# DEVELOPMENT OF EFFECTIVE TECHNOLOGIES FOR WASTE PROCESSING OF THE FOOD INDUSTRY

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## INTRODUCTION

*Actuality of theme.* Mankind faces global challenges related to climate change, environmental pollution[1], food security[2], which requires the solution of ecological, social, political and economic problems[3].

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Today, there is a deep understanding of the consequences of environmental pollution by food waste, so there is great interest in promoting "green technologies"[4]. In food production, only 70% of raw materials end up in the finished product, while 30% of raw materials are converted into waste and not processed at all[5]. Most of them are organic wastes[6] that are rich in nutrients[7] and can be used as raw materials[8] by other enterprises, most of the wastes end up in landfills and dumps.

With the increase in food consumption, the amount of waste increases[9], which requires an increase in the area for their disposal, given the limited space for landfills and increasing the requirements of regulatory documentation for waste disposal.

Waste reduction is a key challenge for the sustainable development of the food industry[10], so reducing it is a pressing issue for most businesses in the industry[11]. Waste recycling and utilization is a strategic goal for each

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company[12], which involves the involvement of innovative technologies[13] based on the evaluation of decisions in reducing the cost of finished products, minimizing raw material losses, increasing the yield of finished products[14]. The practical implementation of innovative measures allows to establish relationships between processes and technologies of food industry processing and provides an opportunity to form the main provisions in the field of waste management[15].

Despite the importance of this issue for the world community in the food industry, the connection between efficient resource-saving and environmental technologies of waste processing, disposal of by-products in the scientific literature is given limited attention[16]. Extensive knowledge was brought by foreign scientists who devoted their work to the processing of food industry waste into biofuels, biogas, biopolymers, biofertilizers[17], bioceramic materials[18], sorbents[19].

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# 1. Characteristics of food industry waste

In the process of frying with smoke and smoking, numerous substances are formed, which are contained in the smoke during incomplete combustion of wood, which enter the product and provide its preservation, flavoring and desired color. Technological properties of smoke depend on its chemical composition and, above all, on the degree of saturation with aromatic substances.

The formation of pyrolyzed wood waste in the process of generating air-smoke mixture[20] involves the use of wood chips[21] of hardwoods (beech, alder, oak, elm, linden, hazel, maple, etc.), as well as stone species (cherry, cherry, apple, apricot, plum, etc.).

One of the most common species is oak[22], which has a positive effect on the composition and concentration of active smoking agents during smoke smoking and reduces tar formation and increases the organoleptic characteristics of meat, sausages, cheese, fish and other foods, resulting in pyrolyzed wood waste with incomplete combustion of wood.

Wood chips is obtained by grinding wood in the form of oblique parallelepipeds with an acute angle in the range of 30–60°, the specified size fractions: *large size* – 6x12x3 mm; *medium size* – 4x6x3 mm; *small size* – 1–3 mm; *very small size* – 0.3–1.0 mm[23]. The use of technological chips of large fractions of 6x12x3 mm, with a mass fraction of chips residues on sieves with holes with a diameter of 30 mm – not more than 3%, 20 and 10 mm – not less than 86%, 5 mm – not more than 10%, on the pallet – no more than 1%, positively affects the formation of liquid and gaseous substances – 60–70% when receiving pyrolyzed chips 30–40%[24].

The size of wood chips fractions affects the profile of its application, depending on the smoking temperature: *cold* – 279–295 K, *hot* – 303–323 K, *high temperature* – 353–373 K, as well as the method of generating air-smoke

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mixture at pyrolysis temperature: *smoke smoldering* – 573–773 K; *smoke friction* – 593–653 K; *smoke condensate* – 593–653 K; *smoke distillate* – from 573 K.

Smoke decay is the most common method of generating an air-smoke mixture, which is formed by flameless combustion of a thick layer of wood chips with an initial mass fraction of moisture of 8–12%, moistened before pyrolysis with drinking water to 35–65%, at a pyrolysis temperature of 573–773 K, with a small amount of air and constant stirring[25].

Table 1 shows the conditions for obtaining an air-smoke mixture.

Table 1

**Terms of use of air-smoke mixture**

| Product name | Roasting with smoke | | Smoking | | | |
|---|---|---|---|---|---|---|
| | $T$, K | $\tau$, s·$60^2$ | $T$, K | $W$, % | v, m/s | $\tau$, s·$60^2$ |
| Boiled sausages | 338–348 | 0.50–1.17 | | | | |
| Semi-smoked sausages | 338–348 | 0.83–1.17 | 308–323 | 60–65 | 1.0 | 6–12 |
| Smoked and cooked poultry products | 363 | 1.00 | 298–303 | | | until color appears |
| Raw smoked and cured sausages | | | 291–295 | 74–80 | 0.2–0.5 | 24–48 |

Wood chips should have an initial humidity of 8–12%, because at a humidity of more than 12% in the wood is formed pathogenic microflora and products of its metabolism, and the use of wood chips with a moisture content of less than 8% is not economically feasible, which leads to additional energy consumption during drying and storage[26].

Before pyrolysis, wood chips is moistened with drinking water up to 35–65%. At a humidity of more than 65% there is a decrease in the mass concentration of phenols and an increase in the mass concentration of aldehydes and acids in the air-smoke mixture, which lead to an acidic taste in the finished product. When the humidity of the chips is less than 35% there is a low smoke with a simultaneous increase in the pyrolysis temperature[27].

Heating wood to a temperature above 573 K leads to its destruction – pyrolysis. At a smoldering temperature below 623 K, phenols and aldehydes are not sufficiently released in the smoke, which leads to a weak taste, aroma and color of products after smoking. The decay temperature of more than

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773 K leads to the decomposition of smoking substances, an increase in the content of *3.4-benzpyrene*, which distorts the taste and smell of the finished product, as well as leads to toxicological hazards. Therefore, the decay temperature should be maintained at 573–773 K[28].

The supply of air leads to an increase in combustion products and in general to an improvement in the taste of the final product, and the lack of mixing of chips during pyrolysis leads to compaction of the surface layer of pyrolyzate and unregulated temperature inside; as a result there can be the centers of an open flame with a temperature to 1273 K.

The pyrolysis time of wood chips depends on the conditions of heat treatment of meat, sausage products, cheese, fish and other food products, which due to frying with smoke or smoking last for 0.5–48.0 hours. So cooked sausages are fried with smoke for 30–70 minutes, and smoked and cured sausages are smoked for 1–2 days[29].

## 2. Characteristics of wood for the production of alcoholic beverages

Together with the scientifically sound selection of oak ridge in the forest, the process of drying-ripening of clapboard plays an important role[30]. Natural drying-maturation of oak clapboard for three years helps to increase the concentration of whiskey lactones by 4.11 times more than with artificial drying; vanillin – 4.63 times; syringaldehyde – 4.47 times; eugenol – 2.7 times. The concentration of phenolic substances in the extract from the clapboard of natural drying is 1.45 times, and the dry extract is 1.16 times less than in artificial drying[31].

The degree of grinding of oak wood (clapboard, micro- clapboard, wood chips and micro-wood chips) affects the rate of aging of wines and cognac alcohols[32]. The differences in the speed of the process of aging cognac alcohol are based on various features of its impregnation in the layers of wood – in the surface layers of oak wood in the inner surface of barrels, clapboards and

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[28] Спосіб виробництва активного вугілля із карбонізату деревини: пат. 112819 Україна: МПК C01B 31/08. № a201505195; заяв. 27.05.2015; опубл. 25.10.2016, Бюл. № 20.

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large pieces, or in the entire volume of wood using small fractions. These features of wood impregnation affect the processes of hydrolysis of high molecular weight substances of oak (lignin, hemicelluloses and others) to low molecular weight components (aromatic aldehydes, monosaccharides, etc.), their extraction, transformation and oxidation[33].

According to the international classification, oak wood for winemaking is divided by the concentration of phenolic substances, including tannins, aromatic components: whiskey lactones (trans- and cis-β-methyl-γ-octalactone), eugenol, vanillin, scopoletin and other lignin cleavage products that form the aroma, bouquet and taste of future wines and their distillates[34], giving them vanilla, spicy, caramel and other noble tones.

The specific surface area of the clapboard, which is laid in the tank for aging cognac alcohol, should be 70–90 $cm^2/dm^3$, which corresponds to the area of the inner surface of the barrel with a capacity of 35–60 decaliters[35].

Extraction of oak components of small fractions takes place at a faster rate than in barrels and clapboard. This occurs only until the moment close to the depletion of wood, which is observed when it reaches 80 % of the total content of extracted components of oak, after which – the extraction slows down sharply. The use of small fractions of oak in the amount of 7.8 and 10.4 $g/dm^3$ (based on the layer of wood on the inner surface of the barrel 1.5 and 2.0 mm) led to the accumulation, respectively, 45–50 and 70–75% of the content of oak components at 5-year aging in oak barrels. Such concentrations of oak components in alcohol are extracted from small fractions of oak after 18–24 months. Among the various fractions of crushed oak in terms of organoleptic indicators of aging of cognac alcohols, wood chips of the middle fraction is recognized as the best[36].

Today there are many ways to prepare crushed oak wood for wine and brandy production[37]: grinding; oxygen treatment at a pressure ($P$) of 1.5–3.0 MPa, temperature ($T$) 383–393 K, time $\tau$ (50–150)·$60^2$ s; grinding;

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Спосіб обробки подрібненої деревини дуба : пат. 50046А Україна, МПК C12G 3/07. № 2001031730; заявл. 15.03.2001; опубл. 15.10.2002, Бюл. № 10.

treatment with *HCl* solution (hydromodule 1:0.6); air treatment ($T$ 373–378 K; $\tau$ 0.5·60$^2$ s); treatment with a solution of ammonia (hydromodule 1:0.6) with subsequent exposure to air $\tau$ 0.17·60$^2$ s; grinding to the size *lxbxh* (20x55x4)·10$^{-3}$ m; enzyme treatment; drying ($T$ 423 K; $\tau$ 48·60$^2$ s) to a humidity (*W*) of 6.0%; crushing of oak wood (petiolate, rocky) aged from 80 years to the size $l$ (5–35)·10$^{-3}$ m, $h \leq 5 \cdot 10^{-3}$ m; treatment with enzyme preparation $\tau$ 4·60$^2$ s; drying ($T$ 423–443 K, $\tau$ (30–36)·60$^2$ s) to $W \leq 6 \pm 2\%$.

Treatment of wine materials with crushed oak wood eliminates their shortcomings – the "mouse tone" disappears due to the adsorption of acetamide by wood and the transformation of substances that cause their appearance. Due to ethanolysis and extraction, the pH decreases, the mass concentration of phenolic substances increases. Due to adsorption, the mass concentration of volatile acids decreases. The stability of wines against colloidal turbidity increases, the stage of treatment with bentonite or activated carbon is excluded[38].

One of the priority areas for alcoholic beverage and wine and cognac production is the production of crushed oak wood from pyrolyzed wood waste. The formation of pyrolyzed wood waste in the process of generating air-smoke mixture involves the use of wood chips of hardwoods – oak, which has a positive effect on the composition and concentration of smoking agents, reducing resin formation and increasing organoleptic characteristics.

*The aim* of the work is to determine the prospects of pyrolyzed wood waste for the production of alcoholic beverages (wine and cognac products, cognac, whiskey, calvados), as well as in the production of porous carbon materials and activated carbon.

### 3. Materials and methods. Description of the experimental stand

The process of heat treatment was carried out in a cooking-smoking thermal chamber of modular type "Jugema KWE-3" with electric heating, which is designed for heat treatment of meat products, cheeses, fish and other food products.

According to the production task for the production of semi-smoked sausage "Viennese salami" (2nd grade; natural pork casing $d$ (34–36)·10$^{-3}$ m; in shape – a horn length of 0.20–0.25 m; the norm of pure mass of products per frame – 180 kg) and technological instructions were carried out: frying with smoke – at $T_1$ 343 K, $\tau_1$ 1·60$^2$ s; smoking – when: $T_2$ 323 K; $W_3$ 62 %; $v_1$ 1 m/s; $\tau_2$ 6.13·60$^2$ s.

Wood chips were fed to the combustion chamber of the gas generator (Fig. 1) using a stirrer, which operates periodically during pyrolysis, as well as in the process of removing spent pyrolyzed wood waste. The burner was

[38] Кузьмин О.В., Королесова В.Г. *Стабилизация вина в процессе хранения. Актуальные проблемы современного товароведения* : матер. междунар. научн.-практ. конф., г. Гомель, 18–19 нояб. 2010 г., Гомель, 2010. С. 89.

Спосіб лікування хвороби вина «мишачий тон»: пат. 72724A Україна, МПК C12G 3/07, C12H 1/02. № 20031213183; заяв. 30.12.2003; опубл. 15.03.2005, Бюл. № 3.

turned on and the wood was ignited for $\tau$ 180–360 s depending on the mass fraction of wood chips moisture. During pyrolysis, air is supplied to the combustion chamber and smoke is formed. The smoke is fed into the extraction area by a fan. To reduce the smoke temperature and counteract ignition, water is sprayed in the combustion chamber. All processes that occur during pyrolysis are controlled by microprocessor control.
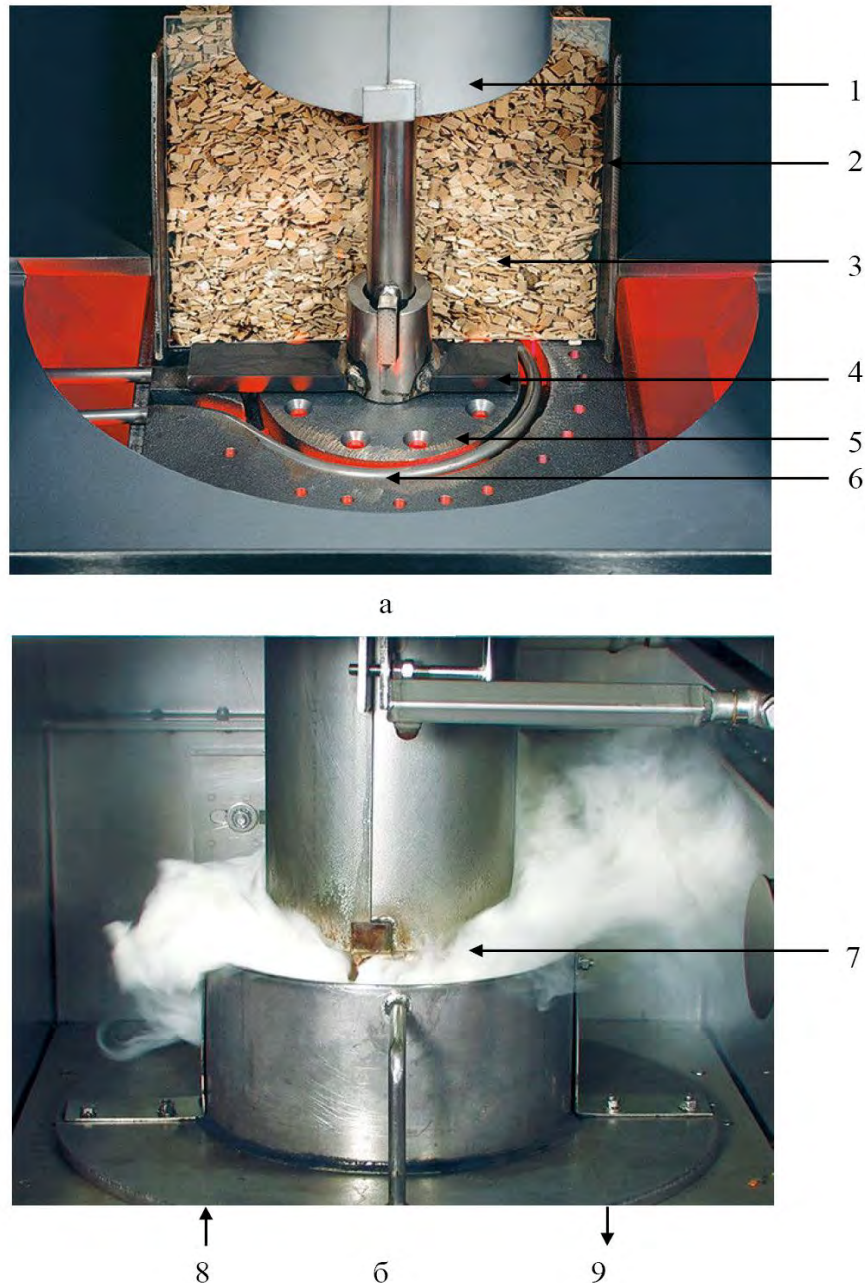


**Fig. 1. Scheme of the smoke generator: a – section of the smoke generator in preparation for pyrolysis of chips; b – appearance of the smoke generator in the process of wood chips pyrolysis; 1 – wood chips hopper; 2 – casing; 3 – wood chips; 4 – mixer; 5 – grate; 6 – tubular electric heater; 7 – smoke; 8 – air; 9 – pyrolyzed wood waste**

# 4. Results and discussions

## 4.1. Experimental studies

Tables 2–4 present the conditions of the study of the processes of preparation of technological chips, the conditions of its pyrolysis and the conditions of preparation of pyrolyzed wood waste.

Table 2

**Conditions for the preparation of technological wood chips**

| Symbol | Name of indicator | Characteristic |
|---|---|---|
| | Type of particles by shape | wood chips |
| | Type of particles by purpose | technological |
| | Type of particles by type of wood | oak |
| $lxbxh$ | Type of particles by fraction size, m | $(6x12x3)\cdot10^{-3}$ |
| | Mass fraction of wood chips residues (%) on sieves with holes with a diameter (m): $d\geq30\cdot10^{-3}$ $30\cdot10^{-3}>d\geq20\cdot10^{-3}$; $20\cdot10^{-3}>d\geq10\cdot10^{-3}$ $10\cdot10^{-3}>d\geq5\cdot10^{-3}$ $d<5\cdot10^{-3}$ | 0.8 (14.0; 80.0) 4.9 0.3 |
| $W_1$ | Mass fraction of wood chips initial moisture,% | 9.42 |
| $W_2$ | Mass fraction of wood chips moisture before pyrolysis,% | 49.08 |

Table 3

**Conditions of pyrolysis of technological chips**

| Symbol | Name of indicator | Characteristic |
|---|---|---|
| | Type of smoking | smokes |
| | Method of air-smoke mixture generation | smoke decay |
| $T_1$ | Frying temperature with smoke, K | 343 |
| $\tau_1$ | Frying time with smoke, s | $1\cdot60^2$ |
| $T_2$ | Smoking temperature, K | 323 |
| $W_3$ | Relative humidity in the thermal chamber,% | 62 |
| $v_1$ | Air velocity in the thermal chamber, m/s | 1 |
| $\tau_2$ | Smoking time, s | $6.13\cdot60^2$ |
| $T_3$ | The decay temperature (pyrolysis), K | 633 |
| $\tau_3$ | Pyrolysis time, s | $7.13\cdot60^2$ |
| $m_\tau$ | Mass consumption of wood chips, kg/s | $9.20\cdot60^{-2}$ |
| $Y_1$ | Yield of liquid and gaseous substances, % | 61.7 |
| $Y_2$ | Yield ratio of pyrolyzed wood waste, % | 38.3 |
| $W_4$ | Mass fraction of moisture of pyrolyzed wood waste,% | 43.01 |

Table 4

**Conditions for preparation of pyrolyzed wood waste**

| Symbol | Name of indicator | Characteristic |
|---|---|---|
| $pH_1$ | Hydrogen index of acid solution, units pH | 2.4 |
| $\tau_4$ | Time of treatment of pyrolyzed wood waste with acid solution, s | 300 |
| $pH_2$ | Hydrogen index of alkaline solution, units pH | 9.84 |
| $\tau_5$ | Time of treatment of pyrolyzed wood waste with alkaline solution, s | 300 |
| $pH_3$ | Hydrogen index of neutral solution, units pH | 6.91 |
| $\tau_6$ | Time of treatment of pyrolyzed wood waste with a neutral solution, s | 300 |
| $W_5$ | Mass fraction of moisture of pyrolyzed wood waste after treatment with aqueous solutions, % | 63.50 |
| $T_4$ | Outdoor drying temperature, K | 295 |
| $W_6$ | Relative humidity, % | 74 |
| $v_2$ | Air speed, m/s | 1.5 |
| $\tau_7$ | Drying time of pyrolyzed wood waste in the open air, s | $336 \cdot 60^2$ |
| $T_5$ | Drying temperature in the oven, K | 373 |
| $W_7$ | Final mass fraction of moisture of pyrolyzed wood waste, % | 6.58 |
| | Mass fraction of pyrolyzed wood waste residues (%) on sieves with holes in diameter (m): $d \geq 5.0 \cdot 10^{-3}$ $5.0 \cdot 10^{-3} > d \geq 3.6 \cdot 10^{-3}$ $3.6 \cdot 10^{-3} > d \geq 1.0 \cdot 10^{-3}$ $d < 1,0 \cdot 10^{-3}$ | 63.8 20.8 11.9 3.5 |

## 4.2. Methods of experimental research

For pyrolysis we used technological chips of hardwood species – from oak wood of large fractions – $(6 \times 12 \times 3) \cdot 10^{-3}$ m; with a mass fraction of wood chips residues on sieves with holes with a diameter of: $d \geq 30 \cdot 10^{-3}$ m – 0.8%; $30 \cdot 10^{3} > d \geq 20 \cdot 10^{-3}$ m – 14%; $20 \cdot 10^{-3} > d \geq 10 \cdot 10^{-3}$ m – 80%; $10 \cdot 10^{-3} > d \geq \geq 5 \cdot 10^{-3}$ m – 4.9%; on the pallet $d < 5 \cdot 10^{-3}$ m – 0.3%. The initial mass fraction of wood chips moisture before loading into the smoke generator was – $W_1$ 9.42%. Before pyrolysis, the chips were further moistened with drinking water to a value of $W_2$ 49.08% to ensure the relative humidity in the chamber $W_3$ 62% when smoking semi-smoked sausages.

Pyrolysis was performed at a temperature of $T_3$ 633 K for $\tau_3$ $7.13 \cdot 60^2$ s. The average wood chips consumption was $m_\tau$ $9.20 \cdot 60^{-2}$ kg/s in the formation of pyrolyzed wood waste – $3.52 \cdot 60^{-2}$ kg/s ($Y_2$ 38.3%). That is, for the cycle of

roasting with smoke and smoking $\tau_3$ for $7.13\cdot60^2$ s, 65.6 kg of wood chips were used and ($m$) 25.1 kg of pyrolyzed wood waste were obtained.

In the process of pyrolysis received pyrolyzed wood waste with a mass fraction of moisture ($W_4$) 43.01%, which was treated with an aqueous solution with a pH of 2.4 for $\tau_4$ 300 s, neutralized with an aqueous solution with a pH of 9.84 for ($\tau_5$) 300 s, adjusted the pH with an aqueous solution with a pH of 6.91 for ($\tau_6$) 300 s.

Drying of pyrolyzate with mass fraction of moisture $W_5$ 63.50% during $\tau_7$ $336\cdot60^2$ s outdoors ($T_4$ 295 K; $W_6$ 74%; $v_2$ 1.5 m/s), and then in the oven at $T_5$ 373 K to the air-dry state with a mass fraction of moisture $W_7$ of 6.58%.

The obtained pyrolyzed wood waste is an intermediate product with the characteristics of wood chips and porous carbon material at the same time, therefore, we determine the fractional composition due to the mass fraction of residue on sieves with holes with diameter: $d\geq5.0\cdot10^{-3}$ m – 63.8%; $5.0\cdot10^{-3}>$ $>d\geq3.6\cdot10^{-3}$ m – 20.8%; $3.6\cdot10^{-3}>d\geq1.0\cdot10^{-3}$ m – 11.9%; $d<1.0\cdot10^{-3}$ m (on the pallet) – 3.5%. In the end, the working fraction of pyrolyzed wood waste with a diameter of $d\geq5.0\cdot10^{-3}$ – 63.8% was selected.

This may indicate that in the process of pyrolysis the largest fractions of wood chips with $d\geq30\cdot10^{-3}$ m (mass fraction 0.8%) and with $30\cdot10^{-3}>$ $>d\geq20\cdot10^{-3}$ m (mass fraction 14%) burn out the least and lose their weight and size (reduction of particle size – up to 60%), with only 40% of the initial wood fractions in the form of pyrolyzed wood waste: wood chips fraction with $d\geq30\cdot10^{-3}$ m is converted into pyrolyzed wood waste with $d\geq12\cdot10^{-3}$ m; wood chips fraction of $30\cdot10^{-3}>d\geq20\cdot10^{-3}$ m is converted into pyrolyzed wood waste from $12\cdot10^{-3}>d\geq8\cdot10^{-3}$ m. The pyrolyzed wood waste of these two largest fractions in the fractionation process remains on the sieve $5.0\cdot10^{-3}$ m.

The smallest fractions of wood chips from $10\cdot10^{-3}>d\geq5\cdot10^{-3}$ m and from $d<5\cdot10^{-3}$ m – lose the most weight and size, burning out by 80% of the original size, and the pyrolyzed residue – up to 20%, which during fractionation remains on the sieve $1.0\cdot10^{-3}$ m and the pallet. Wood chips fraction with $10\cdot10^{-3}>d\geq5\cdot10^{-3}$ m is converted into pyrolyzed wood waste with $2\cdot10^{-3}>d\geq1\cdot10^{-3}$ m; wood chips fraction $d<5\cdot10^{-3}$ m – in pyrolyzed wood waste $d<1\cdot10^{-3}$ m.

The average fraction of wood chips from $20\cdot10^{-3}>d\geq10\cdot10^{-3}$ m in the process of pyrolysis burns out by 70%, and the pyrolyzed residue – (up to 30%) is distributed on three sieves with a diameter of holes: $5.0\cdot10^{-3}$ m; $3.6\cdot10^{-3}$ m; $1.0\cdot10^{-3}$ m. The wood chips fraction of $20\cdot10^{-3}>d\geq10\cdot10^{-3}$ m is converted into a pyrolyzed residue of $6\cdot10^{-3}>d\geq3\cdot10^{-3}$ m – this is the most represented pyrolyzed the balance due to its mass share, which is 80%.

Fig. 2 shows the appearance of wood chips and pyrolyzed wood waste at the main stages of wood preparation.

Fig. 3 shows the scheme of obtaining pyrolyzed wood waste.

**Fig. 2. Stages of obtaining pyrolyzed wood waste: a – oak chips (6x12x3)·$10^{-3}$; b – pyrolyzed wood waste with a mass fraction of moisture $W_4$ 43.01%; c – pyrolyzed wood waste after drying with a mass fraction of moisture $W_7$ of 6.58%; d – pyrolyzed wood waste after fractionation with $d \geq 5.0 \cdot 10^{-3}$; e – pyrolyzed wood waste after fractionation with $5.0 \cdot 10^{-3} > d \geq 3.6 \cdot 10^{-3}$; f – pyrolyzed wood waste after fractionation with $3.6 \cdot 10^{-3} > d \geq 1.0 \cdot 10^{-3}$; g – pyrolyzed wood waste after fractionation with $d < 1.0 \cdot 10^{-3}$**

**CONCLUSIONS**

Using the smallest particles – fractions with $d < 1.0 \cdot 10^{-3}$ and $3.6 \cdot 10^{-3} > d \geq 1.0 \cdot 10^{-3}$ in the technology of production of wine and cognac products, cognac, whiskey, calvados there are certain difficulties: dusty structure pyrolyzed particles complicate the filtration process, so it makes it impossible to use these fractions.

The use of medium fractions with a diameter of $5.0 \cdot 10^{-3} > d \geq 3.6 \cdot 10^{-3}$ also makes it impossible to use these fractions, because in the structure of the pyrolyzed fraction of wood particles involved in the extraction – up to 10%, while fully pyrolyzed particles involved in redox reactions and adsorption – up to 90%.
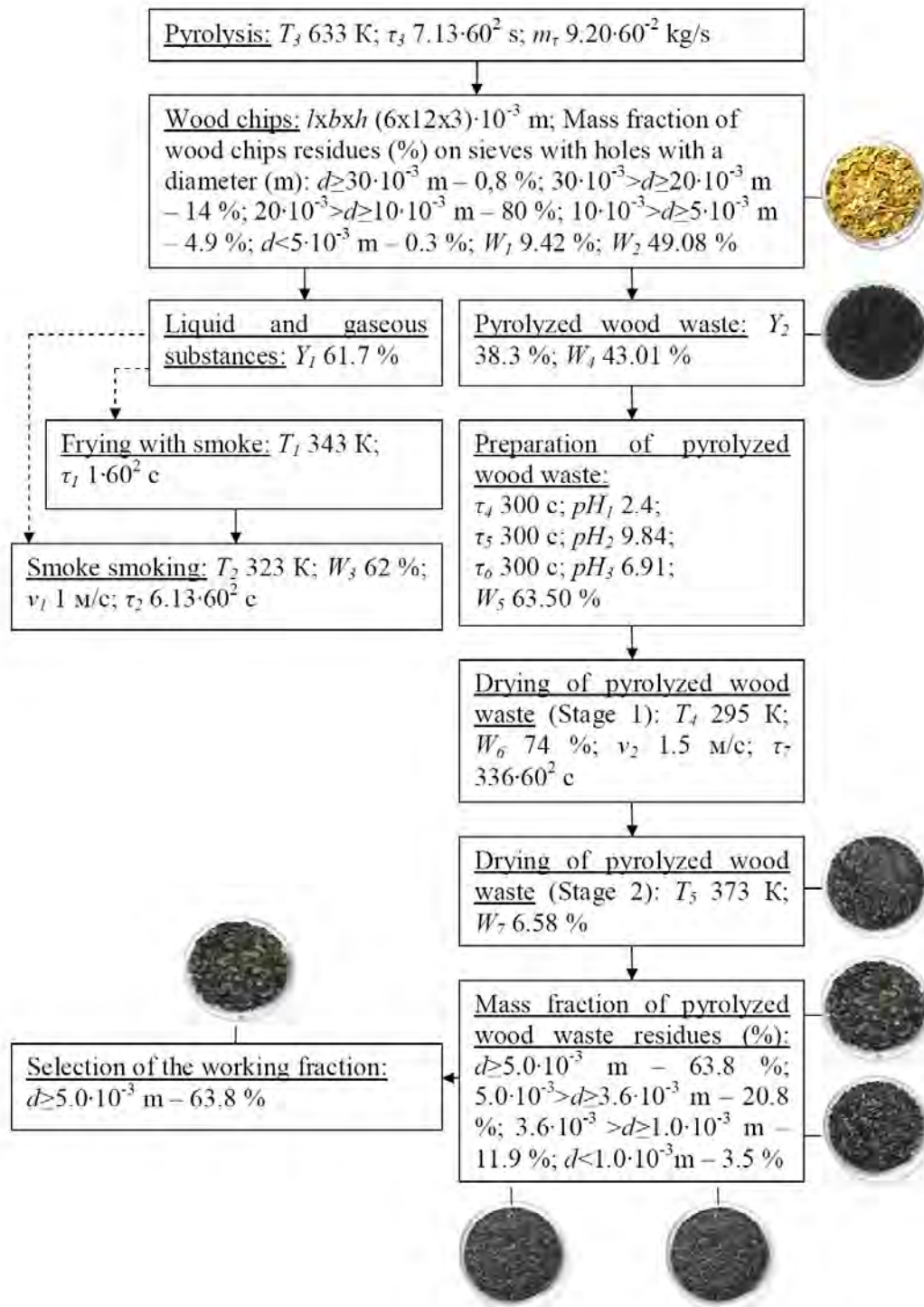
Pyrolysis: $T_3$ 633 K; $\tau_3$ $7.13 \cdot 60^2$ s; $m_\tau$ $9.20 \cdot 60^{-2}$ kg/s

Wood chips: $l \times b \times h$ $(6 \times 12 \times 3) \cdot 10^{-3}$ m; Mass fraction of wood chips residues (%) on sieves with holes with a diameter (m): $d \geq 30 \cdot 10^{-3}$ m – 0,8 %; $30 \cdot 10^{-3} > d \geq 20 \cdot 10^{-3}$ m – 14 %; $20 \cdot 10^{-3} > d \geq 10 \cdot 10^{-3}$ m – 80 %; $10 \cdot 10^{-3} > d \geq 5 \cdot 10^{-3}$ m – 4.9 %; $d < 5 \cdot 10^{-3}$ m – 0.3 %; $W_1$ 9.42 %; $W_2$ 49.08 %

Liquid and gaseous substances: $Y_1$ 61.7 %

Pyrolyzed wood waste: $Y_2$ 38.3 %; $W_4$ 43.01 %

Frying with smoke: $T_1$ 343 K; $\tau_1$ $1 \cdot 60^2$ с

Preparation of pyrolyzed wood waste:
$\tau_4$ 300 с; $pH_1$ 2.4;
$\tau_5$ 300 с; $pH_2$ 9.84;
$\tau_6$ 300 с; $pH_3$ 6.91;
$W_5$ 63.50 %

Smoke smoking: $T_2$ 323 K; $W_3$ 62 %; $v_1$ 1 м/с; $\tau_2$ $6.13 \cdot 60^2$ с

Drying of pyrolyzed wood waste (Stage 1): $T_4$ 295 К; $W_6$ 74 %; $v_2$ 1.5 м/с; $\tau_7$ $336 \cdot 60^2$ с

Drying of pyrolyzed wood waste (Stage 2): $T_5$ 373 К; $W_7$ 6.58 %

Selection of the working fraction: $d \geq 5.0 \cdot 10^{-3}$ m – 63.8 %

Mass fraction of pyrolyzed wood waste residues (%): $d \geq 5.0 \cdot 10^{-3}$ m – 63.8 %; $5.0 \cdot 10^{-3} > d \geq 3.6 \cdot 10^{-3}$ m – 20.8 %; $3.6 \cdot 10^{-3} > d \geq 1.0 \cdot 10^{-3}$ m – 11.9 %; $d < 1.0 \cdot 10^{-3}$ m – 3.5 %

**Fig. 3. General scheme for obtaining pyrolyzed wood waste**

The use of the largest particles – fractions with $d \geq 5.0 \cdot 10^{-3}$ is promising in the technology of production of wine and cognac products, cognac, whiskey, calvados. In the structure of pyrolyzed wood chips involved in extraction – up to 60%, with fully pyrolyzed particles involved in redox reactions and adsorption – up to 40%. It should be used once, because after the first bookmark of wine and cognac products, cognac, whiskey, calvados, its

surface layer is depleted of aromatic and phenolic substances, so further use of wood chips becomes inefficient.

Compared to traditional technology of aging wine and cognac products, cognac, whiskey, calvados in oak containers or enameled tanks with oak rivets, as well as when using crushed oak wood in the form of clapboards, chips, shavings, which are used repeatedly, pyrolyzed chips can be used only as additional chips raw materials when separated from the main raw material. The company individually selects the ratio of pyrolyzed wood chips to wood chips while improving organoleptic characteristics and stabilization of physical and chemical parameters of finished products.

**SUMMARY**

Due to the use of pyrolyzed wood waste from $d \geq 5.0 \cdot 10^{-3}$ m there is a reduction in the cost of used oak wood and intensification of the maturation of wine and cognac products, cognac, whiskey, calvados.

Thus, the method of production of pyrolyzed wood waste from oak, due to its single use, with minimal costs for raw materials and production, will intensify the maturation of wine and cognac products, cognac, whiskey, calvados, improve organoleptic characteristics and reduce their cost.

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