Optimization of processing branches, needles, and leaves (“woody greens”) of dark-coniferous breeds of thin tree stands using a modified plant

E Petrenko*, V Parshikova and E Zaychenko

1 Siberian Federal University, 2 L. Prushinskaya str., Krasnoyarsk 660075 Russia

E-mail: evp.2011@yandex.ru

Abstract. The waste-free technological scheme is proposed in the paper. It is based on an installation which allows to optimize the integrated processing of woody greens (branches, needles, and leaves) from fir and spruce. This scheme takes into account their contribution to the mixtures made, as well as the age of plantations used to produce an essential oil and pine extract. An installation is designed with an internal and external condensation circuit of the vapor stream serving as the basis, the use of which increases yields and significantly reduces the time needed to release the water-soluble products being processed into coniferous extract.

1. Introduction

When felling in Siberian forests, at least half of the tree biomass remains in the cutting area. In addition to the fact that logging waste poses a serious fire and biological hazard, the cost of their harvesting places a burden on the cost of wood products, reducing its competitiveness in the global market [1-3]. To date, only a small part of the green fir wood from their huge mass is processed to produce essential oils with a useful use of raw materials at 1-3% [4]. Developments, testifying to the possibility of using coniferous extracts in the production of furniture plates [5], [6], open up the prospect of large-scale development of this wood chemical direction. Its implementation provides for the involvement in the processing of green wood both fir and spruce, with the development and an increased yield of 15-17% of the second marketable product of coniferous extract. Along with the utilization of the generated logging waste, which increases the profitability of the wood processing industries, the development of this direction creates conditions for the functioning of small businesses in forest depleted areas with the emergence of new jobs. This seriously improves the social status of rural settlements.

The aim of the research is the development of the apparatus, technology, and processing lines for the greenery of fir and spruce in the forest areas covered by logging with the production of essential oil and coniferous extracts.

2. Materials and Methods

In Siberia, only green fir wood is processed on a semi-industrial scale. In rare cases, the processing is accompanied by the production of fir extract in small quantities consumed in feed and recreational purposes [1]. Occasionally, CO₂ extracts of coniferous shoots are obtained at pilot plants in a small amount. Approximately in the same volumes, St. Petersburg State Forestry Academy’s employees produce a large range of wood-chemical products by means of water-gasoline extraction and...
fractionation from pine-spruce wood green. This range does not yet find consumption due to lack of demand [7]. In this connection, and also because of the comparative complexity of the technology, its implementation is hardly justified on the forest territory in Siberia. At the same time, the modification of coniferous extracts of adhesive masses, which improve the ecological consumer properties of furniture, indicates the possibility of the appearance of large-scale demand for them and, consequently, the urgency of developing a technology for producing such products.

The specificity of the raw material, which consists in reducing the content of essential oil with the almost unchanged contribution of water-soluble substances [4], indicates the feasibility of improving the apparatus for their selection.

3. Results
The basis of the developed apparatus, the laboratory setup for the extraction of plant materials was taken [9]. A diagram of the developed apparatus for separate distillation of the essential oil and leaching of extractive substances with water or ethanol (and another solvent) is shown in Figure 1. The extraction chamber and the refrigerator cover with flanges form the basis of the apparatus, as in the prototype [9]. For better sealing and convenience, the gasket between the flanges is replaced with a rubber cord placed in their grooves. Raw materials are located on interchangeable grilles of the chamber. Water (or other extractant) is poured into its bottom part, where the internal heater is placed. Filling is carried out either before loading the raw material or after it through a pipe with a plug in the bell of the lid of the refrigerator, mounted when an installation is improved. The bottom solution is discharged through the pipe at the bottom of the bottom part of the chamber. To complete the drain, its bottom is raised to 10°C on the opposite side of the pipe. Due to the tilting of the bottom, the camera body is mounted on a stand for stability. An additional heater, which allows to force heating, is placed in the resulting space. For process control and sampling, including in the vapor phase, two nozzles with plugs are in the chamber through which the corresponding equipment is introduced.

The main difference of the developed device from the prototype [9] is its addition of the florentine with a collection of essential oil to the external circuit consisting of a refrigerator, as well as a system of pipelines connecting florentin to the camera. Its connection to the main working device is carried out by replacing the regulating hole at the top of the lid-cooler of the prototype with a branch pipe with a valve that is connected to the entrance of an external refrigerator. During operation of this circuit, the steam oil flow is condensed in an external refrigerator with the internal refrigerator-cap disconnected. The florentine condensate is separated into florentine water and essential oil, which is collected in a tank. Removing oil from the condensate allows one to select both of the main commercial products of production in a pure form. This mode is especially important in the processing of raw materials rich in essential oil. Data on the yield of essential oil from fir-spruce wood greens with different ratios in the mixture contribute to the choice of the mode of processing of raw materials. The deoiled florentin water returns to the chamber through a piping system through a nozzle in the conical part of the fridge lid, irrigating the treated green wood and closing the water cycle.

The final stage of processing the oil-depleted raw material is carried out in the internal circuit of the installation during the condensation of the main mass of the stream in the tubes of the cooler lid. In addition, some of it is condensed in the above-pipe part of the cap. For a better discharge of the formed liquid, the upper part of the tubes is made flush with the plate tightening them. The condensate, flowing down the refrigerator’s tubes, flushes out the products it carries from the flow that rises along them and enters the cubic part of the chamber, having passed a layer of green wood. Thus, during the operation of both the external and internal circuits of the installation, multiple extraction of raw materials takes place with almost “pure” reagent.

At the end of the process, the solution in the bottom part of the process (bottom condensate) is sent to the tank and then to the evaporator. Its concentration when bringing to the extract in connection with the viscosity of the product is possible only with external heating of the evaporator. In order to avoid burning and the resulting quality deterioration, this is done with constant mixing and control. An evaporating extractant (water) is condensed in the refrigerator. Then, the liquid is collected in the tank.
and through a pipe embedded in the pipeline with the florentine water, is sent to the chamber through a pipe in the conical part of the cooler lid.

**Figure 1.** A scheme of the installation of the extraction processing of wood greens.

The technology of complex processing of fir-spruce wood greens with obtaining essential oil and pine extract from raw material harvesting to utilizing its spent solid residue is presented in Figure 2. Before felling, the species composition and age of plantations are additionally estimated for making a decision on the choice of the mode of processing raw materials (1). With this in mind, at its completion, the green wood of felled trees is crushed to a predetermined size and accumulates in the bunker of the self-propelled unit. Its delivery to the warehouse of raw materials is carried out by the installation itself (2) or by specialized transport. Loading of raw materials into the working apparatus (5) is carried out by a fan or conveyor (4), using a belt conveyor (3). Wood greens entering the cyclone of the installation are loaded onto the grids with the help of a flexible hose, due to which the mechanized unloading of the spent residue is ensured with the help of a hoist. Upon completion of loading, the chamber is closed with a cooler lid, sealed, and prepared for launching according to the chosen option.

When raw material enriched with essential oils is loaded, the steam-oil flow, which is formed when hot steam passes through wood greens, is processed in the external circuit (6) of the installation. Steam is generated by heating the water in the bottom part of the chamber. In this case, the use of an autonomous steam generator is unrealistic, since the cyclical nature of the treatment of green wood with an agent is violated. Through the uncooled cooling lid and nozzle, the steam-oil flow enters an external cooler, and there it condenses. The resulting condensate in a florentine is divided into oil flowing into the tank and florentine water. The water with traces of oil is returned to the chamber through the nozzle in the conical part of the lid. Irrigating raw materials on the grid, it flows into the bottom part and a new cycle begins.

In the case of the using the depleted essential oil of wood greens after the distillation of its main quantity, the treatment of the steam-oil flow in the external circuit is replaced with the internal one. Such a translation consists in connecting the lid-cooler to the cooling system, which provides condensation in it of almost the entire mass of the steam-oil flow. The condensate is poured into the chamber onto the wood green through the tubes of the refrigerator, due to which the efficiency of leaching of extractive substances increases. The non-condensed part of the flow can be processed in the external sector, which allows high-boiling volatile products to be isolated.
Figure 2. Technological scheme of the line for the integrated processing of fir-spruce wood green: (1) a stand, (2) a self-propelled installation, (3) a 10-belt conveyor, (4) a high-pressure fan, (5) a working unit, (6) an external circuit, (7) an evaporator, (8) a capacity, (9) a bin of spent raw materials, (11) a receiving device.

Processing the bottom condensates consists in concentrating them to the required density and returning the evaporated extractant to the chamber. Technologically, this process consists in accumulating the bottom solution in the collection and pumping it into the bottom part of the evaporator (7). The vapors formed here are condensed in the refrigerator, from where they enter the intermediate tank (8), and then periodically through the pipeline into the chamber. Extracts merge into a tank, are conditioned like an essential oil into a marketable product.

The spent green wood is transferred to the bunker (9) by means of hoists from the gratings, from where, when being used for economic purposes, it is loaded onto transport or during further processing by a conveyor (10), moving to the feed meal production workshop (11).

4. Discussion
A significant drawback of the installation, taken as a prototype, is the simultaneous isolation of the extract and essential oil, which, being constantly in the high-temperature zone, undergo negative changes. To avoid this, the oil should be separated from the rising steam-oil flow, which is advisable to produce outside the device, in the external circuit (which was implemented in this case). Thanks to the collection of the bottom condensate, in the case of using waste materials, wasteful processing of green wood is achieved.

Connecting the external circuit is also advisable when processing the depleted essential oil of wood greens. However, in this case, its functioning is justified during the initial period, when the main amount of terpenoids distills. The study of the dynamics of oil release indicates that 85-90% of its volume accumulates in the first third of the process duration.

The possibility of large-scale application in the production of furniture panels of coniferous extract and the development of equipment for its rational production allow, along with green fir, to have an economically profitable to recycle and seed shoots of other conifers, especially spruce. This increases a proportion of the useful use of this raw material from 1-3 to 15-17%.

The waste mass can be used as feed for animals and poultry, as a basis for fertilizing, structuring and refining the soil, etc. The softening of wood greens during hydrothermal processing and the removal of resin, phenolic and terpenoid compounds from its composition, which impede microbiological decomposition, contributes to this. The absence of volatile terpenoids favors the processing of waste raw materials into feed meal, and this fact reduces the fire hazard and the shredding of green wood.
The development of this direction opens up the prospect of organizing a wide network of small businesses in the wood chemical industry.

5. Conclusion
The high importance of coniferous extract as a multi-tonnage modifier of adhesive compositions of furniture panels indicates the feasibility of joint processing of fir-spruce green trees. With this in mind, waste-free technology, optimizing the choice of the mode of processing of raw materials, depending on the ratio in the mixture of wood green fir and spruce and the age of the stand, was developed on the basis of the modernized installation.

6. Acknowledgments
The work submitted for publication was carried out under the direction of Stepen Robert Alexandrovich (1936-2017), Doctor of Biological Sciences, Professor of the Siberian State Technical University, and the work is dedicated to his memory with gratitude for many years of effective cooperation.

References
[1] Medvedev S O, Soboleva S V, and Stepen R A 2010 Possibilities for the rational use of wood waste in the Lesosibirsk timber industry complex (Krasnoyarsk, Russia: SibSTU)
[2] Can Baser K H, Buchbauer G 2010 Handbook of essential oils: science, technology, and applications (Boca Raton, FL: CRC Press)
[3] Galyavetdinov N R, Safin R R, Voronin A E, and Shaikhutdinova A R 2015 The mathematical modeling of the wood greenery extraction processes In International Conference on Mechanical Engineering, Automation and Control Systems (MEACS) (IEEE)
[4] Stepen R A, Nevzorov V N, and Nevzorova T V 2010 Organization of fir oil production (Krasnoyarsk, Russia: KrasSAU)
[5] Petrenko E V, Parshikova V N, and Stepen R A 2012 Hydrothermal processing of spruce-fir wood green New Advances in Chemistry and Chemical Technology of Vegetable Raw Materials pp 520-521
[6] Petrenko E V, Parshikova V N, and Stepen R A 2010 Use of an alcoholic extract of green wood as an adhesive material Actual Problems of Contemporary Science and Ways to Solve Them pp 187-190
[7] Yagodin V I 2000 Fundamentals of wasteless technology of wood greens Problems of Chemical Processing of Raw Wood pp 50-58
[8] Chernyaeva G M, Dolgodvorova S Ya, and Stepen R A 1987 Disposal of woody biomass (Institute of Forest and Wood SB AS USSR)
[9] Parshikova V N, Stepen R A, and Demina L N 2008 Patent for invention (No. 2281135) Laboratory installation for the extraction of vegetable raw materials