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State and Prospects of Essential Oils Production in Ukraine and the World

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Abstract

The study aimed to determine the economic efficiency of production and export potential of essential oil crops in Ukraine. To achieve this goal, a detailed analysis of the cultivation areas of the leading essential oil crops, such as narrow-leaved lavender, lavandin, peppermint, clary sage, hyssop, lemon balm and catnip, was conducted. The analysis examined trends in major markets, including Europe, North America, and Asia, and used this data to evaluate the competitive advantages and disadvantages of Ukrainian essential oil producers compared to those from other countries. The study found that Ukraine possesses significant potential for essential oil crop production, thanks to its favourable agricultural and climatic conditions. However, this potential is currently constrained by several major challenges, including underdeveloped processing infrastructure, a lack of innovative technologies, and reduced logistics efficiency. The study results showed that the greatest potential in Ukraine is in the cultivation of lavender and peppermint, which are important raw materials to produce essential oils. An assessment of the economic efficiency of growing these crops showed that intensification of production, modernisation of technological processes and infrastructure development could significantly improve the productivity and competitiveness of Ukrainian producers. The analysis of global market dynamics, which revealed the need to adapt to global economic trends, changes in demand and the development of innovations in processing technologies, was emphasised. The study concluded that Ukraine needs to expand investment projects, enhance raw material processing technologies, and lower the costs of transporting and storing products. The assessment of export potential identified the most promising areas for Ukrainian producers to enter international markets, in particular the markets of Europe and North America, where demand for natural essential oils continues to grow.

Keywords

Essential oil crops; Technologies; Export opportunities; Global market; Quality standards; Sustainable agriculture; Agroecosystems; Climate change

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Introduction

The production of essential oils has gained significant attention worldwide due to the growing demand for natural products in various industries, including cosmetics, pharmaceuticals, food, and wellness. Ukraine has favourable climatic conditions for growing essential oil crops, but there is a need for a comprehensive analysis of their cultivation areas, production volumes and trends in national and global markets. The absence of a systematic approach to assessing economic efficiency, product competitiveness and export prospects creates the need to explore ways to improve the efficiency of agricultural production, develop processing infrastructure and establish international cooperation. Small producers of essential oil crops in Ukraine face several systemic challenges that hinder their development and limit their ability to integrate into international markets. One of the key barriers is limited access to modern processing technologies. Many small farms do not have the financial capacity to invest in high-tech equipment for distillation or extraction of essential oils, which leads to the production of raw materials of lower quality compared to large producers. Due to the use of outdated or primitive processing methods, a significant portion of the active components of plant material is lost, which directly affects the quality of the final product and its competitiveness in the global market.

Limited financial resources pose another serious problem. Small producers often have limited access to credit programs, investments or government support needed to modernize their production facilities, expand their crop areas or ensure compliance with international quality standards. Lack of adequate financing also makes it difficult for them to participate in international exhibitions, marketing campaigns, and promote their products in export markets. Difficulties in entering international markets are caused by the low awareness of small producers of certification requirements, customs regulations, and the specifics of demand in different countries. Lack of experience in international trade, lack of efficient logistics channels, and complicated certification procedures create additional barriers to entering new markets. Many potential exporters are unable to be certified according to international standards such as ISO 9235, COSMOS-Standard or REACH, which is a prerequisite for access to the EU, US and Asian markets.

An analysis of relevant sources on the research topic revealed that the essential oils market has been studied by many scholars. Hlushchenko and Pryvedeniuk (2023) analysed the prospects for growing medicinal and essential oil crops in Ukraine, emphasising the advantages of cultivating raw materials compared to collecting wild plants. However, the specifics of the use of modern agricultural technologies and the introduction of innovative approaches to the cultivation of essential oil crops remain insufficiently addressed. The lack of a detailed economic analysis of the profitability of these crops compared to traditional field crops also creates certain gaps in the study. Dudchenko and Stetsenko (2023) studied lavender productivity and determined the economic efficiency of its cultivation under different irrigation methods and fertilisation systems. Despite a detailed analysis of the impact of agronomic factors on yields, the study did not account for the possibility of scaling up these approaches within large farms. In addition, the issue of the long-term economic sustainability of this crop in the context of climate change remained outside the scope of the study.

Zabarna (2024) investigated the technical aspects of lavender cultivation in the Right Bank Forest-Steppe. The study highlighted the possibilities of adapting this crop to local soil and climatic conditions and discussed the practical aspects of cultivation. However, the study did not address the prospects for the use of products on international markets, which is relevant for the integration of Ukrainian producers into global market chains. The study by Bozza *et al.* (2022) analysed regulatory and market aspects of certification in the natural cosmetics industry. The study emphasised the importance of certification standards such as COSMOS and ISO 16128, but did not address the specifics of growing raw materials for such products in different regions of the world. In addition, the role of small farmers in providing certified products was not considered. Shuba and Bazhai-Zhezherun (2021) analysed the chemical composition of essential oils and their pharmacological applications. However, the economic feasibility of producing these products, including the analysis of the costs of growing raw materials and their further processing, is under-studied.Liu (2022) investigated the use of natural products in the cosmetics industry, focusing on their popularity among consumers. The study addressed the potential benefits of using natural ingredients but did not cover the specifics of growing crops to produce essential oils, which are the basis of these products.

Vitrovchak (2024) optimised the technological elements of growing sowing nigella (Nigella sativa) in the Western Forest-Steppe. However, the issue of integrating this crop into the essential oils market was not analysed, which limits the practical application of the results obtained for the development of the industry. Cvejić *et al.* (2022) analysed innovative approaches to breeding climate-resistant crops. Despite the significant emphasis on the genetic aspects of plant adaptation to abiotic stresses, the study did not address the practical implementation of these innovations in the production of essential oil crops. Vijulie *et al.* (2022) highlighted the prospects for the development of small lavender farms in Romania, emphasising socio-economic aspects and challenges such as the lack of a specialised market and labour shortages. At the same time, the study did not conduct a detailed economic analysis of the profitability of cultivation, did not consider Romania's integration into the international lavender market, and did not address the introduction of innovative agricultural technologies. Tkachova and Fedorchuk (2021) studied in detail the allopathic activity of medicinal hyssop (Hyssopus officinalis L.) and its effect on the growth of watercress (*Lepidium sativum* L.) roots. The dependence of the nature of the effect of aqueous extracts of various organs of hyssop and soil in the rhizosphere zone on the age of plants and the concentration of extracts was found. The highest stimulatory effect was observed in plants of the second year of vegetation, while the extracts of the third year had an inhibitory effect.

The present study addresses existing research gaps by providing a comprehensive analysis of the cultivation, economic efficiency, and export potential of essential oil crops in Ukraine. Unlike previous fragmented approaches, this study focuses on the scalability of essential oil crop production, particularly lavender, peppermint, lemon balm, and hyssop, under varying soil and climatic conditions. Special attention is given to assessing the long-term sustainability of production in the context of climate change, considering innovative irrigation methods, fertilisation systems, and precision farming technologies. Furthermore, the study systematically examines the challenges small producers face in accessing international markets, including certification barriers, logistical constraints, and integration into global trade networks. By combining

agrotechnical, economic, and regulatory perspectives, the research offers a holistic framework for improving the competitiveness and resilience of Ukraine's essential oil sector. Despite the importance of the results obtained, the paper did not address the possibility of practical application of the research for the cultivation of hyssop as an essential oil crop. The aspects of economic efficiency of hyssop cultivation under different conditions, the influence of allopathic properties on crop rotation and intercultural cultivation, as well as the potential of using plants of different ages for industrial production of essential oils, remain unclear.

The study aimed to identify effective approaches to growing essential oil crops in Ukraine, accounting for agrotechnical, economic and market aspects that contribute to their competitiveness in the international market. To achieve the stated goal, the following were conducted: an analysis of agrotechnical approaches to the cultivation of major essential oil crops, such as narrow-leaved lavender (*Lavandula angustifolia* Mill.), lavandin (*Lavandula hybrida* Rev.), medicinal hyssop (*Hyssopus officinalis* L.), peppermint (*Mentha x piperita* L.), lemon balm (*Melissa officinalis* L.), clary sage (*Salvia sclarea* L.), under conditions of different soil and climatic regions of Ukraine; an assessment of the economic efficiency of essential oil crops production, including the impact of innovative agricultural technologies, irrigation methods, fertilisation systems and adaptation to climate change on production profitability. Moreover, the study explored modern logistics approaches, certification requirements and market conditions that affect the integration of Ukrainian producers of essential oil products into international market chains.

Materials and Methods

Data Collection

The study was comprehensive in nature and covered the analysis of economic, agricultural, technical and market aspects of essential oil production. The study covered the period from 2014 to 2024, which tracked changes in production processes and market trends. The analysis was based on the integration of statistical, scientific and market data to obtain a complete picture of the industry development.

The data was collected based on the analysis of official statistics, scientific sources and international databases. Information on the areas under essential oil crops and their production volumes was obtained from official statistics, in particular, the Food and Agriculture Organisation of the United Nations (2025) and the State Statistics Service of Ukraine (2025). Scientific research conducted at Mykolaiv National Agrarian University provided a detailed analysis of the agrotechnical and economic aspects of growing essential oil crops. Data on market price dynamics, international trade volumes, and key exporters and importers were collected from the UN Comtrade Database (2025), Trade Map (International Trade Centre, 2025), and Eurostat (2025). These sources provided information on the average value of products, export and import volumes, and the geographical distribution of markets. The integration of different types of data was used to assess the current state of the market and its changes during the study period.

Data Analysis

Ukraine is one of the largest agricultural producers in Europe, known for its diverse agro-climatic zones and fertile soils, which provide favourable conditions for a wide range of crops, including essential oil plants. The country's agricultural landscape is characterised by several distinct natural zones, the most significant of which for essential oil cultivation is the Southern Steppe. This region is marked by chernozem (black earth) soils, renowned for their high fertility and excellent moisture retention properties. The Southern Steppe experiences a continental climate, with hot, dry summers and mild to moderately cold winters, creating ideal conditions for drought-tolerant crops such as narrow-leaved lavender, lavandin, and hyssop. Annual precipitation in this region ranges from 300 to 450 millimetres, and temperatures during the growing season often exceed 25°C, providing optimal conditions for the accumulation of essential oils in plants. These regional characteristics, combined with relatively long periods of sunshine and low humidity, offer significant competitive advantages for the development of the essential oil industry in Ukraine, particularly in the face of increasing global demand for natural and organic products.

Economic and statistical analysis, methods of comparative analysis, logical generalisation, geographical and market analysis, as well as an expert approach, were used in the study. These methods aimed to address specific tasks related to the assessment of the state and prospects of the essential oils market in Ukraine and the world. The economic and statistical analysis was used to assess the dynamics of changes in the areas under essential oil crops, their production volumes, and market prices during the study period. This method revealed the impact of climatic and economic factors on the yield and quality of essential oil products. The regression analysis determined the relationship between climatic conditions (temperature, precipitation) and the productivity of major crops such as lavender, mint and sage.

Benchmarking methods were used to compare production, exports, and competitive advantages between Ukraine and other leading essential oil-producing countries, such as France, India, China, and Bulgaria (Food and Agriculture Organisation of the United Nations, 2025; UN Comtrade Database, 2025; International Trade Centre, 2025). This approach identified key disadvantages of Ukrainian producers compared to international competitors, including limitations in processing technologies and infrastructure. The logical generalisation was used to conclude the main trends in market development, as well as the preparation of recommendations to improve the competitiveness of products. The expert method was used to refine forecasts and development strategies based on the opinions of industry experts.

The regression models constructed in this study included climatic variables such as average monthly temperature and total monthly precipitation, which were selected as key predictors of essential oil crop productivity. Temperature values were analysed within a range of 10°C to 35°C, reflecting the critical thresholds for the growth and biochemical development of lavender, mint, sage, and other major crops. Precipitation was considered within the range of 20 mm to 150 mm per month, corresponding to the minimal and optimal water supply conditions necessary for maintaining plant growth and oil concentration. These ranges were determined based on agronomic studies and

experimental data collected from field research in the Southern Steppe and Forest-Steppe zones of Ukraine. The choice of these climatic variables was guided by their direct biological influence on plant physiology, yield parameters, and the chemical composition of essential oils, ensuring that the models captured the most significant environmental determinants of productivity. The explicit definition of these thresholds enhances the reproducibility of the study by allowing future researchers to replicate the models under comparable agroclimatic conditions and verify the robustness of the results across different temporal and spatial settings.

The interpretation of the results was based on a systematic analysis that involved an objective assessment of economic, agronomic and market indicators. For this purpose, the results of the study were correlated with the data of the leading essential oil-producing countries, such as France, Bulgaria, India and China. Comparison with these countries was used to assess Ukraine's competitiveness in the international market, identify strengths and weaknesses, and determine the prospects for the industry's development in the context of global trends, such as the growing demand for natural and organic products.

The analysis of the relationship between market trends, climate change and technological innovations in the production of essential oils was a substantial part of the study. An assessment of the impact of these factors on the productivity and quality of essential oil crops, as well as the economic efficiency of their cultivation and processing, was conducted as a substantial part of the study. The results of the analysis were used in the study to forecast possible changes in market dynamics, identify key challenges and develop practical recommendations to overcome barriers to the production and export of Ukrainian essential oils. The results of the analysis determined the dynamics of the essential oils market, which identified the key factors that affect the competitiveness of Ukrainian producers.

Results

Global economic and environmental trends are driving the development of the essential oils market, affecting supply, demand and technological aspects of production. The growing popularity of natural and organic products has contributed to the increase in the use of essential oils in the cosmetics, food and pharmaceutical industries. This is due to increased consumer awareness of the benefits of natural ingredients. Economic factors, such as rising raw material costs and energy and transportation costs, influenced pricing, forcing producers to seek ways to optimise costs and improve production efficiency. Environmental challenges, including climate change, soil degradation and declining biodiversity, negatively impacted the cultivation of plants such as lavender, mint, rose, chamomile and other essential oil crops. Resource constraints, such as water and suitable land, caused a decline in the production of some oils, including those made from rare plant species. Growing demand in Asia, as well as steady interest in Europe and North America, encouraged producers to expand their product range. Emphasis was devoted to the production of organically certified products that met the environmental requirements of consumers.

In addition to widespread essential oil crops such as lavender, mint, and sage, climate change is having a significant impact on other important species, including lemon balm (*Melissa officinalis*), hyssop (*Hyssopus officinalis*), and catnip (*Nepeta cataria*). These crops have specific environmental requirements that make them particularly vulnerable to temperature fluctuations, precipitation instability, and extreme weather events. Lemon balm, for example, requires moderately moist soil and a sufficient water supply throughout the growing season. Frequent droughts caused by rising average annual temperatures and reduced precipitation in the summer months lead to a significant decrease in its biomass and essential oil concentration.

Hyssop demonstrates a certain resistance to short-term droughts, but under conditions of prolonged moisture deficit, a decrease in the amount of biologically active compounds is observed, which impairs the pharmacological value of the oil obtained. In addition, unstable weather conditions, such as sharp temperature changes in spring, can damage the generative organs of plants and reduce yields. Catnip is more adaptable to different climatic conditions, but its productivity and oil quality drop sharply during prolonged periods of high temperatures without proper irrigation. In the long run, the sustainability of essential oil crop production will depend on the ability of farmers to adapt agricultural technologies to climate change. In particular, the use of drip irrigation, the selection of more drought-resistant varieties and the optimisation of sowing dates can partially offset the negative effects of global warming. It is also important to introduce agrotechnical measures to improve the water-holding capacity of soils, including mulching and growing cover crops in the off-season.

Another promising strategy is the use of selectively bred varieties of essential oil crops that are characterised by a shorter growing season or increased tolerance to stressful conditions. Studies show that investments in genetic improvement of crops such as narrow-leaved lavender or lemon balm help maintain the stable quality of essential oils even in the face of increasing climate change. At the same time, the development of adaptive land use models that involve the relocation of certain crops to new agroclimatic zones can be a key to long-term sustainability. Climate change and agricultural technologies are central in shaping the productivity and quality of essential oil crops. Temperature changes, frequency of droughts, uneven precipitation and other climatic factors significantly affected the growing season of plants and their chemical composition. Table 1 demonstrates the main aspects of the impact of climatic factors and agricultural technologies on the yield and quality of essential oil crops.

Table 1 comprehensively illustrates how various climatic factors and agricultural technologies influence both the productivity and material quality of essential oil crops. The increase in temperature, one of the dominant manifestations of climate change, leads to a shorter growing season and lower yields, while simultaneously reducing the concentration of key active ingredients in the essential oils. Uneven distribution of precipitation exacerbates moisture deficits during critical growth stages, resulting in yield reductions and deterioration in the chemical quality of essential oils. Droughts further intensify these effects, often causing plant mortality and a substantial decrease in the concentration of biologically active substances critical for oil quality and efficacy. Extreme weather events, such as hailstorms or unexpected frosts, physically damage

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crops and elevate the risk of disease, contributing to inconsistencies in essential oil composition and overall product instability.

Table 1: The impact of climate change and agricultural technologies on the productivity and quality of essential oil crops

Factor	*Impact on productivity*	*Effect on material quality*
Increase in temperature	Shorter growing season, lower yields	Reduced concentration of key ingredients
Uneven distribution of precipitation	Reduced yields due to moisture deficit	Deterioration in the quality of essential oils
Droughts	Plant death, reduced yields	Reducing the concentration of biologically active substances
Extreme weather events	Physical damage to plants, increased risk of disease	Unstable quality of oils
Soil erosion and depletion	Decreased fertility, reduced areas suitable for cultivation	Deterioration in the quality of raw materials
Precision farming	Increase productivity by optimising resources	Maintaining consistent quality
Organic farming	Increased production costs	Increasing the added value of products
Innovative drying and processing methods	Reduced processing losses	Maintaining a stable concentration of essential ingredients
Changes in climatic growing zones	Expansion of premises in new regions	Adapting to new conditions

Source: Agrimonti *et al.* (2020)

Soil erosion and nutrient depletion, driven by both climate factors and unsustainable agricultural practices, significantly diminish soil fertility, reduce the arable land area, and negatively affect the quality of raw plant materials used for oil extraction. Against this background, technological advancements in agriculture offer critical mitigation strategies. Precision farming practices, by optimising resource use and monitoring crop conditions in real-time, help stabilise productivity and ensure a more consistent quality of essential oils. Organic farming, although associated with increased production costs, raises the added value of essential oil products through enhanced ecological certification and market positioning. The application of innovative drying and processing methods effectively reduces post-harvest losses and preserves the stable concentration of essential ingredients, thus safeguarding the quality of oils even under challenging climatic conditions.

Ukrainian producers of essential oils have several advantages that ensure their competitiveness in the global market. The main factor is the availability of fertile soils and favourable climatic conditions for growing essential oil crops such as lavender, mint, sage, lemon balm, thyme, hyssop, lavandin and catnip. This allowed for high yields to be achieved without significant additional costs for fertilization and irrigation (Parvin *et al.,* 2023).

One of the key challenges for Ukrainian essential oil producers is the limited access to modern distillation and extraction technologies, which makes it difficult to produce high-value-added products. Insufficient innovation in production processes and poor infrastructure for storing and transporting raw materials reduce the quality of the final products. Expansion of the range of crops by growing new types of raw materials and investing in the creation of cooperatives and logistics hubs will help reduce production costs and increase efficiency. Improvement of marketing strategies, including the active use of online platforms to promote products and certification according to international standards, such as the organic standards of the European Union and the United States of America, is a substantial solution. This creates new export opportunities and increases the competitiveness of Ukrainian essential oils on the global market.

The efficiency of land use is determined by natural, technological and economic factors. Soil fertility, acidity, texture and moisture retention capacity significantly affect the yield of crops such as lavender, mint and sage. Soil degradation due to intensive use without proper fertilisation poses challenges to the sustainability of production. The use of organic and mineral fertilisers, combined with minimal tillage and crop rotation, helps to maintain fertility and improve the quality of raw materials.

Climate change, including rising average annual temperatures, droughts and uneven precipitation, is affecting the yields of essential oil crops. A shorter growing season reduces mint yields, while longer warm periods favour lavender cultivation. Rational use of water, including drip irrigation, mitigates the negative impact of droughts, while modern agricultural technologies, such as precision farming and automated crop monitoring, increase productivity and optimise costs. The spread of extreme weather events, such as hail and frost, causes damage to plants and reduces their productivity. The use of genetic breeding to create more resilient plant varieties helps address these issues. Regulatory measures aimed at supporting organic farming and subsidising producers are also driving the industry. The use of the latest processing technologies, such as cold pressing, maintains the high quality of essential oils and increases their value in global markets. The development of international cooperation and the introduction of certification programmes can expand the export prospects of Ukrainian essential oils, which is in line with global trends in the growth of demand for natural products.

Climate change has impacted the cultivation of essential oil crops, directly affecting their productivity and quality, while also significantly influencing the economic performance of the industry. Weather-related yield fluctuations affected production costs, supply and market pricing. At the same time, economic aspects, such as demand, pricing and export structure, determined the overall trends in the industry. The study analysed the global essential oils market, as it is crucial in shaping the competitive environment and price points for producers. The global essential oils market is showing a steady upward trend, driven by increasing demand from various industries such as cosmetics, food and beverage, pharmaceuticals, and aromatherapy. The market dynamics also reflect the impact of innovations in production, the expansion of essential oils in new segments and the growing interest in natural and sustainable products. Figure 1 shows the global volume of the essential oils market in billions of US dollars, which was used to analyse the scale and pace of its development in a global context.

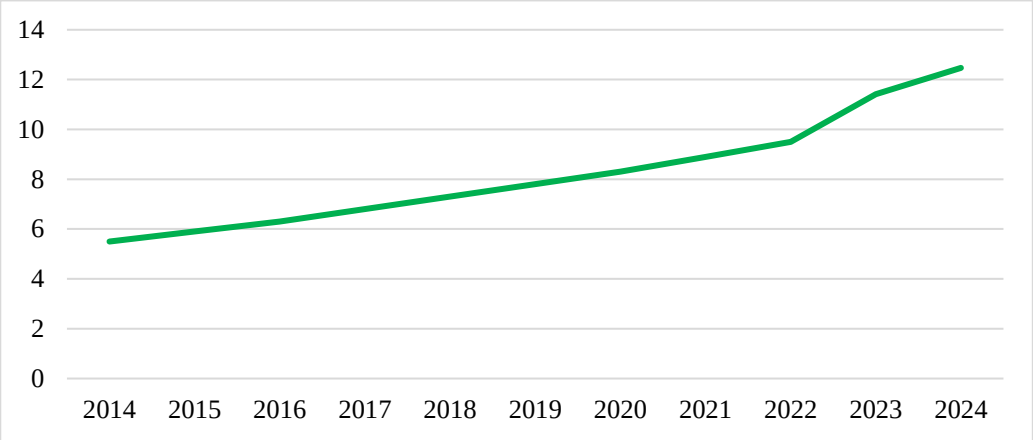

Figure 1: Global essential oils market volume, USD billion [*Source:* UN Comtrade Database (2025), International Trade Centre (2025), Eurostat (2025)]

Figure 1 illustrates the dynamics of the global essential oils market volume from 2014 to 2024, measured in billions of US dollars, and demonstrates a clear and sustained upward trend over the observed decade. In 2014, the global market was valued at USD 5.5 billion. Over the next ten years, the market expanded significantly, reaching USD 12.47 billion by 2024. This represents an overall growth rate of approximately 126.7%, highlighting the essential oils sector as one of the rapidly expanding segments within the broader natural products industry. The figure shows that market growth was relatively steady between 2014 and 2018, with moderate annual increases driven by the traditional sectors of cosmetics, food, and pharmaceuticals. However, a noticeable acceleration is evident starting in 2019. Between 2019 and 2024, the market experienced a particularly rapid expansion, growing by 59.9% within five years. This phase of accelerated growth coincides with a period of increased consumer awareness regarding the benefits of natural and organic products, as well as a surge in demand for sustainable, environmentally friendly ingredients across multiple industries.

Several structural factors underpin this dynamic. First, there was a diversification of essential oil applications, extending beyond traditional aromatherapy and cosmetics to new segments such as natural food preservatives, active packaging solutions in the food industry, and eco-friendly pharmaceuticals. Second, technological innovations in production and extraction methods, such as supercritical CO_2 extraction and improved distillation techniques, contributed to higher yields and more consistent product quality, facilitating broader industrial usage. Third, a global shift in consumer preferences toward wellness and preventive health care, intensified by the COVID-19 pandemic, amplified the demand for natural remedies, where essential oils played a central role. The steady rise in market value also reflects broader macroeconomic and trade trends, including the expansion of international supply chains, the strengthening of organic certification systems (e.g., COSMOS, USDA Organic), and the increasing willingness of consumers to pay premium prices for verified natural and sustainable products. Geographically, the most significant contributions to this growth came from mature markets in Europe and North America, coupled with a rapidly growing demand in emerging markets in Asia, particularly in China and India.

To ensure the effective development of the essential oil industry, it is necessary to address not only general market trends but also practical aspects of growing and processing crops adapted to local conditions. Scientific institutions that conduct research and develop new technologies to improve the productivity and quality of essential oil raw materials play a significant role in this process. Mykolaiv National Agrarian University is one of the key centres that provides an innovative approach to the cultivation of essential oil crops and contributes to the development of science-based solutions for the industry. Mykolaiv National Agrarian University conducts research and implements practical measures aimed at developing essential oil production in the Southern Steppe of Ukraine. The university's research field studies the agricultural and ecological aspects of growing essential oil crops such as narrow-leaved lavender (*Lavandula angustifolia*), lavandin (*Lavandula intermedia*), peppermint (*Mentha piperita*), lemon balm (*Melissa officinalis*) and clary sage (*Salvia sclarea*), in particular in the context of climate change (Manushkina, 2019).

The trials were carried out to evaluate the influence of agronomic practices, soil fertility, and climatic conditions on the yield and quality of essential oils, leading to the identification of effective methods for enhancing the concentration of biologically active substances in raw materials. The university's nursery was engaged in the propagation and adaptation of essential oil crops, focusing on the specific soil and climatic conditions of the region. The development of drought-resistant varieties of narrow-leaved lavender and lavender was emphasised, as well as the study of the impact of organic fertilisers on the yield of mint, lemon balm and clary sage (Shahini *et al.*, 2023). Furthermore, the nursery conducted the selection of adapted varieties characterised by high yields and stability of the chemical composition of essential oils, which is important for industrial production. The research results also included the study of the impact of plant growth regulators on lavender productivity in the Southern Steppe of Ukraine (Manushkina, Kachanova and Samoilenko, 2023).

The data obtained was used to develop modern agricultural technologies that minimise costs and improve product quality even in the face of climate change. These measures strengthen the competitive position of essential oil products in both domestic and international markets, creating a scientific basis for further development of the industry. The dynamics of the essential oils market in Ukraine reflect the significant changes that occurred during the analysed period. Changes in the area under essential oil crops, production volumes and exports indicate the industry's adaptation to economic, technological and climatic challenges. The main trends in the development of the essential oils market can be used to assess its growth rates, key stages of transformation and the impact of external and internal factors on the overall market picture. An analysis of the dynamics of the essential oils market in Ukraine in 2014-2024 showed a stable growth of this segment. The market for most crops showed positive dynamics. The highest growth was observed for such crops as narrow-leaved lavender (*Lavandula angustifolia),* lavandin *(Lavandula intermedia),* and peppermint *(Mentha piperita*). In particular, the market for peppermint grew from USD 6.5 million in 2014 to USD 11.2 million in 2024. Narrow-leaved lavender increased from USD 5.1 million to USD 9.1 million over the same period (Food and Agriculture Organisation of the United Nations, 2025; State Statistics Service of Ukraine, 2025).

Growth rates differed between crops. Nutmeg sage (*Salvia sclarea*) and lemon balm (*Melissa officinalis*) showed the most significant increase in market volume. *Salvia sclarea* grew from USD 4.2 million in 2014 to USD 7.6 million in 2024, driven by its active use in cosmetics and fragrance production. Lemon balm also showed a steady growth from USD 2.8 million to USD 6.2 million. In turn, catnip (*Nepeta cataria*) demonstrated moderate but stable growth in market volumes. The market was driven by growing demand for environmentally friendly products, the expansion of essential oil exports to Europe and Asia, and improved technologies for growing and processing raw materials. Crops such as narrow-leaved lavender and peppermint grew in popularity due to their use in the pharmaceutical, food and aromatherapy industries. Innovations in production-maintained product quality and improved economic efficiency. Table 2 shows the main exporters of essential oils, key import markets and statistics, including total exports (in tonnes) and average price per litre (in USD). This data can be used to assess the geographical distribution of production and consumption, as well as the competitive advantages of each country.

Table 2: Global breakdown of essential oils exports and imports: major countries and key markets

Exporting country	*Main countries of export*	*Total exports (tonnes)*	*Average price per litre (USD)*
Ukraine	European Union (EU) (Germany, France, Italy), China, Japan	5,000	100
France	USA, China, EU	8,000	120
India	EU, USA, Australia	12,000	80
China	Japan, EU, USA	6,000	75
Bulgaria	EU (Germany, France, Spain), USA	7,000	110

Source: Food and Agriculture Organisation of the United Nations (2025), UN Comtrade Database (2025), International Trade Centre (2025), and Eurostat (2025).

Table 2 provides a comparative overview of the main global exporters of essential oils, illustrating the geographical orientation of their exports, the total volumes supplied to international markets, and the average price per litre of essential oil products. The data demonstrate that while Ukraine maintains a notable presence on the global market, particularly in the European Union, China, and Japan, its total export volume of 5,000 tonnes is still lower compared to the leading exporters, such as India (12,000 tonnes) and France (8,000 tonnes). Nevertheless, the relatively high average price per litre of Ukrainian essential oils (USD 100) signifies a strong competitive position, especially in premium market segments that prioritise quality, such as those in Germany, France, and Italy.

France, with an even higher average price of USD 120 per litre, confirms its traditional leadership in the high-value segment of the essential oil market, driven by a strong reputation for quality and established branding in international trade. India, despite its leadership in terms of export volumes, has a noticeably lower average price per litre (USD 80), indicating its orientation toward mass-market segments and more price-sensitive consumers. Similarly, China, exporting primarily to Japan, the EU, and the USA, maintains moderate export volumes and the lowest average price per litre (USD

75) among the countries compared, reflecting a different positioning strategy focused on scale rather than premiumization.

Bulgaria, with 7,000 tonnes exported at an average price of USD 110 per litre, represents a strong competitor within the EU market, combining significant export volumes with relatively high value, especially for crops such as lavender and rose oil. Ukraine's ability to sustain a high price point, despite lower overall volumes, indicates the premium quality of its essential oil products and the success of its integration into environmentally conscious and quality-sensitive market segments. Major importers, including the European Union, the US, China and Japan, generate significant demand for essential oils due to their use in cosmetics, pharmaceuticals and food. France and Bulgaria remain the leading suppliers to the EU, while India and China actively export to the US and Australia. Growing demand in Asia, particularly in China and Japan, is opening up additional opportunities for exporters such as Ukraine, which was able to expand its presence by improving logistics and certifying products to international standards. The development of the industry has also been accompanied by improvements in the certification and quality control system. The use of ISO 9235 (2021) standards for essential oils strengthened the Ukrainian position on the international market.

These trends indicate significant transformations in the production and trade of essential oils, which were influenced by several factors. Economic factors include the growing demand for natural products and changes in the pricing policy for raw materials and finished products. Technological factors include the introduction of innovations in aromatic plant cultivation methods, increased efficiency of essential oil extraction processes and the use of new environmental technologies. Market factors include the growing interest in products for the cosmetic, pharmaceutical and food industries, as well as the expansion of international trade due to Ukraine's integration into global markets (Havryliuk and Kovalyshyna, 2024).

The main obstacles to the export of essential oils from Ukraine to international markets are insufficient product certification, difficulties with supply chains, a lack of stable demand for certain types of oils, and imperfect infrastructure that does not always meet international standards. Problems with product certification for many markets may lead to a lack of access to some promising countries, such as the US, Japan or Australia. The absence of ISO 9235 (2021) standards mainly concerns oils derived from less common plants or new crop species that do not have established international requirements. These are oils from plants such as catnip (Nepeta cataria), lemon balm (*Melissa officinalis*) or medicinal hyssop (*Hyssopus officinalis*). The absence of clear standards for these oils makes it difficult to get them certified and recognised on international markets, which creates barriers to exports, especially to the EU, the US and Asia, where quality standards are mandatory.

Although Ukraine has a significant export potential in the essential oils market, there are a number of trade barriers that can significantly limit access to international markets. One of the key obstacles is the existence of tariff restrictions imposed by individual countries or economic associations to protect domestic production. Even in the context of a free trade area with the European Union, certain products may be subject to tariff quotas or seasonal restrictions, which makes it difficult to export essential oils without

hindrance, especially from new or less common crops. Certification issues also pose a significant challenge for Ukrainian producers. International markets, such as the EU, the US, and Japan, require strict adherence to quality, safety, and environmental standards. Certificates of compliance with ISO 9235 for natural flavours, REACH for chemical safety, and COSMOS-Standard for organic cosmetics are a prerequisite for entering these markets. However, the certification process is financially costly and technically complex, which is particularly problematic for small and medium-sized producers, who often do not have the resources to go through all the necessary procedures (Ruijie *et al.*, 2024).

Geopolitical factors pose additional risks that may hinder export development. In particular, hostilities, political instability, or complications in relations between Ukraine and certain partner countries may result in restrictions on market access, additional customs inspections, logistical delays, or even temporary suspension of trade relations. In addition, global competition in the essential oils market is intensifying, and countries that already have a stable reputation as suppliers, such as France, India or Bulgaria, are actively protecting their positions by introducing technical barriers aimed at complicating access for new players. Another significant problem is the lack of logistics infrastructure for the efficient transportation of products to distant markets. Transportation of essential oils requires specialised storage conditions, which adds to export costs and reduces the competitiveness of Ukrainian products. Asian countries, such as China or India, often lack optimal transport routes or have complicated customs procedures, which also complicate exports (Shebanina, Shebanina and Poltorak,, 2024).

The low level of processing of raw materials at domestic enterprises can be another obstacle to effective exports. The raw materials that are exported often have little added value compared to products that go through high-precision distillation and processing technologies. This limits the opportunities for selling high-quality essential oils at competitive prices. Problems with access to modern processing equipment can also reduce the efficiency of production processes. National producers often face the problem of a lack of information about specific quality requirements in different countries. This means that some batches of essential oils may not meet the requirements of international standards, which becomes a barrier to export. Various requirements for the content of certain components in oils may differ from market to market, making it difficult to adapt products to the needs of consumers (Pavlenko *et al.*, 2025).

Another important factor is instability in financial relations in international markets. Currency fluctuations and inflationary processes can significantly affect the competitiveness of essential oils in foreign markets. For instance, during periods of currency instability in Ukraine, there is a decline in demand from foreign consumers, which negatively affects export volumes. One of the key problems is the lack of effective marketing support and branding of Ukrainian essential oils on the global market. For instance, most Ukrainian producers do not conduct comprehensive marketing campaigns, participate in international exhibitions, or create recognisable brands, which makes it difficult to build trust and loyalty among foreign buyers. In addition, limited financial resources prevent manufacturers from using modern digital tools to promote their products, such as social media targeting or search engine optimisation (SEO) to attract customers. This leads to low awareness of Ukrainian essential oils and reduces their competitiveness in international markets.

Insufficient investment in research and innovation can also be an obstacle to exports. Investment in the development of new varieties of essential oil crops and the latest processing technologies can help improve product quality and reduce production costs. However, the lack of government support and investment in research and development hinders this process. Another important obstacle to export development is the lack of a quality assurance system in Ukraine that meets international requirements. For stable access to global markets, it is necessary to create a national certification system to ensure that products meet international quality and safety standards. This includes the implementation of Good Manufacturing Practices (GMP) standards and certification based on international norms (Hasnan *et al.*, 2022).

To address these challenges, a comprehensive approach is needed, including improving logistics capabilities, improving product quality, and expanding investment in infrastructure and research. Possible measures include expanding cooperation with international organisations, creating conditions for attracting investment in agribusiness, in particular small businesses, and improving the technology for growing and processing essential oils. An important strategy to overcome the obstacles is to actively certify products following international standards such as ISO 9235 (natural aromatics) (2021), ISO 16128-2 (guidelines for natural and organic ingredients in cosmetics) (2017) and ISO 3632 (saffron and other spices that may be related to essential oils) (2011) (Tabari and Osterwalder, 2022). In addition, it is necessary to comply with EU requirements on chemical safety (Registration, Evaluation and Authorisation of Chemicals (REACH)) and organic production standards, such as COSMOS-Standard (2025) or U.S. Department of Agriculture (2025) organic regulations (Jagadeeswaran and Sriram, 2022). Participation in specialised exhibitions and forums will establish a dialogue with international buyers, increase confidence in Ukrainian products and improve their export prospects.

To increase the practical applicability of the implementation of international standards, in particular ISO 9235, in the Ukrainian essential oil industry, it is advisable to implement a set of policy and institutional measures. One of the most effective steps is to introduce state support programs for producers undergoing international certification, in particular through partial compensation of the costs of certification procedures or the provision of soft loans for modernisation of production by the requirements of ISO 9235. At the same time, it is necessary to intensify cooperation with European certification bodies through the creation of joint projects aimed at training Ukrainian producers, organising certification hubs in Ukraine, and speeding up the conformity assessment procedure. Signing framework agreements between Ukrainian line ministries and leading European certification bodies to facilitate producers' access to uniform recognition of certificates in the EU could be an important element.

Discussion

The analysis of the study results revealed several interrelated challenges affecting the production of essential oils, including climate change, insufficient access to modern processing technologies and the need to comply with international certification standards. The growing demand for natural and environmentally sustainable products has confirmed the importance of essential oils as a key ingredient in the cosmetics, pharmaceutical and food industries. The data obtained demonstrated that the introduction of the latest

agricultural technologies and improvement of the logistics infrastructure are crucial factors for increasing the competitiveness of the industry. These findings are of practical value for developing strategies aimed at integrating producers into global market processes and ensuring sustainable economic development of the industry.

Rout *et al.* (2022) analysed the main trends in the production and consumption of essential oils but did not analyse market prices in the dynamics. In particular, the study analysed the importance of demand in the pharmaceutical and cosmetic industries, but limited the analysis to general trends. The results of the study complement these conclusions with a detailed analysis of market price dynamics, which assessed the economic aspects of the industry in greater detail. A comparison of these works confirms the importance of considering pricing policy to increase the competitiveness of producers, especially in the face of climate and market challenges. Analysis of the study by Crișan *et al.* (2023) demonstrated an in-depth consideration of agrotechnical approaches to lavender cultivation, including the specifics of its cultivation in different climatic conditions. However, the study only partially covered the economic side of this process, omitting a detailed calculation of costs and profitability of cultivation. The results obtained in the study complemented these aspects, including an analysis of the economic efficiency of growing essential oil crops such as lavender in Ukraine. The use of comparative analysis determined how agrotechnical innovations affect the cost and profitability of production, which contributed to the comprehensive coverage of this issue.

The study by Assadpour *et al.* (2024) analysed the environmental aspects of essential oils and their impact on the reduction of the chemical burden on the environment. The authors analysed in detail the natural benefits of these products in various industries but left out important issues related to the logistics and storage conditions of essential oils, which are critical to maintaining their quality. The study examined the aspects of transportation and storage of essential oils that affect their stability and preservation of properties during export. The results identified key challenges in the supply chain, including the need to ensure specialised transport conditions and proper storage infrastructure. This approach complemented the environmental context of Assadpour *et al.* (2024) by extending the analysis to aspects important for maintaining product competitiveness.

Riaz *et al.* (2021) analysed exports of medicinal plants used to produce essential oils in European countries. The study covered individual plant species but lacked a comprehensive approach to the study of essential oil crops, which limited the depth of conclusions regarding their market value. The findings of the study complemented these aspects by focusing on the cultivation and export of a wide range of essential oil crops, such as lavender, mint and sage. The assessment of the impact of climatic, economic and technological factors on export potential systematises the notion of Ukraine's role in international trade in essential oils. This combination of analysis of medicinal plant exports and essential oil crops, in general, expanded the scope of previous studies and provided additional data for the development of industry strategies. Kosovsky (2023) highlighted modern technologies for processing raw materials to produce essential oils, in particular, methods of distillation and extraction, which ensure the preservation of high-quality products. The author examined in detail the advantages of innovative technologies, but the issue of Ukraine's integration into the global essential oils market

was not sufficiently analysed, which limited the understanding of the global context of the use of these technologies. The results of the study fill this gap by analysing the export potential of Ukrainian essential oils and their role in international trade. The study established that the introduction of modern processing technologies can serve as an important factor in increasing the competitiveness of products on the global market. The analysis of Ukraine's integration potential complements the technical context of a study by Kosovsky, compiling a more holistic view of the industry's prospects.

Mykhailenko *et al.* (2024) demonstrated that narrow-leaved lavender cultivated in Ukraine exhibits high antioxidant activity and a favourable chemical profile, particularly in terms of linalool and linalyl acetate content, key compounds in essential oils. This confirms its potential as a competitive raw material on the international market for natural aromatic products, especially amid rising demand for eco-friendly phytochemicals in Europe and North America. In their study, Gamayunova *et al.* (2024) analysed the prospects of diversifying oilseed crop production in Ukraine, taking into account current challenges of food security, climate change, and growing demand for high-margin crops. The authors emphasise the need to incorporate new niche crops, including essential oil plants, as a strategic pathway to enhance the competitiveness of the agricultural sector and align with export market requirements.

Silalahi *et al.* (2023) analysed aspects of international trade in essential oils, addressing the dynamics of exports and imports in Asian countries. The study highlighted the key markets in the region but did not address relevant aspects related to the development of trade in Europe and North America, which form a significant part of global demand. The analysis complements the results proposed by Silalahi *et al.* (2023) by addressing trends in European countries, in particular Germany, France and Italy, as well as in North America, with a focus on the US market. The study determined that these regions show a stable demand for organically certified essential oils, which opens new opportunities for exporters. This combination of regional perspectives broadens the scope of the analysis and contributes to a comprehensive understanding of the global essential oils market.

Taghouti *et al.* (2022) analysed in detail the production capacities of enterprises engaged in the processing of essential oil raw materials, including the use of modern equipment and the impact of technological progress on production volumes. However, the study did not address the role of small farmers in this process, which limits the understanding of the potential of decentralised production. The findings of the study complemented these aspects by focusing on the analysis of the contribution of small farms to the cultivation of essential oil crops. The study determined that the development of cooperative structures and investment in small farms can significantly increase the efficiency of the industry. Additions to the conclusions of Taghouti *et al.* (2022) compiled a more comprehensive picture of the production potential of the essential oil industry and its potential for integration of different production actors.

Raj, Appadurai and Athiappan (2022) analysed the impact of innovative agricultural technologies on various stages of the production cycle, including the use of precision farming systems that used a combination of sensors, satellite technologies and geographic information solutions. The study systematised data on precision farming and optimised fertiliser use, which involved the use of variable application rates depending

on soil conditions and phytosanitary characteristics of crops. This approach reduced costs associated with excessive use of resources, while at the same time contributing to an increase in overall yields by targeting the supply of crops with the necessary nutrients. It also covered weather conditions and landscape features, which reduced the risk of crop losses due to unfavourable climatic factors.

The study results confirmed the feasibility of using the latest technologies to increase economic efficiency, as they demonstrated a steady decrease in costs per unit of output and a steady increase in their quantitative indicators. These findings correlated with the assessment of this study, which also considered technological innovations as effective for increasing profitability and expanding resource-saving opportunities. Zaptalova (2024) proposed a conceptual ecological and economic model for the formation of a value chain for the cultivation of medicinal plants, which combined environmental sustainability with economic efficiency. The author described in detail the stages of the chain creation, focusing on an integrated approach to the cultivation, processing and sale of products. The study emphasised the use of organic agriculture, saving natural resources and implementing environmentally friendly technologies, which reduced the negative impact on the environment and ensured the long-term sustainability of the industry. This approach contributed to the sustainable development of the agricultural sector, improving the quality of life of the population and strengthening environmental safety, which was an important element of the study.

Guzmán and Lucia (2021) analysed the use of essential oils in the cosmetics industry, in particular their function as natural active ingredients and preservatives. The study highlights that the increased demand for environmentally sustainable alternatives is encouraging manufacturers to abandon synthetic ingredients in favour of plant extracts. The authors emphasised the multifunctional properties of essential oils, such as antioxidant, anti-inflammatory and antimicrobial effects, which are widely used in the production of cosmetics for skin and hair care and perfumery. However, the study noted that the complexity of chemical profiles and the need for an optimal combination of components pose significant challenges for developers. The results obtained by Guzmán and Lucia are consistent with the conclusions of the study, emphasising the importance of natural ingredients in modern production. The assessment of the multi-functionality of essential oils and their ability to meet international quality standards confirms the prospects for their implementation in various industries, including cosmetics. The identified need to develop sustainable formulas and ensure product quality expands the scope of the study, demonstrating that essential oils are a key element for the development of environmentally friendly and competitive solutions in the cosmetics industry.

Carpena *et al.* (2021) investigated the use of essential oils in active packaging systems to improve the sustainability and functionality of the food industry. The study determined that essential oils derived from natural sources provided antioxidant and antimicrobial protection for food products. The encapsulation of essential oil molecules was used to control the release of bioactive compounds, increasing the stability of packaging materials. The results were consistent with a study that also examined the use of essential oils as natural ingredients in various industries. The study analysed the expansion of the use of essential oils to create innovative products with improved functional characteristics.

A key contribution of the present study lies in the integration of climate resilience strategies into the broader framework of essential oil crop production in Ukraine, an aspect that has not been systematically addressed in previous research. Unlike earlier studies that separately considered agronomic practices, market trends, or technological innovations, this research provides a holistic analysis of how climatic risks, including rising temperatures, droughts, and soil degradation, can be mitigated through adaptive agricultural technologies, precision farming, and the development of drought-resistant crop varieties. Moreover, the study moves beyond a general discussion by systematically linking these sustainability measures to the economic efficiency and international competitiveness of essential oil production. This approach not only identifies practical pathways for the stabilisation and expansion of cultivation under changing environmental conditions but also positions climate adaptation as a critical element of long-term economic and export strategies. By explicitly embedding resilience mechanisms into the analysis of production, processing, and market integration, the study offers a substantive advancement in the understanding of sustainable agricultural development for essential oil crops in Ukraine, thus contributing new depth to the existing scientific discourse.

The analysis confirmed the significant potential of essential oils in various industries, including cosmetics, pharmaceuticals and food. The identified interrelationships between environmental, agronomic and economic aspects of production highlighted the need for innovative approaches in the technologies of growing, processing and using essential oil raw materials. Comparison of the results obtained in other studies supplemented the current scientific base, highlighting the importance of integrating essential oils as environmentally sustainable and functional components, as well as the challenges posed by the complexity of their chemical profiles and logistical constraints.

Conclusions

The uniqueness of the study is determined by a comprehensive approach to analysing the economic, agricultural, technical and market aspects of essential oils production, covering the period from 2014 to 2024. The use of data from international databases, official statistics, and scientific sources made it possible to assess the impact of global trends and local conditions on the development of the industry. This ensured a comprehensive analysis of market dynamics and the relationship between production processes and market conditions.

Global economic and environmental challenges have affected the supply, demand and production technologies of essential oils. The study found that the growing popularity of natural products increased demand in the cosmetics, pharmaceutical and food industries. At the same time, climate change had a negative impact on the yields of major crops such as lavender, mint and sage. Innovative agricultural technologies, including precision farming, helped to mitigate the impact of climate change and stabilise product quality. An analysis of the essential oils market in Ukraine demonstrated a steady increase in demand for export products, reflecting global trends. The analysis identified Ukraine's competitive advantages, including fertile soils and favourable climatic conditions that ensured high yields of essential oil crops.

At the same time, limited access to modern processing technologies and insufficient certification of products following international standards remained the main challenges. Expansion of sales markets and introduction of innovative technologies were identified as key areas for improving the competitiveness of Ukrainian producers. The study recommended accelerating the implementation of international certification standards, such as ISO 9235 and USDA Organic, which will provide access to new markets and strengthen Ukrainian positions in the global essential oils market. An important step is to improve the logistics infrastructure, including the creation of conditions for transporting products in compliance with specific storage requirements. Investments in innovative technologies for growing and processing essential oils, such as precision farming and modern distillation methods, will help improve product quality and reduce production costs.

Further research should emphasise the creation of new varieties of essential oil crops that are resistant to climate change, such as rising temperatures, droughts and uneven precipitation. It is also necessary to conduct an economic analysis of the effectiveness of implementing innovative technologies in different regions of Ukraine. Expanding cooperation with international organisations and participation in research and export support programmes will help Ukraine integrate into global market chains and strengthen its competitiveness.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*
Conceived and designed the research or analysis	Yes	Yes	No	No
Collected the data	Yes	Yes	Yes	No
Contributed to data analysis & interpretation	No	Yes	No	Yes
Wrote the article/paper	Yes	Yes	Yes	No
Critical revision of the article/paper	No	No	No	Yes
Editing of the article/paper	No	No	Yes	Yes
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Overall Contribution Proportion (%)	25	25	25	25

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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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