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The Essential Oil Context of Lemongrass and Its Potential for Innovative ESD-Informed Learning

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Abstract: Lemongrass essential oil contains various active compounds that function as antibacterial (citral and geraniol), deodorizer, insecticide, biocide, anti-fungal, antioxidant, anti-inflammatory, anti-cancer potential, and disinfectant, potentially resulting in innovative processes and products. The process and essential oil products from lemongrass are an interesting context for introducing ESD. This research aims to analyze the potential context of essential oil from lemongrass and aspects of the SDGs to develop innovative learning with ESD content. This preliminary research was carried out by describing the results of searches from various literature regarding the process of extracting essential oils using various techniques and using the products for health. The instruments used in this research were an analysis format of reading sources to produce appropriate themes and sub-themes and an open-ended questionnaire via Google Forms for prospective chemistry teacher participants. The results of the research show that the essential oil process involves extraction, microwave extraction, and steam distillation processes, where student teachers do not fully understand the process and potential product context of essential oil from lemongrass which contains ESD. In addition, 92% of prospective teacher students are interested in creating innovative product solutions that are environmentally friendly and good for health. The opinions of prospective teacher students regarding innovative learning with ESD content can stimulate creative thinking, critical thinking, collaboration, and deep understanding of concepts. The topic of essential oil from citronella has the SDGs aspect of a healthy and prosperous life because it produces potential products for health such as telon oil, massage oil, aromatherapy candles, diffusers, soap, anti-mosquito, floor cleaner, disinfectant, hand sanitizer, and herbal medicine. Based on the results of this research, it shows that the context of essential oils from lemongrass can be applied to innovative learning with ESD content.

Keywords: Essential oil, Lemongrass, Product

Introduction

Health is a critical aspect of achieving a good quality of life. The ESD SDG-3, known as Sustainable Development Goal-3, affirms the commitment to ensuring healthy lives and well-being for all individuals (Nations, 2016). The use of natural ingredients in traditional medicine has become a common practice

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throughout the world, estimated to be used by 75–80% of the population, especially in developing countries, because it is considered to have minimal side effects compared to allopathic medicine (Pujari et al., 2020; Sofowora et al., 2013). This is in line with health problems throughout the world which have led to an increasing need for natural compounds that can be used to develop innovative health products. The use of natural ingredients to become innovative products has also been very popular recently due to the need to use natural compounds to gradually replace chemicals (Tran et al., 2020). Natural ingredients will be more beneficial if they are converted into essential oils. Essential oils are concentrated hydrophobic liquids that contain various chemical compounds that easily evaporate at room temperature originating from natural/plant ingredients (Mahato et al., 2019). Essential oils have antidepressant, stimulant, detoxification, antibacterial, antiviral, and calming properties, so they can be used as medicines that have recently become very popular as a natural, safe, and cost-effective therapy for several health problems (Mahato et al., 2019).

One natural ingredient that has many benefits is lemongrass essential oil. The main active components contained in lemongrass essential oil are limonene, ÿ-myrcene, citral, geraniol, citronellol, geranyl acetate, and neral nerol. Although ÿ-myrcene and limonene are aromatic composites, the main biologically active component of lemongrass essential oil is citral, a mixture of the acyclic monoterpene aldehyde isomers neral (cis-citral) and geranial (trans-citral). In addition, lemongrass essential oil consists of small amounts of geraniol, geranyl acetate, and olefin monoterpenes (Do et al., 2021). The ingredient with the highest content in citronella oil is Citral (which accounts for more than 80% of the citronella oil content), which plays an important role in the functions of disinfectant, biocide, fragrance, and insecticide (Tran et al., 2020). Lemongrass essential oil contains various active compounds which are very useful such as antibacterial (citral and geraniol), odor remover, insecticide, biocide, anti-fungal (Šumiga et al., 2019), antioxidant (Fokom et al., 2019), anti-inflammatory, potency. anti-cancer (Do et al., 2021; Higuchi et al., 2023), and disinfectant (Tran et al., 2020). Lemongrass essential oil can be made into innovative products (Higuchi et al., 2023) such as several products including mosquito repellent (Higuchi et al., 2023), antimicrobial paper coating (Sumiga et al., 2019), as well as antibiofilm and antimicrobial (Pontes et al., 2019). Starting from this, to achieve learning that produces innovative products, creative thinking skills are needed (Rajan et al., 2019).

Lemongrass essential oil is obtained by extracting it through a steam distillation process (Tran et al., 2020). Steam distillation in micro-assisted essential oil extraction can increase the yield of essential oils (Xiao et al., 2021). Steam distillation itself is a method of isolating compounds that decompose at high temperatures through distillation so that steam is introduced into the raw material (Masango, 2005). In this technique, pure aromatherapy oils are extracted, resulting in a product that is free from contamination. Another method, namely vacuum fractional distillation, is an easy method for separating essential oil (EO) components because of its simplicity and economical operational costs (Beneti et al., 2011). This method operates at low pressure, which reduces the boiling point of the components, thereby preventing overheating and burning of the oil. Research has been carried out on vacuum fractional distillation of essential oils for the separation of limonene, increasing the composition of citronellal, citronellol, and geraniol in citronella essential oil (Beneti et al., 2011). The resulting compounds have many valuable uses. However, if there are individual compounds that have high value, it is desirable to separate the mixture properly, thereby increasing the value of the original essential oil. Pure constituents and fractions of essential oils often exhibit stronger pharmacological properties and thus have much greater commercial value than the essential oil itself (Do et al., 2021).

The use of lemongrass essential oil in innovative products for health is quite promising, considering its unique properties and benefits, making it a potential candidate for addressing global health challenges and supporting the achievement of the Sustainable Development Goals (SDGs). Several studies on making innovative products from lemongrass oil that are useful for health, including environmentally friendly mosquito repellent products (Higuchi et al., 2023; Motelica et al., 2021), antimicrobials in microencapsulation applied in pressure-sensitive antimicrobial functional coatings on paper with secondary packaging with a shelf life of 2 years (Šumiga et al., 2019), antibiofilm activity with S. aureus biofilm inhibition (Pontes et al., 2019), and aromatherapy candles (Tran et al., 2020). Thus, the essential oil from lemongrass offers a variety of health benefits, while the cultivation and extraction process provides an opportunity to explore education for sustainable development (ESD) as applied in higher education.

Higher education institutions make maximum efforts to provide education for sustainable development (ESD) (UNESCO, 2012; Veiga et al., 2017) and implement sustainable practices in various sectors (Lozano et al., 2015; Ramos et al., 2015). Education for Sustainable Development (ESD) is a concept designed systematically to understand and change the education system. The aim is to encourage and incorporate the idea of sustainability in the minds, hearts, and actions of future generations (Zgur et al., 2021). The term ESD also reflects initiatives to establish a global education system that supports changes in knowledge, skills, and

attitudes to direct society towards sustainability (Leicht et al., 2018). Thus, Education for Sustainable Development (ESD) equips students with the knowledge, skills, and values to face complex challenges in a global world. This study also investigates the potential of lemongrass essential oil as a context for developing ESD learning activities that are aligned with the ESD Sustainable Development Goals (SDGs), specifically SDG 3: Good Health and Well-Being. Finding interesting and relevant contexts for ESD is critical, and this research explores the potential of lemongrass essential oil as a promising avenue for innovative learning. This research aims to analyze the potential context of essential oil from lemongrass and aspects of the SDGs to develop innovative learning with ESD content.

Method

The research method used in this preliminary study involved an initial exploration of the context of lemongrass essential oil as a means to introduce education for sustainable development (ESD). This research method includes a comprehensive analysis of the context of the process and potential of essential oil from lemongrass as well as aspects of the Sustainable Development Goals (SDGs) to develop innovative learning with the content of Environmentally Sustainable Development (ESD). The sample of 36 chemistry teacher candidates in this study were 5th-semester students who were taking organic chemistry courses. This research was conducted at a university in Bandung City, Indonesia.

This research consists of describing the results of searches from various literature regarding the process of extracting essential oils using various techniques and the use of the products for health. The instruments used in this research were a reading source analysis format to produce appropriate themes and subthemes and an open-ended questionnaire via Google Forms for prospective chemistry teacher participants. The literature review aims to describe the results of searches from various literature regarding the process of extracting essential oils using various techniques and using the products for health. Themes and Subthemes to analyze the literature to identify common themes and subthemes, such as the advantages and disadvantages of each extraction method, the influence of each method on the aromatherapy properties of essential oils, and the importance of comprehensive analytical characterization of essential oils. The open-ended questionnaire via Google Forms for prospective chemistry teacher participants was divided into six sections: critical reflection, systems thinking and analysis, participatory learning, creative thinking for future scenarios, collaborative learning, and the topic of the potential of citronella oil. The research found that the essential oil process involved extraction processes, microwave extraction, and steam distillation, where student teachers did not fully understand the process and context of potential essential oil products from lemongrass containing ESD. The topic of essential oil from lemongrass has an SDGs aspect, namely healthy and prosperous living because it produces potential products for health.

Results and Discussion

Potential Processing of Essential Oil from Lemongrass

There are two commonly known lemongrass plants, namely kitchen lemongrass (*Cymbopogon citratus*) and citronella lemongrass (*Cymbopogon nardus*). Lemongrass has the scientific name *Cymbopogon citratus* or is identical to Andropogon citratus, which currently numbers around 55 species. The main product of lemongrass is the essential oil that accumulates in the leaf stems, with the oil content varying between 0.4 to 2.0% depending on the variety, ecological conditions, and care method. Lemongrass oil contains many beneficial aromatic compounds, some of which have strong deodorizing and antibacterial properties (citral and geraniol) (Tran et al., 2020).

The main active components contained in lemongrass essential oil are limonene, ÿ-myrcene, citral, geraniol, citronellol, geranyl acetate, and neral nerol. Although ÿ-myrcene and limonene are aromatic composites, the main biologically active component of lemongrass essential oil is citral, a mixture of acyclic monoterpene isomers of the aldehydes neral (cis-citral) and geranial (trans-citral). In addition, lemongrass essential oil consists of small amounts of geraniol, geranyl acetate, and olefin monoterpenes (Do et al., 2021). The ingredient with the highest content in citronella oil is Citral (which accounts for more than 80% of the citronella oil content), which plays an important role in the functions of disinfectant, biocide, fragrance, and insecticide (Tran et al., 2020). Recent scientific studies show that various components of lemongrass essential oil have antioxidant properties (Fokom et al., 2019), antimicrobial (Šumiga et al., 2019), antifungal, anti-biofilm (Pontes et al., 2019), anti-inflammatory, anticancer potential, and other activities. anti-mosquito repellents (Do et al., 2021; Higuchi et al., 2023).

In the process of obtaining quality lemongrass essential oil results using Green Chemistry principles. Green Chemistry is a paradigm shift in professional practice. This urgent need for change is in line with the Sustainable Development Goals (SDGs) (Zhang, et al., 2023). Green Chemistry principles are applied using environmentally friendly solvents or techniques. It is important to use Green Chemistry solvents to replace organic solvents and conventional techniques, to avoid harm to the environment, researchers, and consumer health. Lemongrass essential oil is obtained by extracting it through a steam distillation process (Tran et al., 2020). Steam distillation in micro-assisted essential oil extraction can increase the yield of essential oils (Xiao et al., 2021).

Commonly used methods for essential oil separation include solvent extraction, fractional distillation, and Microwave-assisted extraction (MAE). Supercritical fluid extraction methods using carbon dioxide solvent have recently been used to separate and purify essential oils. This method overcomes the disadvantages of traditional extraction which uses organic solvents and produces large amounts of waste (Reverchon et al., 1995; Torres-Valenzuela et al., 2020). Supercritical fluid extraction procedures have been applied to natural products, particularly in pharmaceutical technology. The main advantage of this system is its low operating temperature as the critical point of carbon dioxide is at 31°C and 73.8 bar. At this low temperature, thermolabile compounds will not be destroyed and the organoleptic properties of the extract will not change.

The use of supercritical fluid extraction to segment and isolate pharmaceutical and chemical molecules from essential oils has been published in many studies, including fractional extraction for the fractionation of dried ginger for the production of high-quality essential oils (Shukla et al., 2019), fractions isolated from ten species of Salvia (Wrona et al., 2019), and fractionation of sterols, equipment, and squalene in linseed oil (Dąbrowski et al., 2019). Despite the fact that supercritical fluid extraction is known as a clean technology that provides good yields and purity, the operating pressure high levels requires modern equipment and raises safety issues and cost ineffectiveness (Do et al., 2021). Microwave-assisted extraction (MAE) is a method in which microwave energy is used to heat the solvent in contact with the sample, resulting in the separation of the analyte from the sample matrix into the solvent. The main advantage of this technique lies in its ability to rapidly heat the mixture of solvent and sample, allowing extraction to be carried out at high temperatures. By using a closed container, MAE can carry out extraction at high temperatures which accelerates the mass transfer of target compounds from the sample matrix. The extraction process usually only takes 15–30 minutes and involves the use of a relatively small volume of solvent, ranging from 10–30 ml. The amount of solvent used in MAE is about ten times less than in conventional extraction techniques (Eskilsson & Björklund, 2000).

The fractionation distillation method is a method that is simple to operate and low cost. Batch vacuum distillation is commonly used because it operates at an initial temperature and offers the flexibility to work with a variety of oils. The main advantage of the batch method is its flexibility and the possibility of working on a small scale, allowing the testing of raw materials before large-scale processing. Fractional distillation methods are based on differences in the volatility of compounds and depend on the physical and chemical characteristics of the components as well as the pressure and temperature of the distillation process. Separation productivity also depends on mass and energy transfer between the liquid and vapor phases of the mixture. Thus, the quality of essential oils depends on many different factors. Therefore, to guarantee the quality of essential oils, they must be stabilized and standardized by separation technology. Separation using fractional distillation is necessary to increase the stability of the oil and its commercial value. Essential oils have many valuable uses. However, if there are individual compounds that have high value, it is desirable to separate the mixture properly, thereby increasing the value of the original essential oil. Pure constituents and fractions of essential oils often exhibit stronger pharmacological properties and thus have much greater commercial value than the essential oil itself (Do et al., 2021).

The Potential of Essential Oil Products from Lemongrass for Health

The potential of essential oil products from lemongrass for health can be seen from its various properties and components. Some of the main health benefits of lemongrass essential oil include that lemongrass oil is used as a mosquito repellent product because it contains vegetable ingredients and provides the best mosquito repellent effect with a rejection period of 4 hours (Higuchi et al., 2023), this is because it has the active ingredients citronellal, citronellol, and geraniol which functions as a bio-pesticide (Motelica et al., 2021). Lemongrass oil can also be used as an antimicrobial in microencapsulation and applied in pressure-sensitive antimicrobial functional coatings on paper with secondary packaging with a shelf life of 2 years (Šumiga et al., 2019) and against antibiofilm activity with S. aureus biofilm inhibition up to 100% between concentrations of 0.5 mg/mL and 4 mg/mL (Pontes et al., 2019). Lemongrass oil can also be an aromatherapy product that provides relaxing,

anti-neuro depressive, and sedative effects on people who experience insomnia, thereby improving mood, reducing anxiety levels, and increasing alertness. Thus, the use of essential oil from lemongrass in aromatherapy is one way to treat various diseases. Because it is made from plants and has a distinctive aroma (Adetuyi et al., 2024). Another product that has many benefits is an aromatic candle made from lemongrass essential oil which functions to eliminate the smell of dirt that causes other odors and is usually placed in the living room, bedroom, and kitchen. In particular, many substances in aromatic candles are toxic to the body because they contain toluene ($C_6H_5CH_3$), acetone (CH_3COCH_3), formaldehyde (CH_2O), benzene derivatives, and methylene chloride (CH_2Cl_2). They have been shown to cause cancer, congenital defects, and degeneration of the nervous system. This research shows that the addition of lemongrass essential oil is an important factor that contributes to product quality (Tran et al., 2020).

Based on the literature provided, lemongrass essential oil has various properties and components that make it a potential product for innovative learning with ESD content. For example, it can be used as a mosquito repellent, an antimicrobial, an aromatherapy product, and an aromatic candle. These properties and components can be used to teach students about sustainable living, natural remedies, and the importance of using eco-friendly products. For example, students can learn about the harmful effects of toxic substances found in some aromatic candles and the benefits of using lemongrass essential oil as a natural alternative. Additionally, students can learn about the importance of using natural products to protect the environment and reduce the use of harmful chemicals. The following are the results of a Likert scale for prospective teacher students regarding the potential of essential oil products from lemongrass:

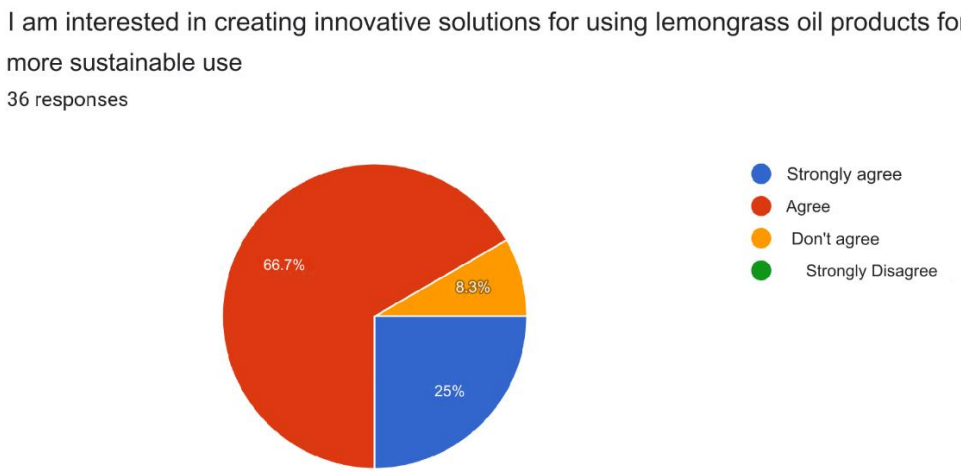

Figure 1. Innovative product application of lemongrass essential oil

The results show that 92% of prospective teacher students are interested in creating innovative product solutions from lemongrass essential oil that are environmentally friendly and beneficial for health. This highlights the growing interest in natural and environmentally friendly products, as well as the potential of lemongrass essential oil in a variety of uses. Some important points from the literature results include: Lemongrass essential oil (LEO) has been identified as a natural preservative with significant antimicrobial and antioxidant properties, making it suitable for use in the food industry as a safer alternative to synthetic preservatives (Faheem et al., 2022). The global lemongrass essential oil market is experiencing steady growth, driven by factors such as increasing demand, technological advancements, and increasing environmental awareness. Lemongrass essential oil is known to have potential benefits for skin health, as it has been shown to improve epidermal hydration and skin barrier integrity in a study conducted on human participants. These findings indicate a strong interest in exploring the potential of lemongrass essential oil in creating innovative and environmentally friendly products that improve health and well-being.

Innovative Learning Contains ESD

Critical Reflection

In the first statement regarding "I know the term ESD (Education for Sustainable Development) or education in sustainable development" which was given to prospective teacher students, the result was that 38.9% of students still did not know the term ESD, so students were given knowledge about ESD through short videos.

Furthermore, to find out whether the lecture they had experienced contained ESD or not, 83.3% stated that it had contained ESD. Questions continued regarding the importance of ESD to increase understanding regarding sustainable development issues in economic, social, and environmental aspects. Based on the results of open questions from prospective teacher students:

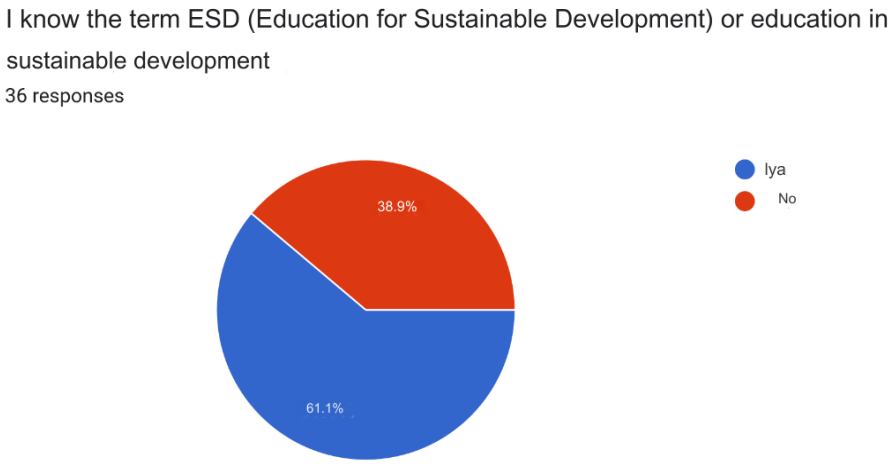

Figure 2. ESD (Education for Sustainable Development)

Table 1. The importance of ESD-based Learning

Theme	Sub-theme
Creating Change Agents	Encouraging students as agents in sustainable development
	Become a leader who cares about global issues
	Chaperone change for the environment
Enhance character and values	Building character and values of sustainable development
	Increase awareness of the environment
	Increase awareness of current issues
Improving knowledge and skills	Increase understanding of sustainable issues
	M e improve higher level thinking abilities
Supporting sustainable development	Prepare self from challenge issues current and future
	Finish issues latest through principle sustainable
	Creating a sustainable and balanced world
Innovation learning	Push use of student - centered learning models
	Push ESD lectures

Systems Thinking and Analysis

About 86.1% of students think that they have experienced the lectures taught which are related to current problems. There are interesting contexts that should be included in lectures, such as innovation and technology, environmental and climate issues, green chemistry, poverty, social humanities, factual education issues, safe health products, and current issues in the environment. Examples that can be applied in learning, starting with phenomena such as the global Lemongrass Essential Oil market experiencing stable growth, are driven by factors such as increasing demand, technological advances, and increasing environmental awareness. This growth trajectory provides an opportunity to incorporate citronella oil into innovative learning experiences that promote sustainability and ESD content

Participatory Learning

Students interested in participating in project-based learning related to sustainable development issues have been implemented in lectures. The suggestions from students in increasing the integration of sustainable development issues in lectures are the latest technology and innovation trends, development of the ESD course curriculum,

sustainable issues to training critical and creative thinking, innovative learning models and methods, practical experience through practice, workshops, and seminars, and strengthen scientific literacy.

Thinking Creatively for Future Scenarios

Increasing demand and developing technology are driving the growth of the Lemongrass Essential Oil Market. This provides an opportunity for educators to think creatively about the future of citronella oil-based products and incorporate them into innovative, ESD-laden learning experiences. This is in line with students' opinions that in lectures there is a need to create innovation regarding social, economic and environmental issues that are currently developing in society. The method or model suggested by students to encourage students to create solutions from the context of current trends in sustainable development issues is project-based learning.

Collaborative Learning

Maximizing the collaboration process within the group is very important. Students' suggestions for maximizing the collaboration process in groups include good communication, self-awareness and openness, good cooperation, and even distribution of tasks.

The Topic of the Potential of Essential Oils from Lemongrass

Some students have already carried out techniques for separating natural materials, including extraction, maceration, surface distillation, soxhlet, liquid-liquid extraction, solid-liquid extraction, gas chromatography, and thin-layer chromatography. The products that have been used are made from lemongrass oil, including telon oil, massage oils, aromatherapy candles, diffusers, soaps, mosquito repellents, floor cleaners, disinfectants, hand sanitizers, and herbal remedies. The functions of lemongrass oil that students know are as aromatherapy, anti-mosquito medicine, anti-inflammatory, relieving diarrhea, alleviating headaches, traditional medicine, and healing wounds. The topic of potential processes and essential oil products from lemongrass is very suitable when applied to organic chemistry learning at universities. Prospective teacher students believe that innovative learning containing ESD can stimulate creative thinking, critical thinking, collaboration, and deep understanding of concepts. These aspects can be incorporated into educational programs to promote sustainability and prepare students to play an active role in a sustainability-oriented society.

Conclusion

In conclusion, this preliminary research revealed the potential of essential oil from lemongrass to be used in innovative learning with Environmental Sustainable Development (ESD) content. The research found that the essential oil process involves extraction, microwave extraction, and steam distillation, where prospective chemistry teacher students do not fully understand the process of making potential essential oil from lemongrass with ESD content. Then the potential products of lemongrass oil as a health product that students already know include telon oil, massage oils, aromatherapy candles, diffusers, soaps, mosquito repellents, floor cleaners, disinfectants, hand sanitizers, and herbal remedies because it functions as aromatherapy, anti-mosquito medicine, anti-inflammatory, relieves diarrhea, relieves headaches, traditional medicine, and heals wounds. The research also revealed that 92% of prospective teacher students are interested in creating innovative product solutions that are environmentally friendly and good for health. The opinions of prospective teacher students regarding innovative learning with ESD content can stimulate creative thinking, critical thinking, collaboration, and deep understanding of concepts. The topic of essential oil from lemongrass has an SDGs aspect, namely healthy and prosperous living because it produces potential products for health. Based on the research results, it shows that the context of essential oil from lemongrass has the potential to be applied to innovative learning with ESD content. Further research is needed to explore the full potential of lemongrass essential oil in developing innovative health products that can address global health challenges and support the achievement of the SDGs.

Recommendations

Based on the findings of the research, the following recommendations can be made:

1. Education and Training: There is a need for educational initiatives and training programs to enhance the understanding of the essential oil extraction process, particularly among prospective chemistry teachers. This will enable them to effectively communicate the process and potential product context of essential oil from lemongrass, which contains Environmentally Sustainable Development (ESD) elements.
2. Product Innovation: The high level of interest among prospective teacher students in creating innovative, environmentally friendly, and health-beneficial product solutions presents an opportunity for collaborative product innovation projects. These projects can be designed to incorporate the use of lemongrass essential oil and align with the Sustainable Development Goals (SDGs).
3. Health and Environmental Impact: Further research is needed to explore the full potential of lemongrass essential oil in developing innovative health products that can address global health challenges and support the achievement of the SDGs. This research should also consider the health and environmental impact of lemongrass essential oil products.
4. Quality and Safety: Given the concentrated nature of lemongrass essential oil, it is essential to ensure the quality and safety of the product. This includes adherence to organic standards and the use of pure, trusted sources of the oil.
5. Innovative Learning: The research has highlighted the potential of lemongrass essential oil to be applied to innovative learning with ESD content. This can be further explored through the development of educational materials and programs that integrate the use of lemongrass essential oil as a case study for ESD-informed learning.

By addressing these recommendations, it is possible to harness the potential of lemongrass essential oil for innovative, sustainable, and health-conscious product development, while also supporting the advancement of ESD and the SDGs.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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