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Chemical Composition and Utilization of Conifer Needles-A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author HTS designed the study and wrote the first draft of the manuscript. Author OUY managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The demand for new material sources is growing and there is an awakening interest in the use of forest residues. However, conifer needles are are still unexploited ones among forest residue. In most conifer growing areas, the needles basically serve as ground cover and can facilitate the spread of fires. For that reason, they are eliminated in many cases by chemical, biological and/or mechanical means. In this context, numerous studies and investigations have already been conducted for determining the anatomical and chemical characteristics of the conifer needles for better utilization practices. However, most studies focus on the anatomical and chemical structures, which depend on the species and have particular characteristics that range from their shape to the arrangement and chemical variations. It has already evaluated as used for pharmaceutical purposes, ornament materials, energy sources, environmental pollution indicator and pulp and paper making potantial. Some important findings have already been reported in literature. But much of the information was available on essential oils and medicinal compounds from some coniferous needles. There have already been exploited, differences among commercially important conifer little needle's chemical constituents in literature. It has consistently reported that the change in compounds of needles depends on geographical, seasonal, and environmental situations. The

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conifer needles could receive rapid approval by consumers and has found to be beneficial to use in manufacturing alternative products including needles powder, extract liquids, soft drinks, healthy food supplements and some pharmaceutical products.

Keywords: Conifer litte needle; forest utilization; pharmaceutical properties; essential oil; extractives.

1. INTRODUCTION

Coniferous trees are sometimes called evergreens, most coniferous trees keep their foliage year-round. They are widespread in the northern hemisphere and form forests, which are called *boreal forests*. But some conifers also grow in the southern hemisphere in places such as; New Zealand and Chile where they are adapted to survive cold weather and acidic soil found in these locations [1,2]. However, due to fine dimensions of coniferous leafs, they are usually called *little needle* or only *needle*. These are small and simple in shape that ranges from a few mm in length to extend only a few cm.

The needles normally stay on the tree year-round, producing evergreen color. They could be provided the key to identifying coniferous trees and protect themselves with a waxy outer coat, which stops moisture evaporation from freezing temperatures. Thereby, the conifer little needles are resistant to frost damage and are able to photosynthesize at low temperature [1]. However, pyramidal form and the diagravitropic branches of many conifers are efficient in capturing the low-angle light that is characteristic of high latitudes. Moreover there is immense variation in chemical composition of needles based on the geographical location and type of species [1-3].

The needles apperance and physical structure varies markedly between the different species (i.e. bundled, spiral, linear, colored, small to large, short to long, etc.) and is often crucial for the identification of species of conifers. However, the pines (*Pinus spp.*) are the most abundant genus of conifers in Northen hemisphere. All pine species bear 1-5 needles that are arranged in groups and that are bundled together form a *fascicle* [3].

The little needles from coniferous trees have already been utilized in some places whether they are cut from the tree, fallen, or dried. Due to their aesthetic apperance and economic value, they are mostly used in gardening and landscaping practices, could be made into decorative crafts.

A number of studies have already been conducted to establish better utilizaition and to ensure valuable product manufacturing. It had already been well reported that essential oils from some coniferous species have high commercial significance and potential antibiotic, anticarcinogenic, sedative effects and even have nutritional properties in medicinal industry [4-6].

However, the fast growing demand has drawn attention for utilization of forest residues, agricultural wastes, and non-wood fibrous materials for the production of commercially important products (i.e. chemical substances, pulp, paper, composite), which might help in reducing the environmental pollution. Although some studies are available in literature to evaluate potential raw material for forest products industry, the conifer's little needles are one of waste/residue material in forestlands that are not consider to use properly to obtain high value products.

In this study, the potential use of little needles as an energy source, through anatomical and chemical characterization, to provide a basis for future applications have been reviewed. Some literature findings have been reviewed and important findings regarding their pharmaceutical properties are reported.

2. THE CHEMICAL PROPERTIES

Up to date, numerous studies have already been conducted for determining chemical composition of conifer needles. However, considerably different chemical properties have been reported based on the geographical location and type of conifer species. It is important to establish exact chemical composition and/or properties of isolated compounds from needles for industrial scale utilization. The data collected in the cited publications, as well as in many other sources, have been used for the evaluation of the chemical properties of conifer needles. Moreover, needles are an important source of various organic substances which perform important biochemical and ecological functions.

Most of the studies have been conducted for determining differences in composition of various chemical groups of lipophilic extractives, low-molecular carbohydrates, phenolic compounds, polysacharides, lignin, ash and essential oil substances. However, the majority of studies are on pine species and less extent on other coniferous tree of spruce, cedar, sequia, fir, douglas fir, juniperus, etc.

Numerous methodolgy and practical approaches have already been conducted for determining chemical composition of conifer needles, and isolated extracts [7,8]. These studies have usually compared their results with various type of little needles and literature findings in order to report chemical properties. All these experimental details have contributed to better utilization of materials from little needles as valuable plant products. It is well established that no single organic solvent is capable of removing all these substances while different solvents remove different combinations of components. However, ethanol-benzene, hexane, ethanol and ether appears to provide the most complete removal of solvent-extractable substances in wood and other lignocellulosic compunds (i.e. needle). The Table 1 shows solubility of wood extractives that should be used for extraction of needles [7,8].

The numerous analytical methods useful for determine the elemental and extract composition of lignocellulosic compounds. However, the gas chromatography (GC) and mass spectroscopy techniques (MS), has been widely used for extractives profiling of lignocellulosic materials [9-11].

2.1 The Main Chemical Composition and Papermaking Properties

It was reported that the pine and spruce needles, like others typically contain cellulose, hemicellulose and lignin with some soluble extractive compounds at various proportions. However, the cellulose dominated in the needles. Moreover, it was found that the spruce needles had significantly higher concentrations of lignin and mannan with lower levels of ethanol-soluble substances, cellulose and galactan than the pine needles. It was concluded that concentrations of carbohydrates in the needles positively correlated with site index [9].

It is important to note that cellulose is the main structural element and most important for paper manufacturing. In this sense, the pine needles was also evaluated for the paper making potential [12]. The chemical composition reported for pine needle was found to be 68.5% hollocellulose, 4.56% extractives and 31.0% lignin. However, cellulose comprises approx 41%, and comparable to softwood (42%), whereas the lignin content (35.1%) was high as compared to both softwood (28%) and hardwood (20%) [12]. Moreover, the ash content of pine needles (3.2%) was comparable to some non-wood materials. The average length of the pine needle fibre was calculated to 1.3 mm was greater than many annual plants and agricultural wastes, but less than softwood. In addition, the average diameter of pine needle fibre was found to be 32 micron was greater than all the common fibres used for papermaking [12]. Within these results, Lal and friends evaluated (2013) pine needles as pulp and paper making potential, and they found promising properties of paper.

2.2 Elementel Composition and Pollution Indicatior Properties

It has well established that coniferous needles are composed principally of carbon, oxygen, hydrogen, nitrogen, potassium, calcium, magnesium, phosphorous, sulphur and some other elements. However, the relative quantities are varied among species and in even within the same species. The carbon, hydrogen, and oxygen could be obtained in main chemical

Table 1. Solubility of extractives and chemical groups (X:Low-, XX: Medium-; XXX: High solubility)

Solvents	Terpenoids	Fats	Phenolic substances	Carbohydrates
Ether	XXX	XXX	XXX	
Acetone	XXX	XXX	XX	XX
Hexane	XXX	XXX	XX	
Ethanol	XX	XX	XXX	X
Ethanol-benzene	XXX	XXX	XX	X
Water			X	XX

constituents of polysaccaharides while nitrogen is absorbed in the form of nitrate and to a limited extent as ammonia; while calcium, magnesium, phosphorus, and sulphur are taken up in the mineral organic compounds.

Joanson (1995) conducted a detailed research on needle litter from 14 stands of Scots pine (*Pinus silvestris*, L.), 13 stands of Norway spruce (*Picea abies* (L.) Karst.) in terms of comparative chemical analyses. It was found that the needles typically contain N, P, K, Ca, Mg and Mn elements. However, although Norway spruce had significantly higher concentrations elements of N, P, K, Ca, Mg, Mn than the pine needles, significant differences were only obtained for Mg. These vital findings considering elemental proportions have been variable for different conifers. It was concluded that nitrogen in the pine needle was negatively correlated with the latitude of the sites [9].

In another study on Scots pine (*Pinus sylvestris* L.) needles that grown in south eastern part of the Netherlands were conducted, whether or not there was a relation between yellowing color of needles with elemental composition. It was proposed that soil samples from the discoloured forests contained more extractable nitrogen than samples from healthy stands, whereas differences in pH values were small. However, needles from yellow trees had higher levels of total nitrogen than needles from green trees as well as severe imbalances of Mg, K and P elements relative to N. Moreover, the amount of needle pigments was substantially lower in the diseased trees, but they contained much higher quantities of free arginine, which accounted for a major part of total nitrogen. This may be an indication of a severe nitrogen overload [13].

Some further studies conducted for determining elemental composition of conifer's needles. In these studies, the following 18 elements have already reported for coniferous needsles; N, P, K, Ca, Mg, Mn, S, Fe, B, Cu, Zn, Al, F, Pb, Cd, Cr, Ni and Co, at various proportions [11,13-15].

Needles from coniferous trees have also been studied as environmental pollution indicatior. For that aim, Dmuchowski and Bytnerowicz [11] was conducted a research for determinine a maps of the distribution of environmental pollution by sulfur (S), zinc (Zn), cadmium (Cd), lead (Pb), copper (Cu), and arsenic (As) for the some territories of Poland. Hence, pine needles were collected and analyzed in those specific areas. It was found that sulfur dioxide (SO_2) and other sulfurous air pollutants have endangered to environment whereas Zn, Cd, Pb, and As do not pose an immediate threat to vegetation in most of the country's territory [11]. Skonieczna and his groups (2014) have also studied elemental composition Scots Pine (*Pinus sylvestris* L.) stands of different densities. They reported that the highest concentration of chemical elements of C, N, P, K, Mg, S, Mn, Na, Fe was observed in the needles while the lowest of C, N, P, S, Cu, Na, Ni, Pb, Zn, Fe, elements in the stem wood [16]. Most of the macronutrients (P, K, Ca, Mg and S) reached optimal values, with the exception of N showing a deficiency, especially in the needles [11].

A similar research but different methodology were conducted by Nuhoglu and his Friends (2015) in Gökova, Turkey. They had studied the anatomical and morphological anomalies in the cross-section of Turkish pine needles *(Pinus brutia Ten.)* caused by air pollutants that was emitted from the Kemerköy (Gökova) Thermal Power Plant, in Turkey. It was clearly demonstrated that air pollutants of sulfur dioxide, nitrogen oxides and fly ashes had caused serious injury, and effect 3 year-old-needles fell very early. However, it was also reported that diameter of the main and especially many subordinate resin canal and the number of resin canals increased. Moreover, the endodermis layer in transmission corymbs and the cells in transfusion texture had become thin, and the intra-cellular material had disappeared owing to air pollutants [17].

Tremolada, and his group (1996) were investigated the spatial distribution and mixture of polycyclic aromatic hydrocarbons (PAHs) in pine needles sampled across the U.K. It was found that PAHs of pine needles via atmospheric transport and deposition processes. However, phenanthrene was distributed irregularly across the U.K, while the other PAHs generally decreased on a northward gradient from the southern England to northern Scotland [18]. In another study on PAHs were conducted by Hwang, et al. [19] in order to contamination monitoring of selected areas of three different country (Korea, Mexico, and the United States). For that reason, pine needles were collected to compare the concentrations of polycyclic aromatic hydrocarbons (PAHs) as contamination monitoring. It was found that the total polycyclic aromatic hydrocarbons (PAH) concentrations ranged from 31 to 563 n gg-1 (wet wt.) and showed clear differences between rural (clean) and urban/industrialized (contaminated) sites. It was reported that three-ring PAHs accounted for 63–73% of the total PAHs and *phenanthrene* was the predominant compound. The ratios of methylphenanthrene to phenanthrene suggest that the contribution of *diesel-operated vehicles* to the signature of PAHs has more significant in samples. It was concluded that the pine needles should be useful for atmospheric organic contaminants monitoring on large spatial scales (e.g., national or global) [19].

2.3 Chemical Composition of Extracts and Pharmaceutical Properties

Although numerous studies already been conducted to establish utilizaition of coniferus little needles, much of the literature available on extractives (i.e. essential oils) and medicinal compounds from some coniferous species that have high commercial significance. Some of the important findings relating to chemical contents of extractives and its properties are briefly reported in below.

Kubeczka and Schultze [14] studied a comparative study on *Abies*, *Larix*, *Pseudotsuga*, *Tsuga*, *Picea* and *Pinus species's litters* in terms of biology and chemistry of oils form those species. However, the essential oils from the *Pinus densiflora*, *Pinus koraiensis*, and *Chamaecyparis obtusa* were quantified by GS-MS technique. Then they were performed antibacterial and antifungal effects of that isolated essential oils [5]. It was found that the major components and the percentage of each essential oil were: 19.33% β-thujene in *P. densiflora*; 10.49% α-pinene in *P. koraiensis*; 10.88% bornyl acetate in *C. obtusa*. However, the essential oils from *P. densiflora* and *C. obtusa* have shown antibacterial effects, whereas essential oils from *P. koraiensis* and *C. obtusa* have antifungal properties. It was also proposed that the essential oils from these trees, which have mild antimicrobial properties, can inhibit the growth of gram-positive and gram-negative bacteria and fungi [5].

The chemical composition of essential oil from needles of Cedrus deodara with its antioxidant and antimicrobial activities were also evaluated [6]. It was reported 25 components in essential oil of needles of Cedrus deodara and representing 95.79% of the oil, were identified by GS-MS. The main components are; α-terpineol (30.2%), linalool (24.47%), limonene (17.01%), anethole (14.57%), caryophyllene (3.14%), and eugenol (2.14%). However, it showed remarkable antioxidant activity in scavenging free radicals, in lipid peroxidation, and in reducing power assays. Moreover, it was also determined that Cedrus deodara needle's oil revealed strong antimicrobial activity against typical food-borne micro-organisms, with minimum inhibitory concentration and minimum bactericidal concentration values of 0.2 to 1.56 and 0.39 to 6.25 μg/mL, respectively. These results suggest that the essential oil from Cedrus deodara has potential to be used as a natural antioxidant and antimicrobial agent in food processing [6]. In another study on same species have conducted by Shi and his friends (2016). They found that flavonoids from C. Deodara's little were able to inhibit the tumor proliferation [20].

The chemical composition of essential oils from twigs and needles of Balkan pine (*Pinus peuce Gris.)* were investigated [10]. However, the oil yield was found to be 2.85% for twigs and 0.57% for needles. Moreover, they reported that the twig oil was rich in α-pinene (7.38%), β-pinene (12.46%), β-phellandrene (26.93%), β-caryophyllene (4.48%), and citronellol (12.48%), while the needle oil was rich in α-pinene (23.07%), camphene (5.52%), β-pinene (22.00%), β-phellandrene (6.78%), bornyl acetate (9.76%), β-caryophyllene (3.05%), and citronellol (13.42%) [10].

The seasonal changes and antioxidant metabolites in eastem white pine (*Pinus strobus L.)* needles determined by monitoring ascorbate and glutathione concentrations and the activity of ascorbate peroxidase, glutathione reductase (GR), and superoxide dismutase [4]. They found that antioxidant metabolites of eastem white pine *(Pinus strobus L.)* needles increased two- to four fold from the summer to the winter season. However, antioxidant enzymes in needle tissue in creased between 2- and 122-fold during this same period. Levels of antioxidant metabolites and enzymes were observed always to be lowest during the summer, or active growing season, and highest during the winter, or dormant season. The increased activities of other enzymes, and the high substrate concentrations observed during the winter are consistent with the protective function this pathway may provide against photooxidative, winter injury [4].

However, extracts from conifer little needles rich for α-pinene, myrcene, and terpinene compunds that these are aromatic hydrocarbons and very high antioxidant activities compare to vitamin E [21]. In this sense, these extracts may be useful for special foods (i.e. health foods or food supplements) and cosmetic products.

In another study on determining pharmaceutical properties of little needles, it was found that pine needles could be effective in treatment of cardiovascular and skin diseases due to their affordability and the presence of bioactive substances [21]. It was hypothesis that pine needle extracts are more cytotoxic on to cancer cells than to normal cell in *vitro*, and the intake of pine needle powder exhibited significant antitumor effect in *vivo* [22]. This antitumor effect appears to be mediated through the antioxidative, antimutagenic, and antiproliferative properties of particular substances in pine needles [22]. In this context, the blood urea nitrogen and aspartate aminotransferase levels were reported to be significantly lower in pine needle supplemented rats. These results clearly demonstrate that pine needles exhibit strong antioxidant, antimutagenic, and antiproliferative effects on cancer cells and also antitumor properties in *vivo* and point to their potential useful against cancer [22].

An alternative use of extract from pine needles have shown that the little needle utilized extract as a novel preservative for cheese products [23]. It was shoen that certain extracts showed a significant effect on the lipid oxidative stability and also on the microbiological characteristics. These improved the oxidative stability and storage time of selected cheese samples and may be commercially exploited as a natural preservative in cheese like products [23].

However, there is a growing interest in a novel natural products from biological sources that could be antioxidant properties for health-promoting medicinal food applications. Moreover, terpenoids that typically occur in little needles are one of complex compounds that exhibit useful effects to remove harmful substances from body with improving health.

It was reported for terpenoids that it is a self-fermentation product and aging improves effects, hence it could be a good source for pharmaceutical product [24]. In another research, it had already reported that certain pine needle extracts shown antioxidants properties that aide in heavy metal detoxification, and have antibacterial and anti-inflammatory properties may have anti-cancer effects [25].

It has proposed that tea from little needles had some health improving properties and may be effective in treating bronchial asthma, arteriosclerosis, and inflammation. In this sense, pine needle products (i.e. as needle powders, teas, drinks and liquid extracts) will be commercially available as supplements or health foods [21,25]. Table 2 shows most common compounds in essential oils of coniferous needles that reported in literarure [4,6,20-25].

Eight phytochemical compounds containing seven phenols and one roseoside were isolated from pine needles are shown in Fig. 1.

3. THE THERMAL PROPERTIES

The relative contributions to combustible products from conifer needles are extractives, holocellulose and lignin. Each of these components makes a sizeable contribution to flammable vapors. However, on thermal decomposition, conifer needles could generate light volatiles, carbon monoxide, hydrogen with some organic vapors that flammable gases. In this sense, through pyrolysis, needles can be densified in the form of briquettes which may be used as a smokeless fuel and can also be used to generate electric power through gasification process. Moreover, the thermal gasification of needles may provide a solution to the problem of energy recovery and waste disposal. Since conifer needles pose serious threat to forests from fires, their collection and disposal for energy recovery is a very attractive proposition.

The thermal degradation behaviour at 100 to 700℃ and biochar production of pine needles was studied. It was reported that the sorption parameters (N and logKf) are linearly related to sorbent aromaticities, which increase with the pyrolytic temperature [27]. However, at 100 to 300℃ level, the biochars originates from an amorphous aliphatic fraction, which is enhanced with a reduction of the substrate polarity. At 400 to 600℃, the partition occurs with a condensed aromatic core that diminishes with a further reduction of the polarity. Simultaneously, the adsorption component exhibits a transition from a polarity-selective 200 to 400℃ to a porosity-selective at 500 to 600℃ levels, and displays no selectivity at 700℃ [27].

Table 2. The most common compounds in essential oils of coniferous needles reported in literarure

No.	Compound
1	Androst-4-ene-3,17 dione
2	Anethole
3	*p*-Anisaldehyde
4	Aromadendrene
5	Aromadendrene oxide
6	Benzylbenzoate
7	*cis*-α-Bisabolene
8	Bornyl acetate
9	δ-Cadinene
10	α-Cadinol
11	δ-Cadinol
12	tau-Cadinol
13	Camphene
14	Δ^3−carene
15	β-Caryophyllene
16	Caryophyllene oxide
17	Cedrol
18	Cembrene
19	Citronellol
20	α-Copaene
21	β-Cubebene
22	β-Elemen
23	Estragole
24	Eucalyptol
25	Eugenyl acetate
26	Eugenol methyl ether
27	all-*trans*-Farnesyl acetate
28	Fenchol
29	Germacrene-D
30	Germacrene-D-4-ol
31	α-Guaine
32	Globulol
33	Geranyl acetete
34	*cis*-3-Hexenyl cinnamate
35	Humulene
36	Isoborneol
37	Isobornyl acetate
38	Isocaryophyllene
39	Limonene
40	Lauric acid ethyl ester
41	Linalol
42	Linalyl acetate (Bergamiol)
43	Methyl neoabietate
44	T-Muurolene
45	tau-Muurolol
46	Myrcene
47	Nerolidol
48	Ocimen
49	*cis*-β-ocimen

No.	Compound
50	α-Phellandrene
51	Phenethyl pivalate
52	α−pinene
53	β−pinene
54	Pimaral
55	Pseudolimonen
56	Sabinene
57	Scloreol
58	Selinene
59	*cis*-β-Terpineol
60	Terpineolen
61	α-Terpineol
62	Terpinen-4-ol
63	α-Terpineol acetate
64	Thujene
65	Thymol methyl ether
66	Thungbergol
67	Tricyclene
68	Undecane
69	Widdrene
70	Verticiol

In another study on thermal degradation of pine needles, it was converted to biochar at different pyrolysis temperatures of 300, 500, and 700℃. It was proposed that pyrolysis temperature showed a pronounced effect on biochar properties. Decrease in molar H/C and O/C ratios resulted from removing O- and H-containing functional groups with increasing temperature, and produced high aromaticity and low polarity of biochars [28].

It was found that the pine needles have good energy potential for exploitation through pyrolysis and gasification. The heating value of pine needles is comparable to that of saw dust (18.2 MJ kg^{-1}) and fuel oil (~18.75 MJ kg^{-1}) and more than that of wood (15.82 MJ kg^{-1}). This is probably due to the fact that pine needles have higher fixed carbon and lower ash content than wood [29].

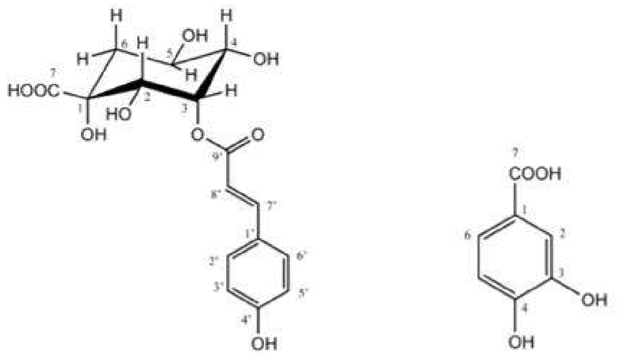
It was also studied the thermal behaviour of Pinus halepensis's needles systematically with using DSC and TG in the presence of $(NH_4)zHPO_4$ and $(NH_4)_2SO_4$. They reported reported very valuable results for thermal degreadtion properties of needles from Pinus halepensis [30].

It was reported that little needles could be utilized as an alternative fuel for off-grid electricity generation in some part of India. In this sense, iIt was found that pine needles would have more competitive edge than coal if emission had reduced [31].

4. SOIL IMPROVEMENT PROPERTIES

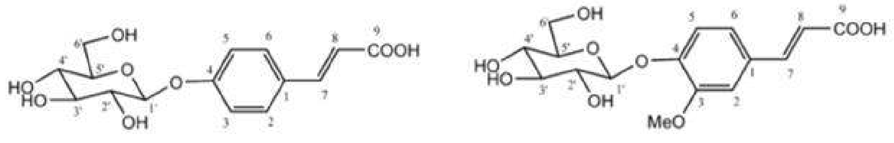
Pine needles typically stay on the branches for about 2 years, after which they turn reddish brown and fall. While needles can fall throughout the year, under normal weather conditions most pine needles drop in September and October [32]. However, they interlock and hold together during hard rains and heavy winds, even on sloping landscapes. Because pine needles interlock, pine straw could not wash out of beds like other mulches. The fine texture and uniform color of conifer little needles are more aesthetically pleasing to some people. Its attractive. However, the earthy look brings out the color, contrast, and texture of landscapes. [32].

It has already established that needles have great water-holding capacity, and litter on the forest floor can also reduce evaporation from the ground surface [33]. On the other hand, they provide protection against surface erosion and supply moderate soil temperature and moisture, and they inhibit growth of weeds. Thereby, these could be considered a valuable resource on the forest floor [33].



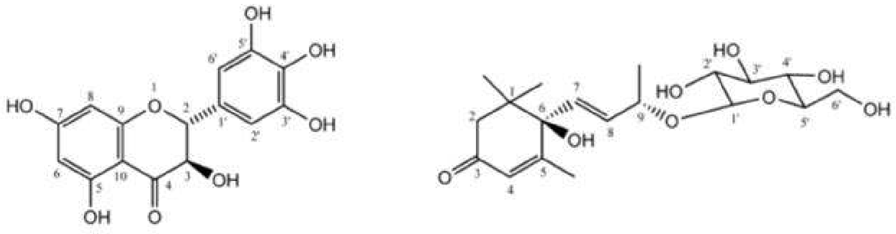
3-p-trans-coumaroyl-2hydroxyquinic acid

Protocatechuic acid



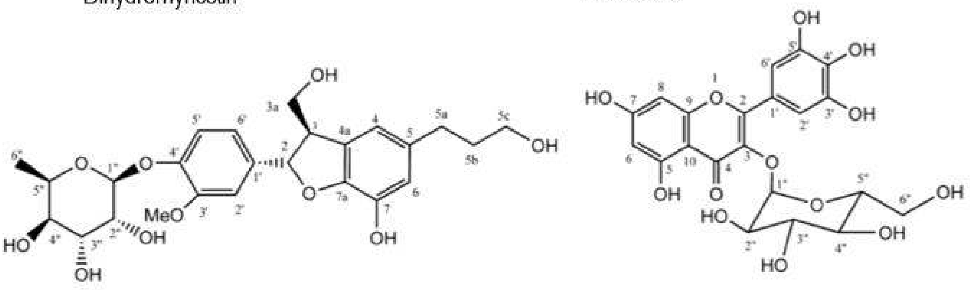
Trans-p-coumaric acid-4-O-β-D-glucopyranoside

Trans-ferulic acid4-O-β-D-glucopyranoside



Dihydromyricetin

Roseoside



Massonianoside B

Myricetin-3-Oβ-D-glucopyranoside

Fig. 1. Chemical structures of some isolated compunds from pine needles [26]

Studies also indicates that pine and spruce needle litters during the first stages of decomposition (up to 165 days) emits monoterpene hydrocarbons into the gas phase with the rates comparable to those in emissions from live needles of these trees. This clearly suggest that leaf litter is an important source of atmospheric terpenes. It has also been proved that the litter contains considerable amounts of nonvolatile substances that can be precursors of oxidized volatile compounds formed after enzymatic reactions. Nonvolatile but water soluble secondary metabolites of the leaf litter may be involved in nutrient cycling and have an influence on soil properties [34].

5. CONCLUSIONS

Needles from coniferous trees have already investigated various purposes including gardening and landscaping practices, decorative crafts, environmental pollution indicatior, extraction for essential oil production, gasification and biochar manufacturing, pulp and papermaking so on. In all these studies, it has been clearly demonstrated that needles from coniferous trees have chemical, and fibrous properties similar to wood substrate but in various proportions. However, the fast growing demand on lignocellulosic substrates has drawn attention for utilization of forest residues (i.e. needles) Moreover, the use of needles in forest products industry as raw materials has been considered but the logistic of tonnage, collection and delivery problems may be the major obstacle for its potential use. Furthermore, much of the efforts have made on essential oils and medicinal compounds from some coniferous needles. Some of the essential oils from coniferous needles have already in high commercial significance.

However, production of non-timber forest products such as pine needles could be a way to earn an income, especially when unemployment is a problem in those areas. However, freshly fallen needles could be raked and sold to retailers, landscapers, and others who use the material as ground cover. Moreover, the development of a novel utulization from conifer needles will be beneficial since that showed some pharmeutical activities and therapeutic effects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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