process conditions on the development of the porous structure of adsorbents prepared by chemical activation of lignin with alkali hydroxides, *Journal of Colloid and Interface Science*, 486, pp. 277–286.
4. Marsh H., Rodriguez-Reinoso F. (2006), *Activated carbon*, Amsterdam, Elsevier.
5. Acikyildiz M., Gurses A., Karaca S. (2014), Preparation and characterization of activated carbon from plant wastes with chemical activation, *Microporous and Mesoporous Materials*, 198, pp. 45–49.
6. Rivera-Utrilla J., Sánchez-Polo M., Gómez-Serrano V., Álvarez P.M., Alvim-Ferraz M.C.M., Dias J.M. (2011), Activated carbon modifications to enhance its water treatment applications. An overview, *J. Hazardous Materials*, 187(1–3), pp. 1–23.
7. Kuzmin O., Shendrik T., Zubkova V. (2017), Substantiation of the conditions of obtaining porous carbon materials from pyrolyzed wood wastes by chemical activation of H_3PO_4, *Ukrainian Food Journal*, 6(1), pp. 103–116.
8. Kuzmin O., Suikov S., Niemirich O., Ditrich I., Sylka I. (2017), Effects of the water desalting by reverse osmosis on the process of formation of water-alcohol mixtures. ^{1}H NMR spectroscopy studies, *Ukrainian Food Journal*, 6 (2), pp. 239-257.
9. Kuzmin O., Tamarkina J., Shendrik T., Zubkova V., Koval O., Roman T. (2017), Production of active coal from pyrolyzed wood wastes by alkaline activation of KOH, *Ukrainian Food Journal*, 6(3), pp. 443–458.
10. Kuzmin O., Suikov S., Koretska I., Matiyashchuk O., Poliovyk V. (2017), Identification of equilibrium state of hydroxyl protons in vodkas by ^{1}H NMR spectroscopy, *Ukrainian*

Food Journal, 6 (2), pp. 314-336.
11. Muhin V.M., Poljakov V.A., Makeeva A.N., Shubina N.A. (2003), Novye aktivnye ugli dlja likjorovodochnogo proizvodstva, *Proizvodstvo spirta i likjorovodochnyh izdelij*, 3, pp. 36–37.
12. Muhin V.M., Poljakov V.A., Burachevskij I.I., Shubina N.A., Makeeva A.N. (2004), Vysokoprochnye aktivnye ugli i blochnye fil'try na ih osnove, *Likerovodochnoe proizvodstvo i vinodelie*, 55, pp. 8–9.
13. Petrov A.N., Oloncev V.F., Limonov N.V. (2004), Tendencii v ispol'zovanii aktivnyh uglej v likero-vodochnoj otrasli, *Likerovodochnoe proizvodstvo i vinodelie*, 57, pp. 5–7.
14. Mank V., Melnik L. (2007), Adsorptive purification of food raw materials and semi-finished products with help of carbon and natural adsorbents, *Carbon for Energy Storage and Environment Protection: The 2nd International Conference CESEP, 2-6 September, Krakow*, 142.
15. Portnoj S.V. (2004), Aktivnye ugli OAO «Sorbent» dlja likerovodochnoj promyshlennosti, *Likerovodochnoe proizvodstvo i vinodelie*, 53, pp. 5.
16. Zhabkina T.N., Krechetnikova A.N., Revina A.A. (2005), Primenenie nanochastic serebra dlja modificirovanija fil'trujushhih materialov, *Proizvodstvo spirta i likerovodochnyh izdelij*, 1, pp. 20–21.
17. Tamarkina Ju.V. ta in. (2011), Pat. 61059 Ukrai'na, Sposib otrymannja poruvatogo vuglecevogo materialu z burogo vugillja, Bjul. № 13.
18. Sokolov V.N. (1996), Mikromir glinistyh porod, *Sorosovskij obrazovatel'nyj zhurnal*, 3, pp. 56–64.
19. Osipov V.I., Sokolov V.N., Rumjanceva N.A. (1989), *Mikrostruktura glinistyh porod*, Nedra.
20. Grabovska-Ol'shevska B., Osipov V.I., Sokolov V.N. (1984), *Atlas mikrostruktur glinistyh porod*, Varshava.
21. Melnik L., Turchun O., Tkachuk N. (2014), Water-alcohol adsorbing cleaning out of higher alcohols by shungite, *Ukrainian Journal of Food Science*, 2 (2), pp. 312–317.
22. Mank V., Melnik L. (2004), Using paligorskit for purifying the aqueous-alcoholic solutions, *XVII Conference on Clay Mineralogy and Petrology, 13-17.09.04, Prague*, 46.
23. Kubasov A.A. (1998), Ceolity – kipjashhie kamni, *Sorosovskij obrazovatel'nyj zhurnal*, 7, pp. 70–76.
24. Kurtov V.D., Furmanov Ju.A., Mahrovskaja N.K., Davidenko I.P. (2003), *Jelektroaktivirovannaja voda – istochnik zhizni i zdorov'ja*, NPF «JekoVod».
25. Braun T., Navratil J.D., Farag A.B. (1985), *Polyuretane Foam Sorbent in Separation Science*, Boca Raton, CRC Press.