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DETERMINATION OF CARBOHYDRATE CONTENT IN *MAHONIA AQUIFOLIUM* (PURSH) NUTT.

Actuality. *Mahonia aquifolium belongs to the barberry family (Berberidaceae) and originates from the western regions of North America. In Ukraine, it is commonly cultivated in parks and public spaces and is widely used in landscape design. Traditionally, American medicine has employed Mahonia aquifolium to treat conditions such as fever, digestive disorders, gout, rheumatism, kidney and biliary diseases, and particularly chronic skin conditions. The biologically active compounds found in this plant demonstrate a wide spectrum of pharmacological activities, including antioxidant, anti-inflammatory, hypoglycemic, hepatoprotective, hypotensive,* *antimicrobial, antibacterial, antimutagenic, antitumor, and immunomodulatory effects, especially beneficial for dermatological disorders. Although some research has been conducted on the alkaloid and phenolic content in certain parts of the plant, its overall chemical composition remains insufficiently studied. Therefore, a comprehensive phytochemical analysis of all plant organs is both necessary and timely.*

The present study aimed to analyze the carbohydrate content in the roots, flowers, leaves, and fruits of Mahonia aquifolium.

Material and methods. *The material for the research was the leaves, roots, fruits, and flowers of Mahonia aquifolium, harvested in the experimental plots of the Laboratory of Medical Botany of M.M. Hryshko National Botanical Garden of the NAS of Ukraine (Kyiv) in 2024. Identification and quantitative content of carbohydrates in the studied medicinal plant raw materials was carried out by gas-liquid chromatography-mass spectrometry using the Agilent 6890N/5973inert gas chromatography-mass spectrometry system (Agilent Technologies, USA). Identification of monosaccharides was based on comparing their retention times with retention times of standards of the mass spectral library NIST 02. Quantification was done by using sorbitol added to the sample.*

Research results. *This study identified and quantified nine carbohydrate compounds using GC/MS method. Among all carbohydrate compounds identified in various parts of Mahonia aquifolium, D-glucose was present in the highest concentration. After hydrolysis, L-fucose was the leading monosaccharide derivative, with recorded amounts of 11,96 mg/g in fruits, 18,41 mg/g in flowers, 10,07 mg/g in leaves, and 17,46 mg/g in roots. Similarly, D-xylose was also a prominent hydrolysis product, with concentrations of 3,25 mg/g in fruits, 6,98 mg/g in flowers, 14,62 mg/g in leaves, and 17,87 mg/g in roots.*

Conclusion. *For the first time, GC/MS analysis revealed nine distinct carbohydrate compounds in Mahonia aquifolium, present in both their free and hydrolyzed forms. These sugars are associated with significant pharmacological activity, supporting existing knowledge of the plant's medicinal value. D-glucose was the most abundant carbohydrate across all studied organs of the plant. Following hydrolysis, L-fucose and D-xylose were identified as the dominant monosaccharides in the samples. These results suggest that the carbohydrate profile of Mahonia aquifolium may provide a useful foundation for developing pharmaceutical and nutraceutical products.*

Key words: *Mahonia aquifolium, carbohydrates, monosaccharides, gas-liquid chromatography-mass spectrometry (GC/MS).*

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ВИЗНАЧЕННЯ ВМІСТУ ВУГЛЕВОДІВ У *MAHONIA AQUIFOLIUM* (PURSH) NUTT.

Актуальність. *Магонія падуболиста належить до родини барбарисових (Berberidaceae) і походить із західних регіонів Північної Америки. В Україні її зазвичай культивують та широко використовують у ландшафтному дизайні. Традиційно в американській медицині використовували магонію для лікування таких станів, як лихоманка, розлади травлення, подагра, ревматизм, захворювання нирок, жовчовивідних шляхів, шкірні захворювання. Біологічно активні сполуки, що містяться в цій рослині, мають широкий спектр фармакологічної активності, зокрема й антиоксидантну, протизапальну, гіпоглікемічну, гепатопротекторну, гіпотензивну, антибактеріальну, протипухлинну й імуномодулюючу дію. Науковцями були проведені дослідження щодо вмісту алкалоїдів і фенольних сполук у частинах рослини, проте загальний фітохімічний склад магонії падуболистої залишається не досить вивчений. Тому комплексний фітохімічний аналіз усіх органів рослини є необхідним дослідженням.*

Мета дослідження *– провести аналіз вмісту вуглеводів у коренях, суцвіттях, листках і плодах магонії падуболистої.*

Матеріал і методи. *Матеріалом для дослідження були листки, корені, плоди та суцвіття Mahonia aquifolium, зібрані на дослідних ділянках лабораторії медичної ботаніки Національного ботанічного саду імені М.М. Гришка Національної академії наук України (місто Київ) у 2024 році. Ідентифікацію та визначення кількісного вмісту вуглеводів у досліджуваній лікарській рослинній сировині проводили методом газорідинної хромато-мас-спектрометрії з використанням інертної газової хромато-мас-спектрометричної системи "Agilent 6890N/5973" (Agilent Technologies, США). Ідентифікацію моносахаридів проводили на основі порівняння їхнього часу утримування із часом утримування стандартів мас-спектральної бібліотеки NIST 02. Кількісне визначення проводили за допомогою внутрішнього стандарту сорбіту, доданого до зразка.*

Результати дослідження. *У результаті дослідження методом ГХ/МС було ідентифіковано та кількісно визначено дев'ять вуглеводних сполук. Серед усіх виявлених вуглеводів у різних органах Mahonia aquifolium найбільший вміст установлено для D-глюкози. У результаті гідролізу найвищу концентрацію серед моносахаридів становила L-фукоза: 11,96 мг/г у плодах, 18,41 мг/г у суцвіттях, 10,07 мг/г у листках і 17,46 мг/г у коренях. Також у значних кількостях після гідролізу містилася D-ксилоза у плодах (3,25 мг/г), суцвіттях (6,98 мг/г), листках (14,62 мг/г), коренях (17,87 мг/г).*

Висновок. *Отже, за результатами проведеного ГХ/МС аналізу в сировині Mahonia aquifolium виявлено дев'ять вуглеводних сполук як у вільному, так і у зв'язаному стані. Ці речовини відомі своєю фармакологічною активністю, що узгоджується з наявними даними щодо лікувальних властивостей цієї рослини. Найвищий вміст серед вуглеводів спостерігався для D-глюкози в усіх органах рослини. Після гідролізу основними моносахаридами, що переважали, були L-фукоза та D-ксилоза. Отримані дані свідчать про перспективність використання вуглеводів магонії падуболистої для створення нових лікарських препаратів на рослинній основі.*

Ключові слова: *Mahonia aquifolium, вуглеводи, моносахариди, газорідинна хромато-мас-спектрометрія (ГХ/МС).*

Introduction. Actuality. Modern pharmacotherapy increasingly incorporates traditional herbal knowledge, using plant-based remedies both as standalone treatments and alongside synthetic medications (Budniak, et al., 2021a). Despite the development of synthetic drugs, many of which replicate plant-derived bioactive compounds, natural remedies have retained their significance. Medicinal plants remain a unique and valuable source of therapeutic agents used for both the prevention and treatment of numerous human health conditions (Feshchenko et al., 2021; Budniak et al., 2022; Oproshanska et al., 2024).

The *Berberidaceae* family includes around nine genera and encompasses approximately 590 species, primarily distributed across the Northern Hemisphere and parts of South America. *Mahonia* Nuttall ranks as the second most extensive genus within this family, comprising nearly 70 species found predominantly in Eastern Asia, North America, and Central America (Dulin & Kirchoff, 2010). Species of *Mahonia* have long been utilized in traditional healing practices, and research has demonstrated that these plants exhibit a wide range of biological activities, including antioxidant, anti-inflammatory, antifungal, antimicrobial, antiproliferative, hepatoprotective, and analgesic effects (Hu et al., 2011; Li et al., 2007; Zhang et al., 2011).

Mahonia aquifolium (Pursh) Nutt. is among the most widely grown and commonly used medicinal species of the *Mahonia* genus. Research on *Mahonia* plants has primarily focused on their alkaloid content, particularly compounds such as berberine, jatrorrhizine, and palmatine, which are recognized as their principal active constituents. These alkaloids contribute to the plant's ability to inhibit keratinocyte proliferation and reduce inflammation, making it effective in managing conditions like psoriasis and atopic dermatitis (He & Mu, 2015; Lastovychenko et al., 2025a). In addition, phytochemical investigations of *Mahonia aquifolium* have identified various secondary metabolites, including chlorogenic acid, *p*-coumaric acid, ferulic acid, rutin, isoquercitrin, and quercetin (Andreicut et al., 2018b).

In traditional American medicine, *Mahonia aquifolium* is used to treat fever, diarrhea, dyspepsia, gout, rheumatism, kidney and biliary tract diseases, and especially chronic recurrent dermatosis (Godevac et al., 2018; Andreicut et al., 2018a). The chemical profile of *Mahonia aquifolium* remains insufficiently explored. Some research has examined the presence of alkaloids, amino acids, and phenolic compounds in select types of raw plant materials from this species (Sedláčková et al., 2022; Coklar & Akbulut, 2017; Lastovychenko et al., 2025b).

To date, no published studies have addressed the carbohydrate composition of *Mahonia aquifolium*.

The study aimed to analyze the carbohydrate content in the roots, flowers, leaves, and fruits of this plant. To the best of our knowledge, this work represents the first investigation into the monosaccharide profile of *Mahonia aquifolium*.

Materials and research methods. Roots, fruits, flowers, and leaves of the *Mahonia aquifolium* were collected at the experimental sites of M.M. Hryshko National Botanic Garden of the NAS of Ukraine, Kyiv, in 2024. The raw material was authenticated by Senior Scientist Nadia Dzhurenko. A voucher specimen was deposited in the herbarium at the Department of Pharmacognosy and Medical Botany, TNMU, Ternopil, Ukraine.

The carbohydrate composition of *Mahonia aquifolium* was determined by GC/MS method on gas chromatograph Agilent 6890N with 5973 inert mass detector (Agilent Technologies, USA). Samples were analyzed on a capillary column HP-5MS of 30 m in length and an internal diameter of 0,25 mm, a thickness of the stationary phase is 0,25 µm. The first set up oven temperature at 160 °C and held for 8 min, then raised to 240 °C at the rate of 5 °C/min and kept at this point for 6 min. At a constant flow rate of 1,2 sm^3/min was used Helium as the carrier gas. Detection was performed in the SCAN mode at the width range of 38–400 m/z (Khvorost et al., 2023).

Sample Preparation. For the extraction of bonded monosaccharides or monosaccharides after hydrolysis 500 mg of powdered of the raw materials was placed into the flask and added 5 ml of 2 M trifluoroacetic acid. Hydrolysis was performed under 100 °C for 6 hours. 2 mL of obtained hydrolysate was evaporated and was added 2 mL of an internal standard.

For the extraction of free monosaccharides, 0,5 mg of methanol solution with internal standard (sorbitol) was added to 500 mg of powdered raw materials. The extraction was performed at the ultrasonic water bath at 80 °C for 4 h. Then, to obtain acetylated aldonitriles 2 ml of the extract was evaporated to dryness and was added 0,3 ml of derivatization reagent (32 mg/ml of hydroxylamine hydrochloride in pyridine/methanol (4:1 v/v)). The extract was incubated at 75 °C for 25 min. To the samples was subsequently added 1 ml of acetic anhydride and incubated at 75 °C for 15 min. 2 ml of dichloroethane was added, and the excess of the derivatization reagents was removed by the double extraction with water and 1 M hydrochloric acid. The dichloroethane layer was dried and dissolved in 300 µl of the mixture of ethyl acetate/heptane (1:1 v/v).

Identification of monosaccharides was based on comparing their retention times with retention times of standards of the mass spectral library NIST 02. Quantification was done by using sorbitol added to the sample (Huzio et al., 2020; Budniak et al., 2021b).

Research results and discussion. Carbohydrates are high-energy compounds that serve not only as fuel for vital biological processes but also as structural components in the cell walls of both plants and animals. In animal organisms, they are essential for immune function, contribute to disease mechanisms, and participate in blood coagulation processes. Polysaccharides, in particular, exhibit a range of biological activities, including absorbent, expectorant, anti-ulcer, anti-inflammatory, and detoxifying effects (Sun et al., 2020).

This study identified and quantified nine carbohydrate compounds using gas chromatography-mass spectrometry (GC/MS), as detailed in table 1. The chromatographic profiles illustrating the carbohydrate content in various *Mahonia aquifolium* plant parts are presented in fig. 1–8. The results of the qualitative composition study and quantitative content determination of carbohydrates of the raw materials are shown in table 1.

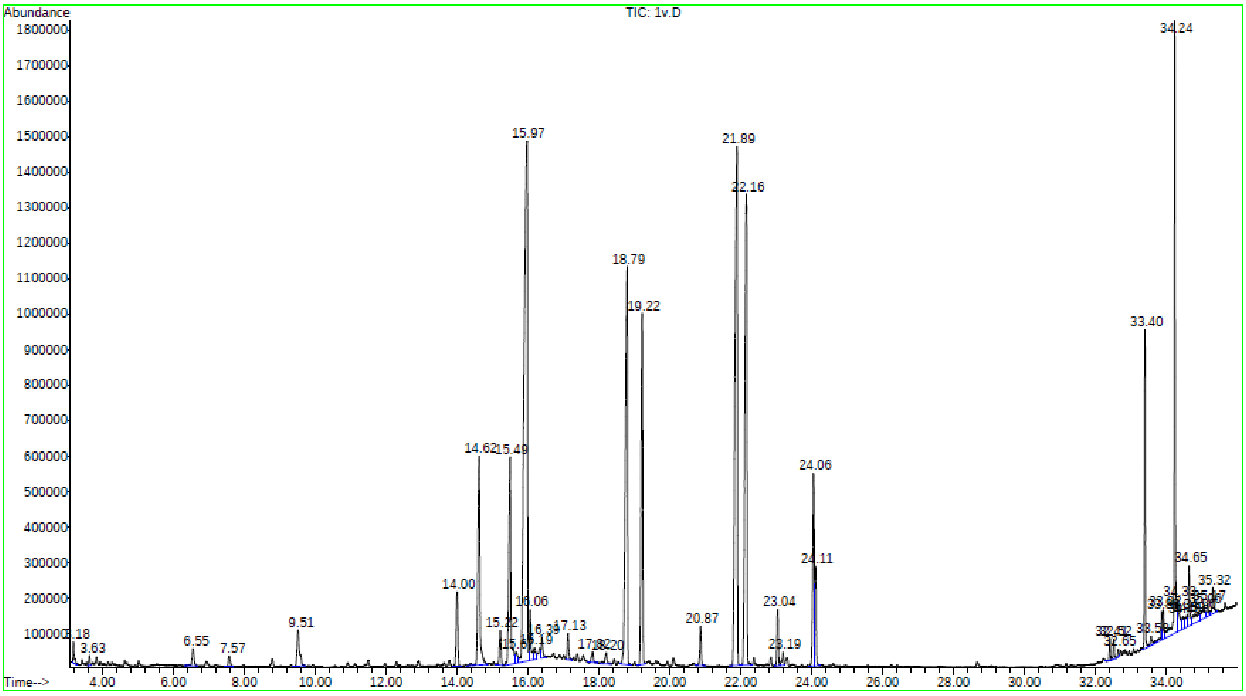

Fig. 1. GC/MS chromatogram of free carbohydrate of *Mahonia aquifolium* leaves

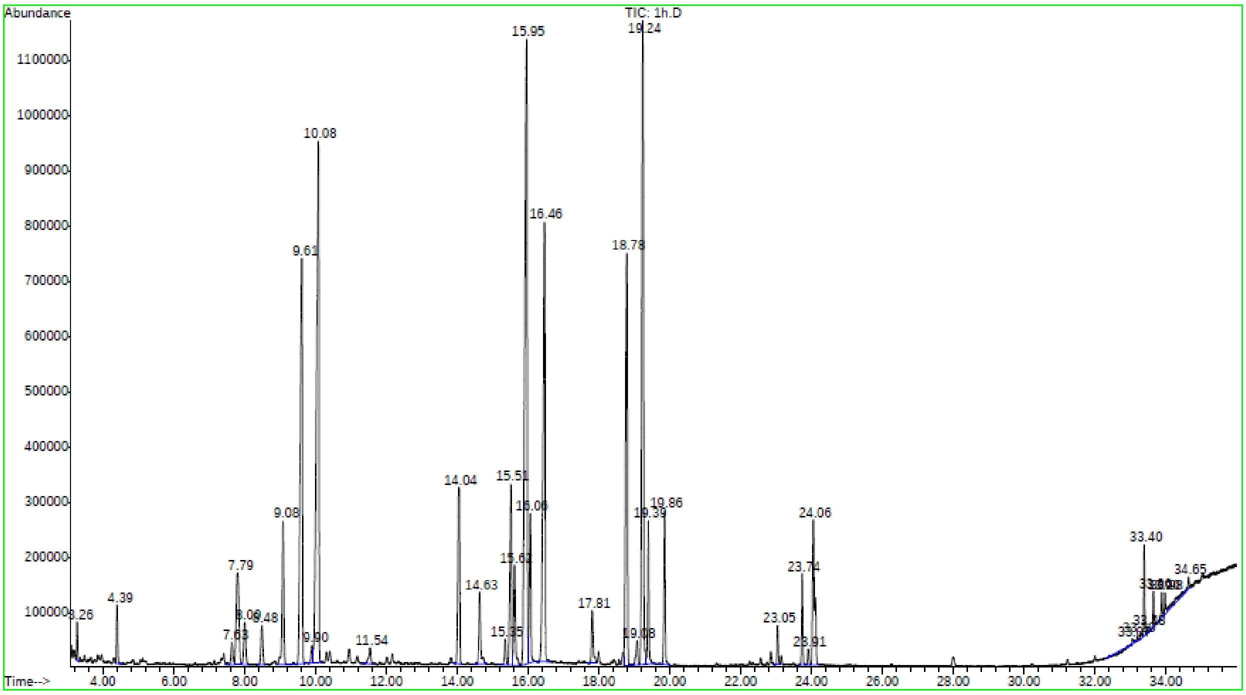

Fig. 2. GC/MS chromatogram of monosaccharides and their derivatives after hydrolysis of *Mahonia aquifolium* leaves

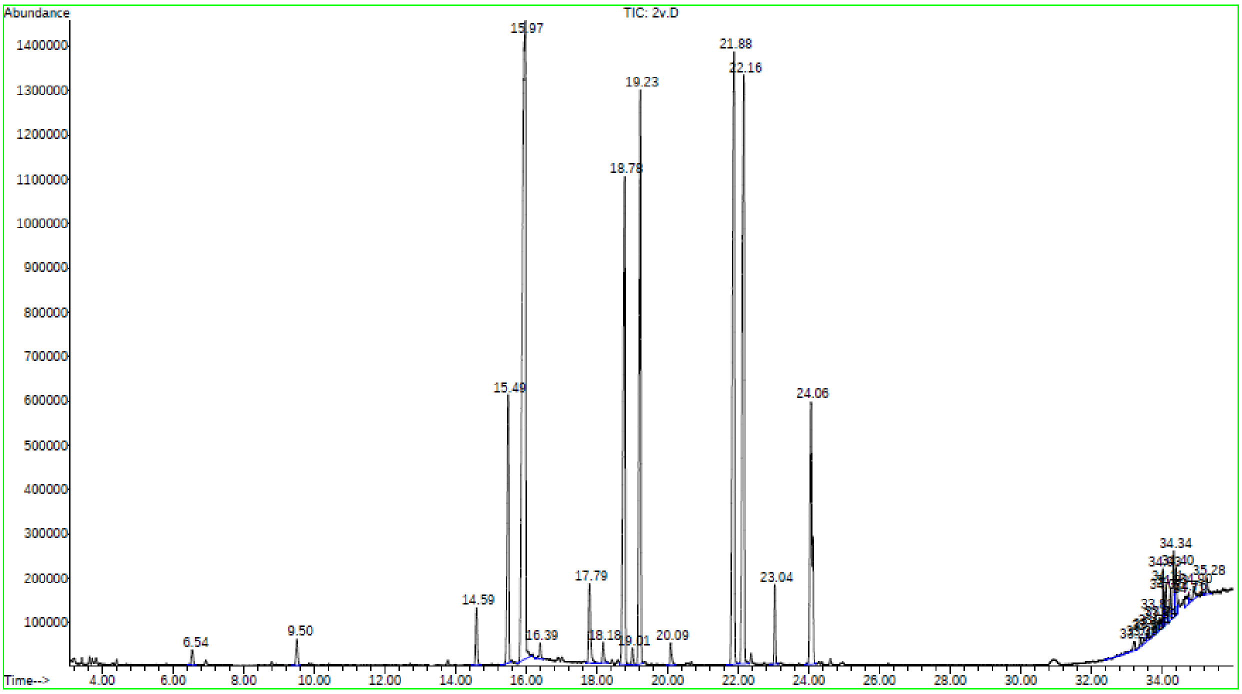

Fig. 3. GC/MS chromatogram of free carbohydrate of *Mahonia aquifolium* roots

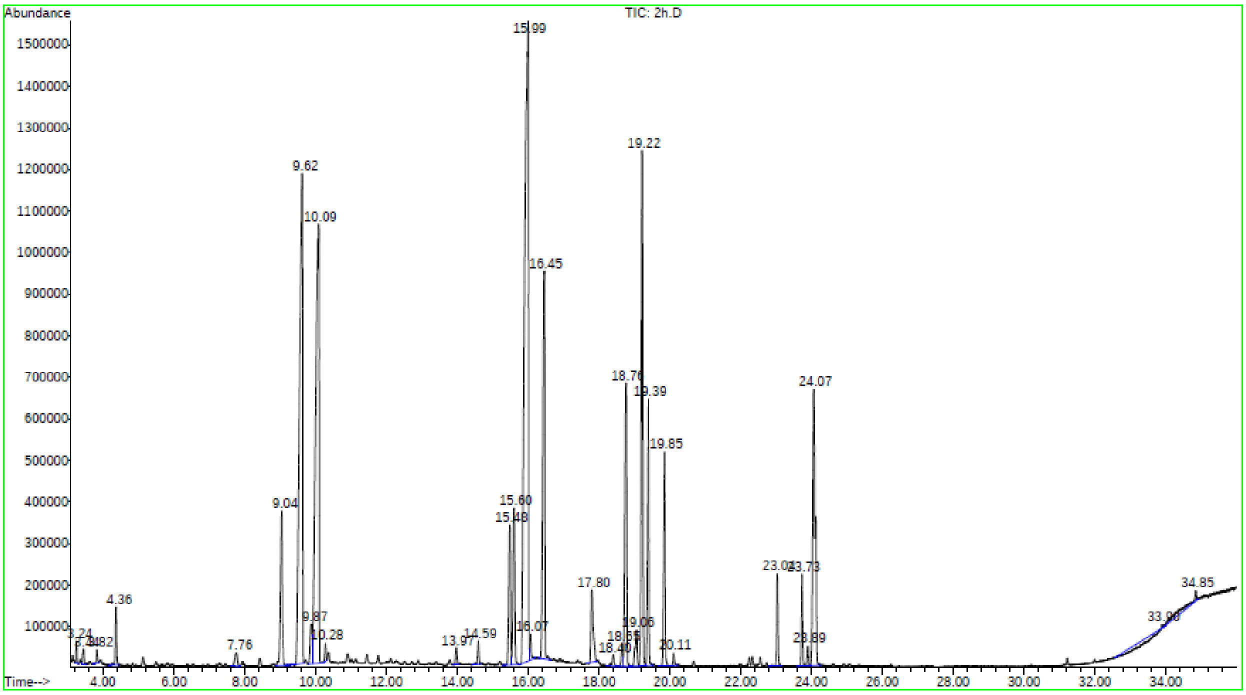

Fig. 4. GC/MS chromatogram of monosaccharides and their derivatives after hydrolysis of *Mahonia aquifolium* roots

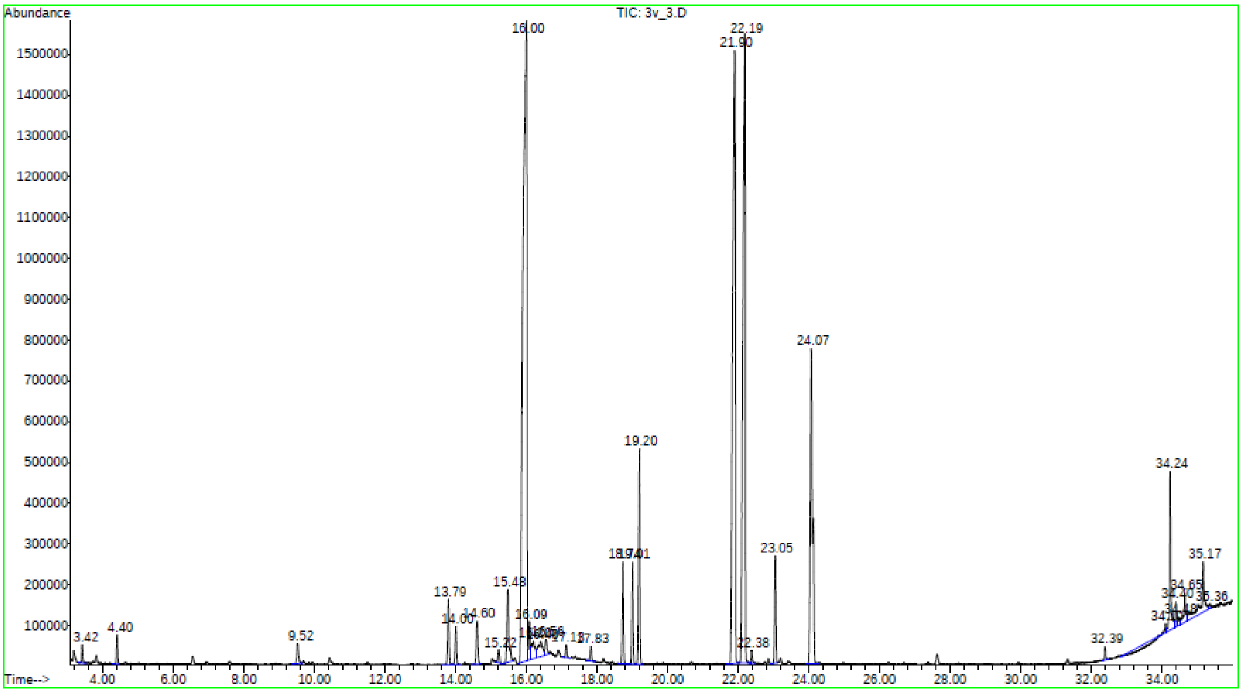

Fig. 5. GC/MS chromatogram of free carbohydrate of *Mahonia aquifolium* fruits

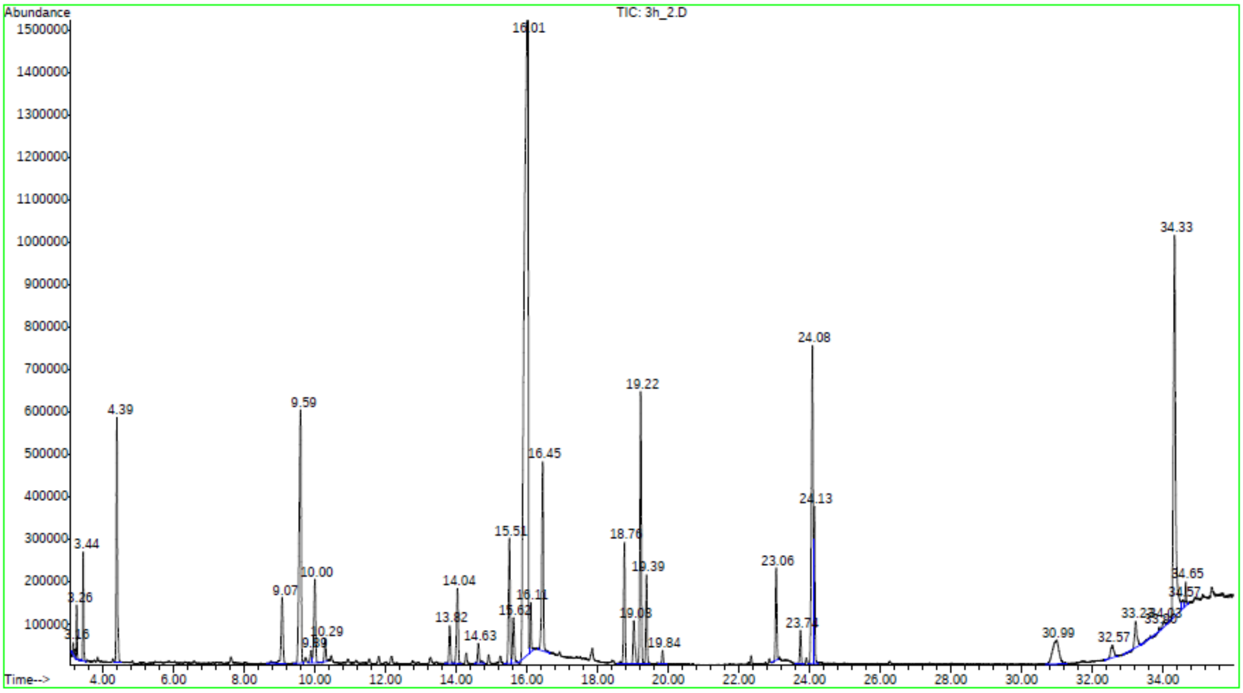

Fig. 6. GC/MS chromatogram of monosaccharides and their derivatives after hydrolysis of *Mahonia aquifolium* fruits

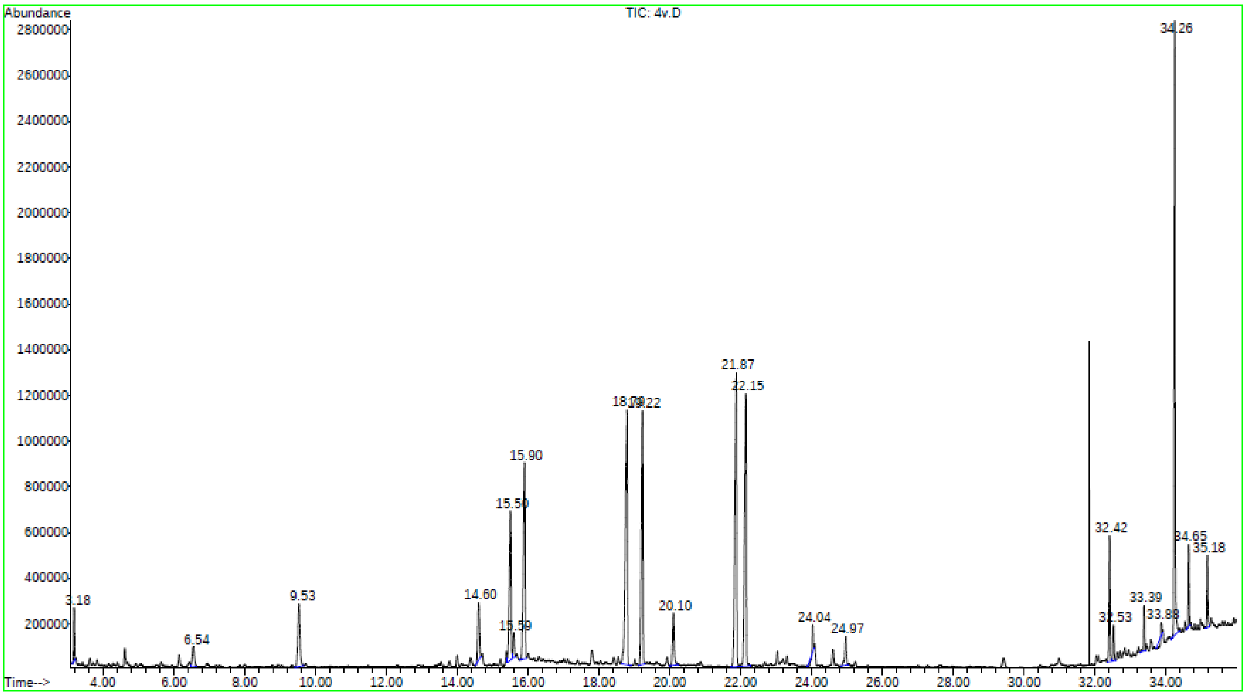

Fig. 7. GC/MS chromatogram of free carbohydrate of *Mahonia aquifolium* flowers

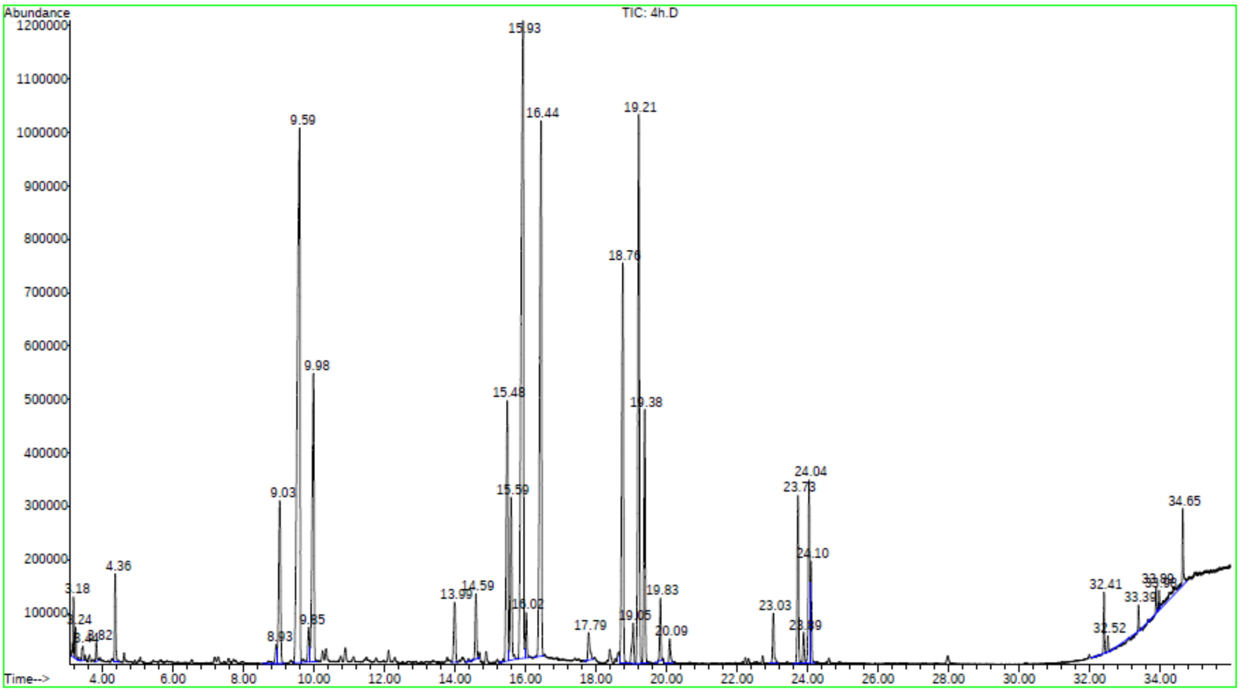

Fig. 8. GC/MS chromatogram of monosaccharides and their derivatives after hydrolysis of *Mahonia aquifolium* flowers

As shown in table 1, D-glucose was found in the highest concentration among all carbohydrates across the different parts of *Mahonia aquifolium*. Glucose serves as a primary energy source for a wide range of living organisms, from microorganisms to humans. The human brain alone consumes approximately 75% of the body's daily glucose supply (Khowala et al., 2008). Additionally, neurons and developing red blood cells have substantial energy requirements. A decrease in glucose levels can impair cognitive processes and reduce mental performance (Mergenthaler et al., 2013).

Following hydrolysis, L-fucose was identified as the dominant monosaccharide derivative in all examined parts of the plant, with concentrations of 11,96 mg/g in fruits, 18,41 mg/g in flowers, 10,07 mg/g in leaves, and 17,46 mg/g in roots, as presented in table 1. L-Fucose is an uncommon sugar found across a wide range of organisms, from bacteria to humans (Kim et al., 2019). Owing to its diverse biological activities, L-fucose holds promise for applications in anti-inflammatory, anticancer, and immunomodulatory therapies. It is also considered a valuable ingredient in cosmetics for its skin-whitening, moisturizing, and anti-aging effects, as well as in dietary supplements (Robert et al., 2005; Peterszegi et al., 2003).

After hydrolysis, D-xylose emerged as the predominant monosaccharide in all analyzed parts of *Mahonia aquifolium*, with concentrations of 3,25 mg/g in the fruits, 6,98 mg/g in the flowers, 14,62 mg/g in the leaves, and 17,87 mg/g in the roots (Table 1). Commonly known as wood sugar, xylose is recognized for its antifungal and antibacterial properties, showing notable activity against *Candida* species and various gram-negative bacteria. This aldopentose is typically found in the embryos of many edible plants (Yoon et al., 2003). It is important to highlight that D-xylose was absent from the free carbohydrate fraction across all plant organs studied.

Additionally, D-fructose was the major sugar detected in the fruits of *Mahonia aquifolium*, with its content reaching 12,52 mg/g among the free carbohydrates and 7,46 mg/g in the monosaccharide fraction following hydrolysis.

The results of the study suggest that *Mahonia aquifolium* holds significant potential, largely owing to the vital functions carbohydrates perform in numerous physiological processes.

Conclusions. In summary, GC/MS analysis indicated the presence of nine carbohydrate compounds in *Mahonia aquifolium*, detected in both free and bound forms. These compounds are known for their notable pharmacological properties, aligning with existing data on the plant's therapeutic potential. D-glucose was found in the highest concentration among all carbohydrates across the different parts of *Mahonia aquifolium*. Among monosaccharides, after hydrolysis, L-fucose and D-xylose were the predominant monosaccharide compounds in the analyzed raw material. Based on these findings, carbohydrates extracted from *Mahonia aquifolium* show promise for use in pharmaceutical formulations and the development of nutraceutical products.

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