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Comparative Analysis of Fatty Acid Composition: *Urtica dioica* and *Lamium purpureum*

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Abstract

Fatty acids are essential components of plant lipids, playing a key role in growth and development. In medicinal plants, their importance extends beyond structural functions, contributing to biological activity, nutritional properties, and potential health benefits. Their composition is not fixed, varying according to plant organ, developmental stage, environmental conditions, and extraction methods.

The aim of this study was to comparatively examine the fatty acid composition of Urtica dioica and Lamium purpureum based on data reported in the scientific literature. Particular attention was given to identifying the main saturated and unsaturated fatty acids and to highlighting differences in their relative proportions. The analysis indicates that Urtica dioica is richer in polyunsaturated fatty acids, particularly linoleic and α-linolenic acids, while Lamium purpureum shows relatively higher levels of saturated fatty acids. These differences likely reflect species-specific metabolic characteristics as well as variations in study conditions.

Keywords: *phytochemistry, lipid profile, bioactive compounds, chemical variability, plant metabolism*

1. Introduction

Fatty acids are the basic building blocks of plant lipids which play an essential role in the structure and function of cells [1]. They take part in membrane organization, storage of energy, and other various physiological processes [2]. One of the most important features of fatty acids is the degree of their saturation which affects the way plants respond to environmental stress such as temperature or water availability [3].

Fatty acids derived from plants are the main source of interest for nutrition because of their possible health benefits. Polyunsaturated fatty acids, for example, linoleic and α-linolenic acids are essential for human nutrition while other compounds derived from lipids may have certain biological activities [4]. In plants, the oxidized derivatives of these fatty acids, called oxylipins, are the main players in the defense mechanisms and the signaling process, especially under stress conditions [1, 5].

The composition (qualitative and quantitative) of fatty acids is not the same all the time, it can vary with different factors such as species, plant organ, developmental stage, and environmental conditions [3]. Besides this, the reported profiles can be greatly

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affected by the extraction and analytical methods, therefore, comparative studies are required in order to gain a deeper knowledge of plant lipid composition [6].

Urtica dioica L. (stinging nettle) is one of the most widely studied medicinal plants, which have been traditionally used as food as well as in phytotherapy. Its phytochemical composition is very complex, and it mainly consists of polyphenols, flavonoids, lignans, and lipid-derived compounds [7].

Although it has been thoroughly studied, its chemical composition is not yet fully understood because analytical methods keep finding new metabolites [8].

Research into nettle leaves metabolome has revealed that hydroxycinnamic acid derivatives and flavonoids are the main constituents. Along with these, lipid-derived compounds such as oxylipins are present [7]. Oxylipins are generated via the oxidation of polyunsaturated fatty acids, and they play an important role in plant defense as they are involved in reaction to biotic and abiotic stress factors [9].

The fatty acid composition of *Urtica dioica* (UD) is mainly dominated by unsaturated fatty acids, especially α-linolenic and linoleic acids, together with smaller amounts of saturated fatty acids such as palmitic acid [10,11]. However, the concentration of these compounds can differ depending on environmental factors and the analytical methods used, highlighting the adaptability and complexity of plant metabolic processes [12].

Compared to UD, *Lamium purpureum* (LP), despite growing under similar ecological conditions, has received considerably less scientific attention, particularly regarding its lipid composition and fatty acid profile [4].

Available studies indicate the presence of common fatty acids such as palmitic, oleic, linoleic, and α-linolenic acids, but also the occurrence of specific compounds, including lamenallenic acid, which may reflect distinct metabolic pathways within the Lamiaceae family [3].

LP, besides these points, has become a focus of study for its phytochemical variety as well as its potential biological properties. Uncommon fatty acids in the species, especially allene derivatives, point to distinctive metabolic traits and might possibly be a factor in the chemical uniqueness of this species. Changes in the fatty acid profile have been observed in response to environmental factors and the type of plant materials analyzed, thereby, reinforcing the necessity of comparative investigations [3, 4]. Since both species share some phytochemical features, differences in their fatty acid profiles indicate that their lipid metabolism may be quite different, which in turn could affect both their chemical composition and their biological properties. Such diversity of factors points out the need for comparative methods to uncover their nutritional and pharmacological values more accurately.

The aim of this study was to comparatively evaluate the fatty acid composition of UD and LP based on available literature data, focusing on identifying the main fatty acids and highlighting differences in their relative abundance.

2. Materials and method

This study is based on comparative analysis of fatty acid composition of UD and LP. In order to gather relevant information, we searched articles available in various scientific databases, such as Google Scholar, ScienceDirect and PubMed.

Studies were selected based on relevance to the theme. The studies included in the analysis provided qualitative and/or quantitative data regarding the fatty acid composition. Data analysis was conducted using the PAST software, version 3.2.

3. Results and Discussion

While much focus has been placed on the fatty acid content of UD, particularly the polyunsaturated varieties, the lipid content of the plant is more complex and comprises other species of compounds including sterols and terpenoid-type molecules [13].

Several bioactive substances have been reported to be present in UD, which are possibly responsible for several biological activities. These bioactive compounds are known to cause inflammation, increase microbial growth, increase oxidation, and also have cardiovascular benefits. Consistent with this, the lipid fraction of UD has wider roles than just being a component of plant metabolic pathways and could have potential applications [14].

The fatty acid composition of UD is marked by the dominance of unsaturated fatty acids, mainly linoleic and α-linolenic acids, which are essential components of the human diet. These fatty acids are present in such quantities that they heavily influence the nutritional value of the plant. However, it has also been noted that fatty acid content varies in different parts of the plant. Roots, for example, are usually richer in unsaturated fatty acids, whereas

aerial parts tend to have a relatively higher share of saturated fatty acids [12].The principal fatty acids of UD and LP, as reported in the literature, are presented in Table 1.

Table 1. Comparative fatty acid composition of *Urtica dioica* and *Lamium purpureum* in different plant organs

Fatty acid	UD Roots (% DW)	UD Stems (% DW)	UD Leaves (% total FA)	UD seeds oil (% total FA)	LP Leaves (% total FA)	LP Flowers (% total FA)	LP seeds oil (% total FA)
Caproic (C6:0)	0.082 [12]	–	–		–	–	
Caprylic (C8:0)	0.096 [12]	–	–		0.28 [3]	0.19 [3]	
Capric (C10:0)	0.213 [20]	–	–		0.57 [3]	0.95 [3]	
Lauric (C12:0)	0.296 [12]	–	–		2.93 [3]	2.26 [3]	
Myristic (C14:0)	0.061 [12]	–	–		4.04 [3]	4.15 [3]	
Palmitic (C16:0)	–	23.6 [13]	20.1 [13]; 17.9 [15]; 20.2 [16]; 18.57 [17]	12.52 [13]	24.46 [3]	21.72 [3]	11 [18]
Palmitoleic (C16:1)	–	0.5 [13]	3.9 [13]; 3 [15]; 1 [16]; 0.24 [17]		2.40 [3]	3.57 [3]	
Stearic (C18:0)	4.166 [12]	1.8 [13]	1.9 [13]; 1.6 [15]; 3.3 [16]; 8.72 [17]	7.52 [13]	11.70 [3]	7.91 [3]	2 [18]
Oleic (C18:1)	16.615 [12]	2.1 [13]	2.8 [13]; 1.7 [15]; 3.2 [16]; 13.16 [17]	34.93 [13]	11.57 [3]	24.35 [3]	25 [18]
Linoleic (C18:2)	22.203 [12]	33.8 [13]	18.1 [13]; 11.6 [15]; 18.6 [16]; 3 [17]	44.29 [13]	14.75 [3]	15.27 [3]	34 [18]
α-Linolenic (C18:3)	–	12.2 [13]	29.6 [13]; 40.7 [15]; 22.6 [16]; 1.02 [17]		25.21 [3]	15.87 [3]	28 [18]
Arachidic (C20:0)	0.256 [12]	–	1.034 [12]; 6.9 [15]; 6.9 [16]; 5.26 [17]		2.10 [3]	3.76 [3]	
Lamenallenic acid (C18:3, allenic)							16 [18]

Table 1 illustrates the variation in the fatty acid composition of different plant organs of UD. The data clearly indicate dominance of unsaturated fatty acids, whereas considerable differences between various studies exist primarily due to environmental and experimental variations. The presence of individual saturated fatty acids, such as palmitic and stearic acids, suggest a complex biochemical basis of its seed oil.

In LP, α-linolenic acid was the major fatty acid in the leaves and oleic acid in the flowers. However, the data for LP are very limited as they are only based on one study [3].

A more detailed composition of fatty acids from

nettle seed oil were studied using GC–MS. Linoleic acid, followed by oleic acid and other long-chain fatty acids, appeared to be the most abundant fraction and comprised approximately 30–40% of fatty acids with C18 fatty acids dominating the composition. Such a fatty acid composition confers nutritional value to nettle oil as an essential source of fatty acids for human consumption.

The fatty acid profile of UD can be influenced by several factors including environmental, plant, and analytical sources of variation. Variations in temperature and light as well as soil and harvest time are shown to influence the proportions of the most abundant fatty acids in UD, explaining some of the variation reported in the scientific literature [12].

Saturated and unsaturated fatty acids have been found in a number of marine organisms, in some cases unsaturated species exceeding fifty percent of the total lipid content and in nearly all cases unsaturated species exceed the content of their saturated counterparts (including 16:1 ω9 being the most abundant unsaturated fatty acid at 16%). Chromatographic analyses have aided in this determination [19]. Essential fatty acids, including linoleic acid (ω-6) and α-linolenic acid (ω-3), are crucial for maintaining membrane integrity, regulating lipid metabolism, and supporting normal cellular activity. They have also been linked to several positive physiological effects, such as enhanced vascular health and improved immune system function [20].

Compared with other species, LP has been investigated to a much lesser extent. Current studies suggest that its lipid profile contains both saturated and unsaturated fatty acids, predominantly C16 and C18 types, including palmitic, oleic, linoleic, and α-linolenic acids [3]. In addition, LP is notable for containing rare fatty acids, particularly allenic fatty acids such as lamenallenic acid, which are uncommon in plant lipids and could be linked to unique metabolic processes [4].

Figure 1 exhibited the hierarchical clustering of the major fatty acids according to their similarity of composition. The dendrogram reveals the existence of very different groupings, with some fatty acids, like oleic and linoleic acids, being so closely grouped that point to similarity of their distribution. On the other hand, saturated fatty acids such as palmitic acid that came first in the list of fatty acids are less similar to others, which reflects the difference in their relative abundance. The clustering mostly shows the hidden relationships between fatty acids, and it also reveals the structural organization of the lipid profile.

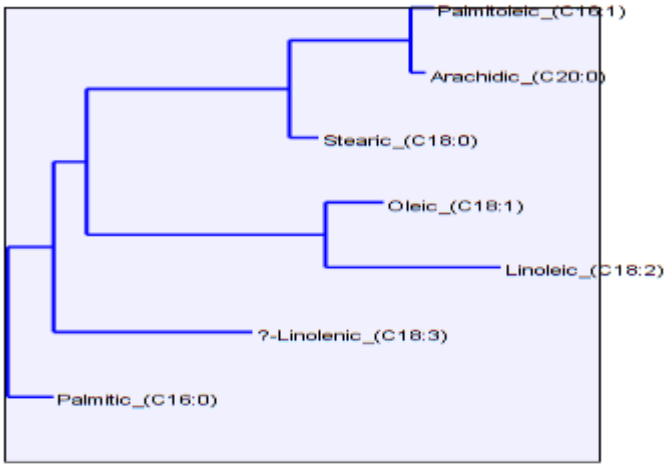

Figure 1. Cluster analysis of major fatty acids revealing similarity patterns
Legend: UDLe=Urtica dioica leaves, UDSO=Urtica dioica seeds oil, LPLe=Lamium purpureum leaves, LPF=Lamium purpureum flowers, LPSO=Lamium purpureum seeds oil

Figure 2 illustrates the spatial distribution and density patterns of fatty acids in roots (UDR) and stems (UDST) of UD. The contour plot indicates areas of densely and sparsely packed data with warmer colors signaling regions of higher density.

Several fatty acids cluster very tightly in the low-value region, indicating similar composition, while others as linoleic and oleic acids, are widely scattered and thus cause total variability. The linking of the points accentuates the fatty acids' relationships even more and unveils the presence of both grouped and separate lipid patterns across plant organs by the gradients in their distribution.

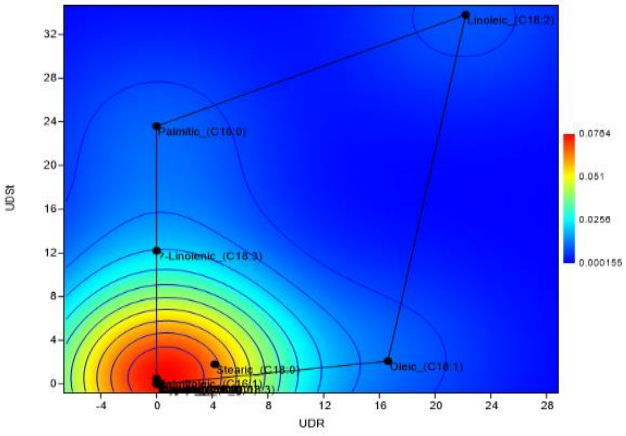

Figure 2. Density distribution and spatial relationships of fatty acids in roots and stems of *Urtica dioica*
Legend:UDR=Urtica dioica root; UDSt=Urtica dioica stem

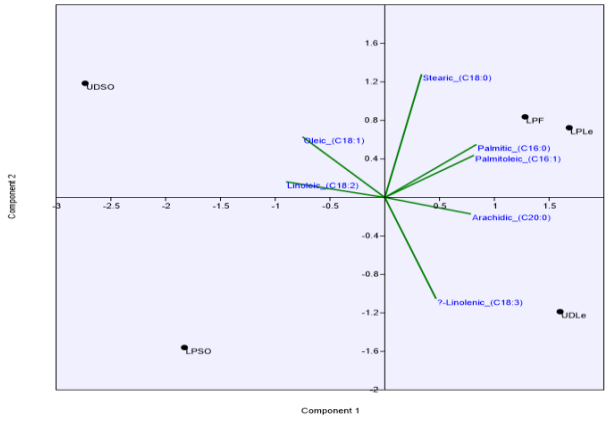

Figure 3. Principal component analysis of fatty acid composition in *Lamium purpureum* and *Urtica dioica Legend: UDLe=Urtica dioica leaves, UDSO=Urtica dioica seeds oil, LPLe=Lamium purpureum leaves, LPF=Lamium purpureum flowers, LPSO=Lamium purpureum seeds oil*

The PCA biplot depicted in Figure 3 shows how fatty acids are related to samples of LP and UD according to the first two principal components. The clear spatial division of the samples from different plant parts shows that they are quite different in terms of these components, with the seed oils (LPSO, UDSO) being especially apart from the leaves and flowers.

Fatty acids such as palmitic, palmitoleic, and stearic acids are closely linked with the aerial parts of LP, linoleic and oleic acids follow somewhat different patterns. On the other hand, α-linolenic acid is pointing toward UD leaves, which indicates a greater presence of this fatty acid in the leaves of this plant. The biplot exposes associations among variables as well as samples' differences, which is characteristic of the lipid profiles of different species and plant organs.

Although the two species contain many of the same predominant fatty acids, their composition differs considerably in terms of concentration. UD is known to have a higher proportion of polyunsaturated fatty acids, particularly α-linolenic acid, whereas LP tends to contain more saturated fatty acids as well as several uncommon lipid components [11,16]. These compositional differences could contribute to variations in nutritional quality and biological activity, underlining the importance of conducting additional studies on underexplored species such as LP.

4. Conclusion

Research on UD and LP showed that both plants contain fatty acids that may be important from a nutritional point of view. Even though some of these compounds are commonly found in many plant species, the two plants do not share the same lipid profile. UD was observed to contain larger amounts of polyunsaturated fatty acids, mainly linoleic and α-linolenic acids, which are often connected with positive health effects and good nutritional quality. LP, however, differed through the presence of less common fatty acids, including lamenallenic acid, giving this species a more particular chemical profile.

The differences identified between UD and LP could also affect the way these plants act biologically and how they might be used in the future. Based on these findings, both species appear to have potential for applications related to nutrition and plant-based remedies. Still, information about LP remains limited, which means further studies are necessary to better understand its composition and possible benefits.

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