Ways to improve the properties of natural wood when using waste vegetable oils

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Abstract. The article is devoted to the development and study of new compositions based on spent sunflower oil for the protective treatment of natural wood. Samples of birch and aspen wood were selected as the subjects of the study. The processing of wood samples was carried out by the method of “hot-cold impregnation”. Refined sunflower oil was used as the oil base of the propearedized compounds developed. Plant oil fillers were chosen wood flour, stearic acid, canifol and sikkativ based on metal salts. The use of developed compounds can improve the hydrophobic properties of wood, increase its water and water resistance, as well as reduce swelling in tangential and radial directions. The optimal compositions on the basis of spent vegetable oil for protective processing of birch wood have been selected. The difference in the modifying capacity of the developed compositions for different types of wood is shown on the example of birch and aspen. Propriary compounds based on spent vegetable oil have environmental safety and their use allows the disposal of food waste.

1. Introduction
Natural wood and materials based on it are valuable raw materials for various areas of human production and activity. Interest in it is constantly growing due to the tightening of environmental requirements for manufactured products, which are in contact with humans.

It should be noted that the possibilities of wood and its unique properties as a renewable natural biocomposite are currently greatly underestimated. This is due to the presence of natural wood shortcomings, preventing its wider use. Such disadvantages include, first of all, its significant indicators of water-absorption. The ability to absorb water vapor and drip-liquid moisture leads to its swelling, change in the shape of wood parts, deterioration of properties and strength characteristics. In order to reduce the negative impact of this deficiency, work continues to develop wood processing compounds to give it new properties and reduce water and water absorption, as well as swell natural wood, especially
hardwood. Therefore, the task of the careful use of forest resources and the creation of technologies and materials that extend the life of products based on natural wood is urgent.

In order to protect and modify natural wood, a variety of chemical compounds and compounds are used for impregnation, which should have a good penetrating ability in the wood cavities of the material, have a low cost, be accessible and safe for humans and animals.

When preparing food in the food industry in large volumes, wastes of vegetable oils, which have undergone repeated thermal treatment, are formed. This spent sunflower oil is poorly disposed of and its waste pollutes the environment, complicating the work of treatment plants. At the same time, spent vegetable oils are a valuable raw material and can be used in compositional compositions for the protective treatment of natural wood.

Soaking wood with vegetable oil is one of the oldest ways to protect it from adverse factors and improve the properties of natural wood. Previous work [1-2] shows the prospect of using spent vegetable oils, which are food waste products, for protective processing and modification of natural wood.

The studies [3-4] provide the results of the development of propyic compositions based on flax, sunflower and other vegetable oils in order to produce composite materials based on wood used in construction and everyday life. The authors [5] used compositions based on vegetable oils, paraffin and beeswax to chemically modify and improve the durability and stability of the wood sizes of various breeds.

The study [6] studied the effects of processing time by hot vegetable oils on the physical and mechanical properties of wood: average density, strength limit when compressed along fibers, water absorption and volume changes. For oak and pine wood it is established [6] that the treatment of natural wood with hot vegetable oils leads to a significant improvement in its properties.

The paper [7] proposes propicommens based on various vegetable oils that improve the properties of wood. To create wood composites with increased hydrophobic indicators and to protect wood products from UV radiation were used [8] emulsion on the basis of vegetable oils.

The siloxane-based wood [9-11] is environmentally friendly. After application to wood and subsequent heating there is a chemical interaction of the components of the composition with the components of wood matter with the formation on the surface of the wood water repellent coating, effectively protecting the product from moisture and other adverse effects. To obtain superhydrophobic wood, the authors [11] used polymethylsiloxane. The angle of wetting with water of such wood reached 153°.

A promising modern direction of protective wood treatment is its impregnation compositions based on nanoscale particles of zinc oxide, titanium oxide and oxides of other metals, as well as nanoglin [12-13]. Processing of such compounds allows not only to improve the water repellent properties of the surface of wood, reduce its water absorption, but also increase resistance to the effects of fungi.

Therefore, the purpose of this study was to develop and study new compositions for wood processing based on spent vegetable oil to produce a wood composite with improved hydrophobic properties, increased water and water resistance, as well as to compare the developed compositions for different types of wood.

2. Experimental part

As objects of the study, samples of ordinary birch and aspen wood were selected, harvested in the experimental training forestry of the Voronezh State Forestry University named after G F Morozov. Birch is common among hardwoods, its point of hardness exceeds the level of 38.6 MP. Birch wood is highly strong, especially when it hits. Aspen is one of the fastest growing breeds. The wood of aspen is homogeneous and refers to soft breeds. It has low durability, moderately dries, little cracks and cracks well.

All samples of birch and aspen wood were dried at a temperature of 103 °C to a constant mass. For impregnation of wood used after cooking refined sunflower oil was used.

2.1. Wood impregnation technique

Samples of birch wood of standard sizes were used for testing. Modification of wood with used vegetable oil was carried out by the method of “hot-cold baths”. Modifying wood impregnation was
carried out at a temperature of 120°C for 30 min. After that, the samples were placed for 30 min in used vegetable oil at room temperature.

2.2. Determination of water absorption, moisture absorption and swelling of wood
To evaluate the effectiveness of the applied impregnating compositions based on vegetable oil waste, the following indicators were determined: the amount of the introduced modifying composition, moisture absorption, water absorption, wood swelling in the tangential and radial directions. Detailed methods for determining these indicators and formulas for calculating them are given in previous studies [2,14].

2.3. Determining the edge angle of wetting wood with water
The surface tension of the wood was determined by the edge corner of wetting. The edge angle of wetting the wood with distilled water was measured by the lying drop method on a goniometer collected in the laboratory using the HIview 10 program. The liquid was applied to the wood surface with a 0.01 ml micro-syringe. The image was recorded using a portable Digital Microscope camera (Ruihoge, China) and recorded for 1, 30, 60, 90 sec.

3. Results and discussion
Table 1 presents the results of determining the content of impregnation composition and the edge angle of wetting water for birch wood.

| Prop drink | Content impregnated composition, % | Edge wetting, °C |
|------------|-----------------------------------|-----------------|
| Wood without impregnation | – | 15 |
| Spent vegetable oil | 36.6 | 30 |
| Spent butter with 1% wood flour and 3% sikkativa | 55.4 | 53 |

Figure 1 shows the results of the determination of valgo-absorbing (A) and water absorption (B) of untreated birch wood and processed compounds based on vegetable oil waste.

Figure 2 shows the results of determining swells in radial (D) and tangential (E) directions of untreated birch wood and processed formulations based on vegetable oil waste.

Figure 1. Indicators of water absorption (A) and water absorption (B) of birch wood after 1 and 30 days of testing (%).
Table 2 presents the results of the definition of swell, water and water absorption indicators for aspen wood after 30 days of testing.

Table 2. Indicators of swell, water-intake of aspen wood.

| Modifying compound                  | Content of the modifying compound, % | Vlago-absorption, % | Water-absorption, % | Swelling in tangential direction, % | Swelling in the radial direction, % |
|-------------------------------------|--------------------------------------|---------------------|---------------------|------------------------------------|-------------------------------------|
| Wood without impregnation           | -                                    | 15.2                | 128.3               | 6.6                                | 5.2                                 |
| Spent vegetable oil                 | 21.7                                 | 12.9                | 102.4               | 6.4                                | 5.1                                 |
| Spent oil with 1% stearic acid      | 24.5                                 | 13.2                | 113.6               | 5.8                                | 4.6                                 |
| Spent oil with 1% stearic acid and 1% canifoli | 28.1                                 | 12.4                | 104.5               | 5.9                                | 4.8                                 |

Based on the results of the experiment, it can be concluded that spent vegetable oil easily and at sufficient depth penetrates into the structures of wood. Multiple thermal treatment of oil at high temperatures leads to noticeable changes in the structure of spent vegetable oil, strengthening polymerization and oxidative processes and, as a result, changing the physical and chemical characteristics of the oil [15]. As a result, its viscosity increases. An indicator of the effectiveness of impregnation is the amount of impregnated composition in wood. Comparison of this indicator for spent vegetable oil (36.6%) and non-heat-treated sunflower oil (35.2%). This is probably due to the fact that the efficiency of impregnation with spent vegetable oil is even slightly higher.

A comparison of the surface tension of treated and untreated birch wood (table 1) shows that the treatment of wood with vegetable oil waste makes natural wood hydrophobic. Thus, the modification of birch wood with sunflower oil waste increases the edge wetting angle by more than 2 times compared to unprotected natural wood. The use of composition based on oil, wood flour and sikkativa increases the value of the edge angle of wetting by 3.5 times, making it especially hydrophobic.

Vegetable oils, when applied to wood under the influence of air and light oxygen, are polymerized and turned into a solid, elastic film. To reduce the drying time of oil and to obtain a firmer coating in its composition add compounds of metals (sikkativ). In addition, it should be noted in the spent oil as a result of its repeated heating decomposed substances that slow the curing of the coating on its basis. The use of wood flour or starch as fillers not only makes it cheaper, but also helps to consolidate vegetable oil in the cavities of wood material.
Filling the cavities of wood material with spent vegetable oil can significantly reduce the water intake of birch wood. Thus, after 1 day of testing, the intake of oil-soaked wood decreased by 1.5 times, and water absorption decreased by 3 times compared to natural wood (figure 1). Even more effectively protects natural wood from moisture and water composition containing wood flour and sikkativ. The intake of the wood-soaked field of 1 day of testing decreased by 3 times, and water absorption decreased by almost 5 times (figure 1). After 30 test grids, the effectiveness of protection is somewhat reduced, but still the rates of water-absorbing of modified oil-treated wood are significantly lower than that of unprocessed wood.

As can be seen from figure 2, the treatment of birch wood by compositions based on waste vegetable oil reduces wood swelling in both radial and tangential directions. Thus, after 1 day in the water, the swelling of wood modified with vegetable oil waste decreased both tangentially and radially by about 2.5 times compared to untreated birch wood.

Several other patterns have been observed for aspen wood (table 2), which refers to soft wood. Samples of aspen wood, soaked in spent sunflower oil without additives, had the amount of water absorption after 1 day of testing only 20% less than natural wood without impregnation. Water absorption decreased by only 15%. Introduction to the impregnation composition of supplementation with stearic acid and canifoli reduced the rates of water absorption slightly, and water absorption even increased slightly. It should be noted that the use of stearic acid as an additive in the impregnation composition reduces the swelling of aspen wood in the tangent direction by 18%, and in the radial direction – by 21%.

4. Conclusion
Thus, the study developed and researched new plants for the processing of natural wood based on waste vegetable oil. The proposed compositions can significantly improve the hydrophobic properties of wood, reduce its water and water resistance, as well as swelling in the radial and tangential directions. The optimal composition for impregnating birch wood has been chosen. A comparative assessment of the use of compounds based on waste vegetable oil for different types of wood was made using birch and aspen.

It is noted that the proposed proprietary compounds on the basis of waste vegetable oil has no odor and has environmental safety. The processing of natural wood compositions on the basis of spent sunflower oil can improve the decorative properties of the surface of wood, showing the natural texture of the tree, making the structure of low-value hardwood trees similar to valuable wood varieties.

References
[1] Dmitrenkov A I, Nikulin S S, Nikulina N S, Borovskaya A M and Nedzelsky E A 2020 Study of the process of impregnating wood birches spent vegetable oil. Forest Journal 10(2) 161 doi: 10.34220 / issn .2222-7962/2020.2/16
[2] Belchinskaya L I, Zhuzhukin K V, Dmitrenkov A I, Novikova L A and Khodosova N A 2019 Elaboration of a composition based on spent engine oil and wood flour for birch woodimpregnation and railway sleepers production. IOP Conf. Ser.: Earth Environ. Sci. 392 012075 doi: 10.1088/1755-1315/392/1/012075
[3] Croitoru C, Patachiaand S and Lunguleasa A 2015 A mild method of wood impregnation with biopolymers and resins using 1-ethyl-3-methylimidazolium chloride as carrier. Chemical Engineering Research and Design 93 257 doi: 10.1016/j.cherd.2014.04.031
[4] Schwarzkopf M, Burnard M, Tverezovskiy V, Treu A, Humar M and Kutnar A 2018 Utilisation of chemically modified lampante oil for wood protection. Eur. J. Wood Prod 76 1471. doi: 10.1007/s00107-018-1336-6
[5] Németh R, Bak M, Ábrahám J, Fodor F, Horváth N and Báder M 2019 Wood modification research at the University of Sopron. Siberian Forest Journal 3 20 doi: 10.15372/SJFS20190303
[6] Shamshin M S, Kislytsyn S N and Shitova I Y 2019 Effect of soaking wood with hot vegetable
oilson its properties. *Youth Scientific Gazette* 3(40) 225

[7] Ahmed S, Morén T, Sehlstedt-Persson M and Blom A 2017 Effect of oil impregnation on water repellency, dimensional stability and mold susceptibility of thermally modified European aspen and downy birch wood. *J. Wood Sci.* 63(1) 74 doi: 10.1007/s10086-016-1595-y

[8] Berube M, Schorr D, Ball R Landry V and Blanchet P 2018 Determination of In Situ Esterification Parameters of Citric Acid-Glycerol Based Polymers for Wood Impregnation. *J. Polym. Environ.* 26(3) 970 doi: 10.1007/s10924-017-1011-8

[9] Lin W, Huang Y, Li J, Ran L and Chen H 2018 Preparation of highly hydrophobic and anti-fouling wood using poly(methylhydrogen)siloxane. *Cellulose* 25 7341 doi: 10.1007/s10570-018-2074-y

[10] Kumar A, Ryparova P, Skapin A, Humar M, Pavlic M, Tywoniak J, Hajek P, Zigon J and Petric M 2016 Influence of surface modification of wood with octadecyltrichlorosilane on its dimensional stability and resistance against Coniophora puteana and molds. *Cellulose* 23 3249 doi: 10.1007/s10570-016-1009-8

[11] Zhaoa M, Taob Y, Wanga J and He Y 2020 Facile preparation of superhydrophobic porous wood for continuous oil-water separation. *Journal of Water Process Engineering* 36 101279 doi: 10.1016/j.jwpe.2020.101279

[12] Sulafa H, Temiz A, Aslan M, Hazim M and Amini M 2020 Physical properties, thermal and fungal resistance of Scots pine wood treated with nano-clay and several metal-oxides nanoparticles. *Wood Mater. Sci. and Eng.* 16(1) 1 doi: 10.1080/17480272.2020.1836023

[13] Tana Y, Wangb K, Dongb Y, Zhanga W, Zhanga S and Li J 2020 Bulk superhydrophobicity of wood via in-situ deposition of ZnO rods in wood structure. *Surface and Coatings Technology* 383 125240 doi: 10.1016/j.surfcoat.2019.125240

[14] Nikulin S S, Dmitrenkov A I and Nikulin S S 2020 About the possibility of using 1 -inylnaphthalene to modify natural wood. *IOP Conf. Ser.: Earth and Environmental Science* 595 012021 doi: 10.1088/1755-1315/595/1/012021

[15] Perevozhikov E N and Slugin V V 2016 Effect of Heat Treatment on Physical characteristics and polymerizationof vegetable oils. *International Research Journal* 3(45) 94 doi: 10.18454/IRJ.2016.45.023