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QUANTITATIVE AND QUALITATIVE ANALYZING METHODS OF VARIOUS BIOACTIVE COMPOUNDS FROM DIFFERENT BIRCH PRODUCTS – A REVIEW

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ABSTRACT
The aim of this literature study is to discuss the quantitative and qualitative analyses carried out on products derived from various parts of birch (Betula spp.), such as extracts from bark, leaves or buds, with an emphasis on determining their chemical makeup and assessing their biological potential. In numerous studies, samples from different parts of Betula sp. were subjected to analyses in order to determine their concentration of bioactive substances such tannins, flavonoids, or polyphenols, but also many other chemical constituents. The obtained results indicate that the examined birch components had a great deal of chemical diversity, indicating their potential for use in the food, cosmetics, and phytotherapy industries. This demonstrates their wide range of applications in industry, medicine, and nutrition, offering a plethora of opportunities for further advancements in these domains. Research focuses on identifying and characterizing the compounds found in the different parts of the tree with the aid of thin-layer chromatography (TLC) or Fourier Transform Infrared Spectroscopy (FTIR). Accurate quantification and characterization of these compounds has been rendered easier by quantitative and qualitative analyses, including high-performance liquid chromatography (HPLC) and UV-VIS spectrophotometry. These advanced techniques offer accurate concentration measurements of substances, enabling a more thorough comprehension of their chemical makeup and possible uses.
KEY WORDS: *Birch sap, Brich products, quantitative, qualitative tests.*

INTRODUCTION

Birch contains various biologically active components, in different aerial parts, like bark, buds or leaves, which can be utilized in numerous commercial products, preferred by the people who want to have a healthy diet (Grundemann et al. 2011; Guon et al. 2002; Vladimirov et al. 2019; Toplicean et al. 2022). The extracts and various substances found in it have been marketed on a modest scale and are used to create different key products, from food supplements (Dayan, 2023), cosmetics (Smiljanic et al. 2022), biocides (Moskalev et al. 2017), to biofuels (Kumaniaev et al. 2020). Many birch species exhibit antibacterial properties, as proved experimentally in *B. utilis, B. pendula*, and *B. papyrifera* (Acquaviva et al. 2012).

The bark, leaves, and sap of the Betula species have been the subject of extensive research due to their diverse and rich chemical profile (Vladimirov et al. 2019). These studies have identified a variety of bioactive compounds that contribute to the medicinal and therapeutic potential of birch trees (Demets et al. 2022; Isidorov et al. 2022; Miranda et al. 2013; Laszczyk et al. 2006).

The sap of the birch is a colorless or slightly opalescent, odorless liquid with a somewhat sweet mineral water flavor due to its low carbohydrate content and high concentration of dissolved minerals (Peev et al. 2010). Birch sap, taken from the stem in early spring, was used to treat renal and urinary tract disorders, skin problems, and rheumatism/gout (Mashentseva et al. 2011; Saha et al. 2025). Additionally, birch sap can be extracted individually in an easy manner, which is the reason why some people prefer to extract it by themselves and to preserve it. Raw birch sap has different properties, some of which are retained even when it is preserved by freezing (Mingaila et al. 2024). Birch sap includes soluble sugars, ascorbic acid, phenolic compounds, and other micro and macro elements, with potassium being the most prevalent (Sancho et al. 2022).

The consumption of birch extracts is due to their main bioactive compounds, such as essential oils, saponins, tannins, hydrocarbons, carbohydrates, flavonoids, coumarins, carotenoids, and terpenoids (Patocka, 2003; Subba et al. 2024). According to Rastogi et al. (2015) each of these classes offers distinct pharmacological qualities that are used in both conventional and contemporary medicine.

Much attention has been paid to pentacyclic triterpenoids, particularly the derivatives of lupane. Such substances include betulin, betulin diacetate, betulinaldehyde, betulinic acid, platanic acid, lupeol, lupeol-3-acetate, and others (Fuchino et al. 1996; 1998). The antiviral, anti-inflammatory, antioxidant, and anticancer properties of betulinic acid, for example, have been emphasized (Nikolayevich et al. 2020; Dehelean et al. 2012; Kuznetsova et al. 2014). The antimicrobial qualities of betulin, which is frequently present in birch bark, as well as its function in fostering wound healing and bolstering skin health are also being investigated (Scheffler, 2019; Demets et al. 2022).

Birch's traditional uses in wound care and skincare are supported by additional compounds, such as tannins, which have astringent and antimicrobial properties. In the meantime, flavonoids which have antioxidant and anti-inflammatory properties include kaempferol and quercetin (Rastogi et al. 2015). Birch's anti-inflammatory and antioxidant properties are further enhanced by coumarins and carotenoids found in its bark and leaves (Isidorov et al. 2022; Ciurlea et al. 2010; Šiman et al. 2016). These discoveries have sparked interest in the pharmaceutical and cosmetic sectors, where birch extracts are prized for their inherent anti-aging and skin-soothing properties, in addition to their traditional medical applications. Birch extracts are a common natural ingredient in skincare and haircare products because of these characteristics (Demets et al. 2022; Ahn et al. 2022; Miranda et al. 2013).

A variety of elaborate techniques, surrounding both quantitative and qualitative approaches, can be used to detect and extract different components. The importance of these methods is shown through comprehensive profiles and precise detection of the compounds which underline the comprehension of their medicinal potentials.

The aim of this study is to describe both quantitative and qualitative extraction methods of different birch products.

MATERIALS AND METHODS

A literature study was accomplished in 2024 in order to achieve these results. Google (www.google.com) as search engine, and Google Academic (https://scholar.google.com/) were utilized to find and choose literature for our study. A careful review of the most relevant publication abstracts was completed, and articles in other languages, not English, were excluded. Research included reading and analyzing several papers, both research articles, and reviews. In addition, logical diagrams were created using the website VOSviewer (https://www.vosviewer.com/), to integrate the obtained material. Data served as the foundation for these graphic representations. The diagram made using VOSviewer is a network map that presents the links between various notions or entities based on bibliometric data, such as scientific papers, terms, or authors. The main premise behind the construction of diagrams in VOSviewer is the co-occurrence or co-citation of phrases in the examined data corpus.

RESULTS AND DISCUSSIONS

QUANTITATIVE ANALYSES

In order to accomplish quantitative analysis, a series of analytical techniques can be utilized (Table 1).

High performance liquid chromatography (HPLC) is one of the most popular quantitative techniques for measuring flavonoids, according to peak height or area (Keinanen, 1993; Lahtinen et al. 2006; Ossipov et al. 1995). Triterpenoids are frequently extracted using ultrasound-assisted extraction (UAE), and their quantification is then done using methods like HPLC or gas crompatography (GC) (Diouf et al. 2009; Wang et al. 2015). Additionally, HPLC works well for precisely measuring carotenoids (Grazhdannikov et al. 2018) and tannins (Salminen et al. 1999, Bertaud & Crampon Badens, 2017). Furthermore, the quantification of carbohydrates is often accomplished using GLC-MS (gas-liquid chromatography coupled with mass spectrometry) (Piispanen & Saranpää, 2001), whereas the quantitative determination of carbohydrates in solution is commonly accomplished using UV-VIS spectroscopy (Miranda et al. 2013). In addition, ultra-high performance liquid chromatography with quadrupole time-of-flight mass spectrometry (UPLC-QTOF-MS) offers thorough examination and accurate coumarin quantification (Blondeau et al. 2020).

TABLE. 1: Main bioactive compounds from birch products and quantitative methods of analysis for these

Compounds	Method of Analysis	References
Carbohydrates	GLC-MS (Gas-liquid chromatography coupled with mass spectrometry); UV-VIS Spectroscopy (Quantitative determination in solution)	(Piispanen & Saranpää, 2001; Miranda et al. 2013)
Carotenoids	High Performance Liquid Chromatography (HPLC)	(Grazhdannikov et al. 2018)
Coumarins	Ultra-performance liquid chromatography–quadrupole time-of-flight mass spectrometry (UPLC-QTOF-MS)	(Blondeau et al. 2020)
Flavonoids	High Performance Liquid Chromatography (HPLC)	(Keinanen, 1993; Lahtinen et al. 2006; Ossipov et al. 1995)
Tannins	High Performance Liquid Chromatography (HPLC)	(Salminen et al. 1999)
Triterpenoids	Ultrasound-Assisted Extraction (UAE)	(Diouf et al. 2009)

Using VOSviewer, a logical scheme between the utility of analytical methods and their actual usage has been generated (Figure 1). The orange cluster (which contains terms like "performance liquid chromatography" and "phenolic compounds") and the red cluster are especially related, indicating that quantitative techniques like high performance liquid chromatography (HPLC) are frequently used for flavonoid identification and quantification. Terms like "soil," "forest," and "metabolome" are linked to the yellow cluster, suggesting that the study of flavonoids and other chemical compounds in plants has ecological ramifications and is impacted by soil composition and the forest surroundings. A relationship between analytical and botanical chemistry is suggested by the three-pointed cluster's association with the green cluster (which contains the phrase "plants"), which highlights the use of HPLC in research on plant phenolic chemicals.

Terms like "carbon" and "lignin" are among the important connections between the purple cluster and the light blue cluster. These links suggest that lignin and carbon content analysis are key components of Norway spruce research, which is crucial for comprehending ecological adaptability and regional diversity. The connections among the clusters point to a complicated network of connections between many study disciplines (forest ecology, ecology, botany, and analytical chemistry) and quantitative methodologies. For instance, chemical components in plants are analyzed using HPLC quantification techniques, and the results are utilized in ecological and forest ecological research. At the same time, an interdisciplinary quantitative approach to comprehending ecological variety and adaptation is suggested by the examination of species distribution by latitude and plant chemical composition.

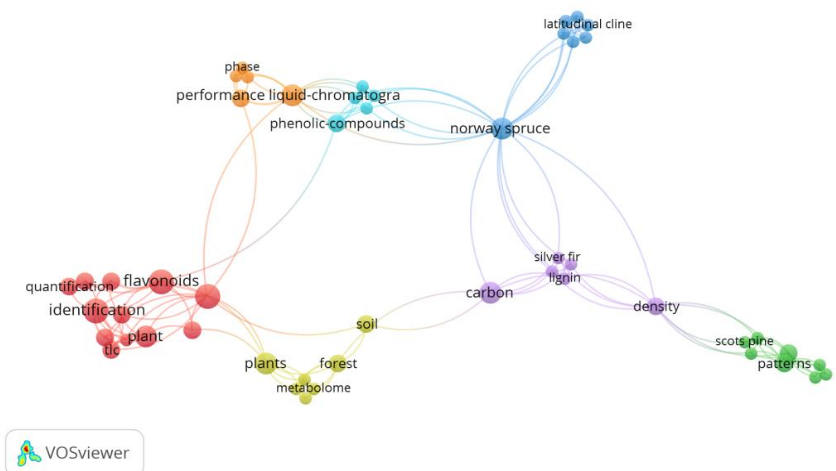

FIG. 1: Map of Quantitative Analyses key (https://www.vosviewer.com/)

QUALITATIVE ANALYSES

Qualitive analyses can be represented by different methods, such as the ones described in Table 2. To determine the functional groups of triterpenoids, one qualitative technique that can be used is infrared spectroscopy (Kovač-Bešović et al. 2009). Moreover, essential oils for identification are obtained by steam distillation extraction (SDE), while gas chromatography (GC) is frequently utilized for component separation in subsequent analysis (Baser & Demirci, 2007). Gas chromatography is a useful technique for component identification and separation, used also in essential oil identifications (Orav et al. 2011).

TABLE 2. Birch compounds and their quantitative methods of analysis

Compounds	**Method of Analysis**	**Citations**
Essential Oils	Steam Distillation Extraction (SDE), Gas Chromatography (GC)	(Baser, & Demirci, 2007; Orav et al. 2011)
Hydrocarbons	Infrared Spectroscopy (IR)	(Abyshev et al. 2007)
Phenolic Acids	Thin-Layer Chromatography (TLC)	(Hawrył & Soczewiński, 2001)
Saponins	Thin-Layer Chromatography (TLC)	(Fuchino et al. 1995)
Tannins	Fourier-Transform Infrared Spectroscopy (FTIR)	(Ostapiuk et al. 2021)
Triterpenoids	Infrared Spectroscopy (IR)	(Kovač-Bešović et al. 2009)

One common method for determining the functional groups in tannins is Fourier-transform infrared spectroscopy (FTIR) (Ostapiuk et al. 2021). A common method for separating and identifying substances like phenolic acids (Hawrył & Soczewiński, 2001) and saponins (Fuchino et al. 1995) is thin-layer chromatography (TLC). According to Abyshev et al. (2007), IR spectroscopy can also be used to identify the presence of hydrocarbons by analyzing their distinct absorption bands. The qualitative method of analysis can be viewed in table 2, alongside the main compounds of birch.

Using VOSviewer, a logical scheme between the utility of qualitative methods and their actual usage was created (Figure 2). The orange cluster (which contains terms like "performance liquid chromatography" and "phenolic compounds") and the red cluster are especially related, indicating that quantitative techniques like liquid chromatography high performance (HPLC) are frequently used for flavonoid identification and quantification. Terms like "soil," "forest," and "metabolome" are linked to the yellow cluster, suggesting that the study of flavonoids and other chemical compounds in plants has ecological ramifications and is impacted by soil composition and the forest surroundings. A relationship between analytical and botanical chemistry is suggested by the three-pointed cluster's association with the green cluster (which contains the phrase "plants"), which highlights the use of HPLC in research on plant phenolic chemicals.

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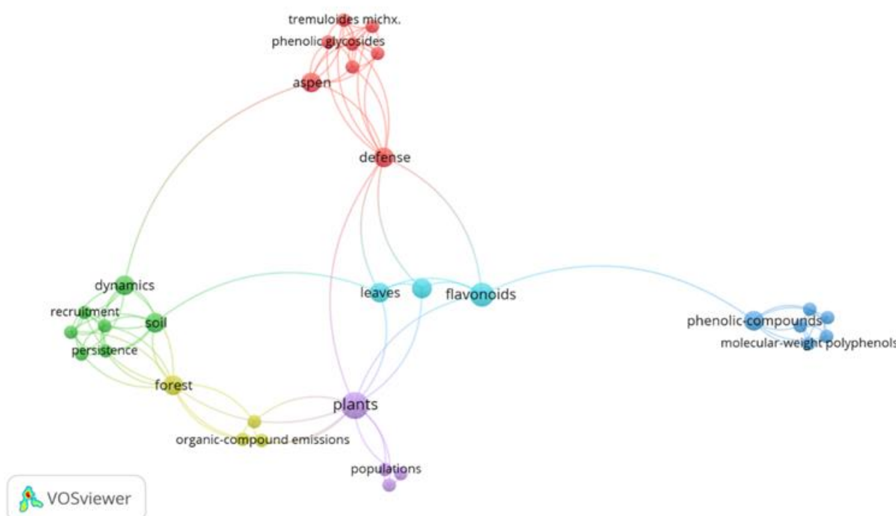

FIG. 2. Map of Qualitative Analyses key (https://www.vosviewer.com/

CONCLUSIONS

To summarize, this work emphasizes on one hand, the great chemical variety and substantial biological potential of chemicals originating from many portions of birch trees (*Betula spp*.), including bark, leaves, and buds, and, on the other hand, quantitative and qualitative methods used for their characterization and quantification. Researchers have accurately described and measured the values for various bioactive compounds in birch using different types of analyses, including techniques such as high-performance liquid chromatography (HPLC), gas chromatography (GC), thin-layer chromatography (TLC), Fourier-transform infrared spectroscopy (FTIR), and UV-VIS spectrophotometry.

The chemicals from birch products, which include tannins, flavonoids, triterpenoids, and polyphenols, have prospective uses in a variety of sectors. The study's findings highlight the adaptability of birch-derived chemicals, which are beneficial to the food, cosmetics, and phytotherapy sectors due to their antioxidant, antibacterial, and anti-inflammatory qualities. The quantitative quantification methods used, such as HPLC for flavonoids, carotenoids, and tannins and GLC-MS for carbohydrates, provide precise measurement and a better understanding of these components' functional qualities. Techniques such as FTIR and IR spectroscopy help to detect functional groups, which improves the capacity to discern chemical structures.

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