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Thyme Sediments for Energy Storage Systems and Its Benefit Evaluations for Agricultural Economics

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Abstract
In this study, the use of thyme residue as an electrode in energy storage systems was analyzed. The electrochemical analysis started by analyzing the CV in the ±0.5V range. However, due to low current values and misleading data, the measurement range was extended to ±1V and ±2V. Current plateaus of varying widths were observed in the ±0.5V and ±1V ranges at all scan rates. However, as the scan rates increased, redox peaks started to appear at the thyme sediment electrodes. At a scan rate of 200 mV/s, two different redox events were detected at 0.35 V and 1.4 V. Charge-discharge and power performance analyses were performed on capacitors made with thyme sediment electrodes. The results show that thyme sediment, an organic material, can store energy in capacitors and supercapacitors can be formed with a capacitance of about 101 F g^{-1}. As a result of the determination that thyme residue can be used as an alternative electrode material, evaluation analyzes were also made in terms of agricultural economy and it was concluded that this discovery could lead to significant economic developments for both the energy sector and agriculture.

Research Article

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1. Introduction

In recent years, many disasters experienced around the world (Covid-19, earthquakes, climate changes, drought, etc.) have made people more conscious and encourage them to take precautions for a healthy life and a proper environmental structure (Doğan et al., 2022; Coşge Şenkal, 2020; Raihan, 2023; Tandrayen-Ragoobur, 2023). Especially in terms of the environment, minimizing waste production or reusing waste to a level that can be used in different areas or in different forms is of great importance for the future.

Many plants (such as lavender, thyme, daisy, rosemary etc.) around the world can be used for health, cosmetics and food (Tamboli, 2021; Sarihan & Tonçer, 2021; Shahrajabian & Sun, 2023). Of course, for such uses, plants must first be subjected to certain processes. For example, essential oils are produced from a plant used in cosmetics by the boiling method, which is the simplest process (Schmidt, 2020). While the essential oils produced are mostly used in cosmetics, they can also be used in health, cleaning and food applications (Schmidt, 2020; Shahrajabian & Sun, 2023; Tamboli, 2021). However, the evaluation of the residual sediment released after essential oil production is important in terms of environmental pollution. Because the plant sediment remaining after essential oil production, which is obtained with an average yield of 3%, is thrown away as garbage if it is not used for any other purpose (Demirel et al., 2023). This situation should be considered as an opportunity to improve environmental sustainability.

In contemporary practices, many plants and agricultural products are processed for various purposes, utilizing their distinct properties. Yet, the examination of the residual sediment from these processes holds promise for advancing environmental sustainability across diverse scientific domains. This study explores the feasibility of harnessing energy from the sediment of a plant commonly employed in health, cosmetics, and food sectors. Furthermore, it scrutinizes the findings through the lenses of agricultural economics, thereby bridging the realms of energy storage and agriculture.

Batteries and capacitors, both essential components of energy storage systems, share structural similarities. However, their distinguishing feature lies in their energy storage capacity. Batteries excel in storing substantial amounts of energy, albeit releasing it gradually for sustained use. In contrast, capacitors offer rapid deployment of the stored energy, albeit in relatively smaller quantities compared to batteries. Despite their nuanced differences, both systems comprise positive and negative pole materials, interspersed with an electrolyte layer that prevents electrical short circuits while facilitating energy storage (Olabi et al., 2021).

Many energy storage systems used today generally contain substances that are harmful to the environment and human health with their toxic structures (Co, Mn, S, K, P etc.) (Feng & Zhang, 2022; Zhang et al., 2022; Hou et al., 2023). This means using structures that may cause environmental harm instead of using fossil energy resources that have environmental damage. For this reason, it is important to choose the materials to be used in such energy storage systems from materials that will not harm the environment and humans. Although energy storage systems containing toxic substances have high-capacity performances, many scientific researches to be conducted today and in the future will result in environmentally friendly and healthy alternative products that can be used in these systems.

Within the scope of efforts to produce alternative products for use in energy storage systems, the idea of using the sediment of an agricultural product used in different fields has emerged (Demirel et al., 2023). Within the scope of this idea, the usability of Thyme sediments (TS), whose essential oil has been extracted, which has never been tried before, in energy storage systems was investigated. Thyme, a medicinal and aromatic product, is widely used in food, health, perfumery, etc. According to 2020 world thyme import and export figures, China is the leader in world exports with a share of 29.3%, while India has a share of 16.64%, the Netherlands 8.63%, and Germany 4.08%. At the end of 2020, while China exported 3.22 billion dollars of thyme for thyme, the United States of America, which is the leader in terms of imports, imported 3.19 billion dollars of thyme (‘2023 Thyme global market overview today’).

Türkiye has a rich natural thyme production, especially in the Mediterranean regions. Thyme, traditionally collected from regions with wild plant resources, has increased in production in recent years with the spread of controlled agricultural practices (Şeker and Özçelik, 2017; Ege and Kalaycıoğlu, 2019). These practices are concentrated in the Mediterranean and Aegean regions, including Antalya, Isparta, Muğla and Aydın. Thyme production in Turkey fluctuates annually and is estimated to range between 10,000 and 15,000 tons. In addition, the prominence of oil distillation facilities in Antalya and Isparta puts Turkey at the forefront of the world in thyme oil production. Oregano oil production is emerging as a significant component of Turkey's agricultural income and offers an alternative for farmers seeking an additional income stream.

Thyme is a plant that grows easily, does not discriminate between soil types and does not require much water to grow. It can be easily grown not only as professional agriculture but also as a potted plant at home. Thyme's agricultural production does not require much effort and financial investment, and the essential oil it contains can be easily extracted, which has been an important factor in choosing to use it in energy storage systems. Within the scope of this study, thyme sediment, whose essential oil was previously extracted, was dried and powdered to create an electrode form for energy storage systems. A simple capacitor application was made with electrodes produced from thyme sediment and it was discovered that it is an alternative electrode material for supercapacitors, which are today's most up-to-date energy storage systems. It has also been determined that the capacitors formed with thyme essential oil have rechargeable properties. Following this discovery, in the next stage of the study, the use of thyme sediment in energy storage systems was evaluated in terms of agricultural economy. As a result of the evaluations, it was determined that discovering a different alternative area for thyme could increase agricultural thyme production and increase the current import and export figures in the world to even higher levels. In conclusion, this study aims to investigate the viability of utilizing thyme sediment as an alternative electrode material in energy storage systems and to assess its potential impact on agricultural economics. By exploring the feasibility of repurposing thyme residue for energy storage applications, this research seeks to contribute to both the advancement of sustainable energy technologies and the enhancement of agricultural productivity and economic growth.

2. Materials and Method

2.1. Materials

Thyme sediment obtained after the extraction of essential oil served as the primary raw material for electrode production. Carbon black (CB) was employed as a conductive material, enhancing the electrochemical properties of the electrodes. Carboxymethyl cellulose, acting as a binder, facilitated the uniform mixing of thyme sediment and carbon black, ensuring cohesive electrode formation. Platinum foils, cut into precise 1 cm^2 sizes, were utilized as substrates onto which the electrode materials were coated. A cellulosic paper membrane was employed as a separator between thyme sediment electrodes in the formation of symmetrical capacitors. 6 mol $KOH_{(aq)}$ solution, chosen for its conductivity and stability, served as the electrolyte for the energy storage experiments. The Gamry 1010-E model Potentiostat provided precise control and measurement capabilities for the analysis of energy storage properties.

2.2. Method

The electrode production process commenced with the weighing of thyme sediment, followed by its drying in an oven at a constant temperature of 65°C for a duration of 4 days. Subsequently, the dried thyme sediment was ground into a fine powder using a grinder, ensuring uniformity in particle size (Figure 1-a). The powdered thyme sediment was then mixed with pure water to form a mud-like consistency. In the sludge creation process, a mixture was prepared with predetermined ratios of thyme sediment, carbon black, and carboxymethyl cellulose. This mixture was then evenly coated onto platinum foils, serving as the foundation for electrode assembly.

For the energy storage experiments, symmetrical capacitors were constructed by placing electrodes in a cell, with a cellulosic paper membrane acting as a separator to prevent electrical contact between the two electrodes (Figure 1-b). Electrolyte preparation involved the use of 6 mol $KOH_{(aq)}$ solution, ensuring optimal ion conductivity within the capacitor. Cyclic voltammetry (CV) measurements were conducted using the Gamry 1010-E model Potentiostat to assess the energy storage characteristics of the capacitors. Charge-discharge measurements were performed over 400 cycles to evaluate the capacitors' performance under varying conditions. CV measurements were made at constant scan rates of 200, 400, 800 mV/s and 1200 mV/s in the ranges of ±0.5, 1 and 2V.

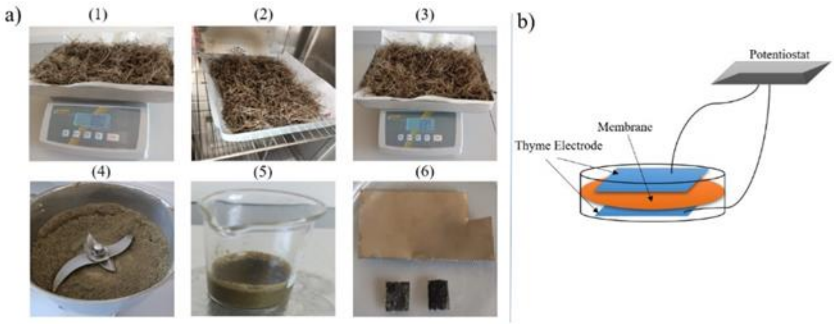

Figure 1. a) Distillation method schematics, b) simple capacitor cell application schematics.

Capacitance was calculated from CV measurements using the formula (1) referenced in previous literature, and the energy stored by the capacitors was determined using established equations (Demirel et al., 2023). This comprehensive methodology facilitated the systematic investigation of thyme sediment as a potential electrode material for energy storage applications.

$$W = \frac{1}{2} C V^2 \quad (1)$$

where, W is the energy stored (joules, J); C is the calculated capacitance (farad, F); V is the potential difference (voltage, V). After calculating the amount of energy stored by the capacitor, the electrical power that this capacitor can produce is calculated with the formula (2).

$$P = \frac{dW}{dt} \quad (2)$$

where; *P* is the potential power (watts, W), *dt* is the dissipation time (s).

3. Results and Discussion

3.1. The energy storage performance analysis

Electrochemical analysis studies on thyme sediment started with CV analysis. For energy storage system analyses, firstly, the ±0.5V range, which is the lowest possible voltage range suitable for technological and industrial applications, was selected. However, since the current values obtained in this voltage range were at very low levels and some data showed misleading values called "noise-data", it was decided to increase the measurement range. After this decision, measurements were made within the range of ±1V and ±2V, again taking industrial applications into consideration. Figure 1 shows the current characteristic in the range of ±0.5V, ±1V and ±2V. Wide current plateaus were observed at all scan speeds in the ±0.5V, ±1V ranges. This indicates that energy storage systems that can be produced with thyme sediment electrode can store electrical energy. However, at increasing scan rates such as after 1V, some redox peaks began to be observed in the thyme sediment electrodes. Two different redox formations, seen in Figure 2-a and occurring at 0.35 V and 1.4 V levels at a scanning speed of 200 mV/s, stand out. As seen in Figure 2-b, c and d, there was an average shift of 0.1 V in these redox peaks due to increasing scanning speed. It is known that redox reactions that develop between 0-0.5 V under normal conditions are caused by the bonding of OH^- ions of the $KOH_{(aq)}$ electrolyte with the electrode (Habekost, 2016). Since the study on thyme sediment is new and there is not yet complete information about its physical and chemical structure characterizations, it is thought that the second redox occurring at 1.4 V levels is caused by OH- forming a different bond in a different region. New studies on this will be carried out in detail.

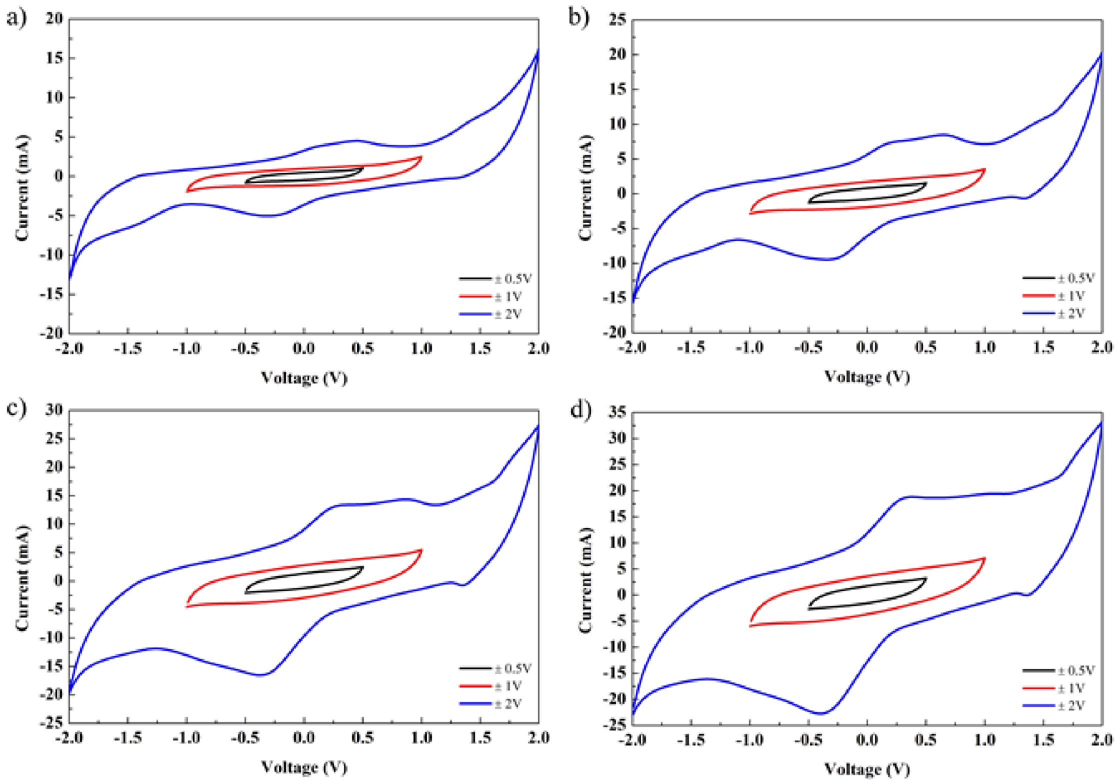

Figure 2. Current-Voltage characteristics of thyme sediment electrodes in different voltage ranges a)200 mV/s, b) 400 mV/s, c) 800 mV/s and d) 1200 mV/s

In the CV analyzes seen at different scanning speeds in Figure 2, it was also investigated whether the current characteristics to be obtained in the next cycle had continuity. In other words, can each voltage scanning rate be obtained again at similar values and in similar ways? To analyze this situation, scans were made 3 times at each scanning speed and the same current characteristics were obtained in repeated CV measurements. To avoid data confusion, only one of each of these three-loop data is shown in Figure 2.

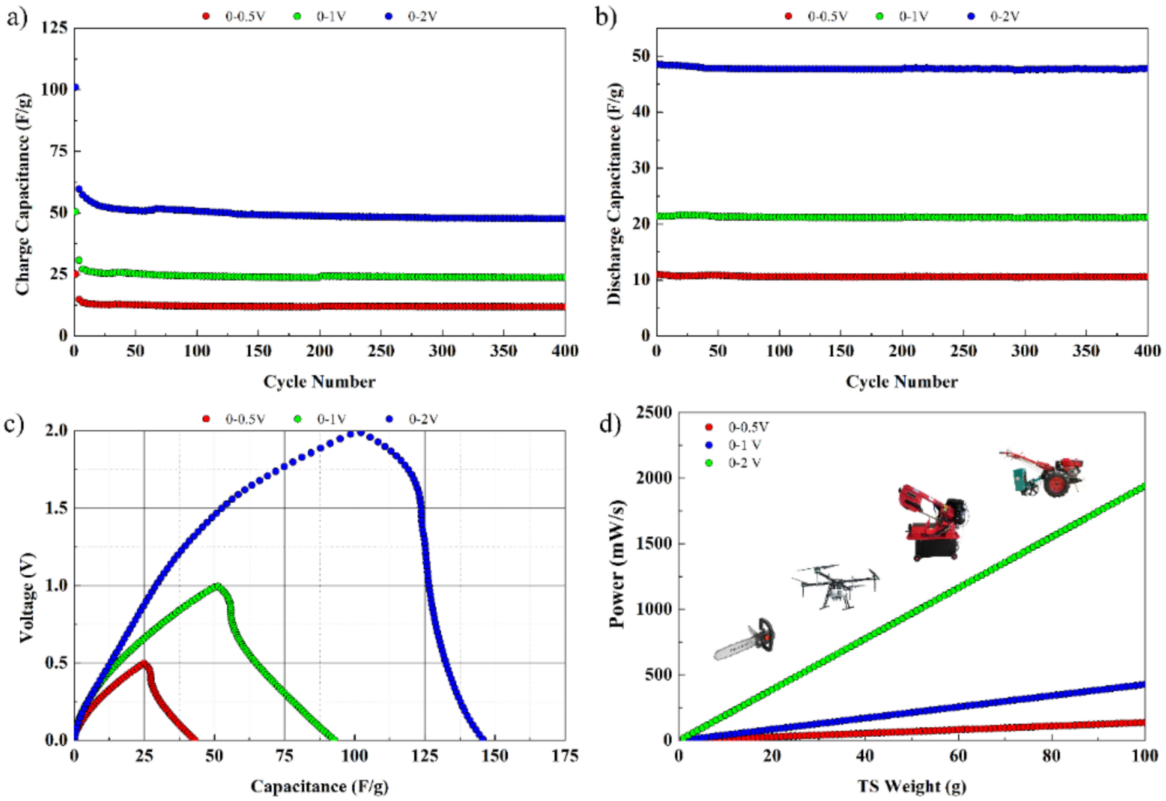

Figure 3. Charge-discharge performances of the capacitor formed with thyme sediment electrodes. a) 400-cycle charging performance, b) 400-cycle discharge performance, c) Initial charge-discharge capacity analysis and d) power performance analysis.

Figure 3 shows the charge-discharge and power performance analyzes of capacitors produced with thyme sediment electrode. When Figure 3-a and b were examined, it was determined that the highest capacitance values were reached for both charging and discharging in the 0-2V range. Under normal conditions, when capacitors have capacitance above Farad levels, they are called "Supercapacitors" (Demirel, 2020). In addition, it is known that supercapacitors are used in the power systems of high-performance electric vehicles in today's technology. In this context, when the first charge-discharge capacity values are analyzed, 101.04 F g^{-1} charge and 48.52 F g^{-1} discharge capacitance for the 0-2V range; 50.54 F g^{-1} charge, 21.41 F g^{-1} discharge capacitance for 0-1V range; For the 0-0.5 V range, 25.25 F g^{-1} charge and 11.02 F g^{-1} discharge capacitance values were obtained.

Figure 3-d and b show the charge and discharge capacitance characteristics of the capacitor formed with thyme sediment in 400 charge-discharge cycles. In general, while there was a slight decrease in capacitance values in the first 10 charge-discharge cycles, the electrodes exhibited stable energy storage characteristics in the continuing charge-discharge cycles. This stable behavior indicates that characteristic capacitors that exhibit particularly long charge-discharge life are produced. This shows that capacitors produced with thyme sediment can be operated stably for long cycles and that it is an electrode material that can be used for industrial and technological applications.

Table 1. Capacitance performance comparison of thyme sediment electrodes

Electrode	Capacitance (F g^{-1})*	Reference
Activated Carbon	39.8	(Yong et al., 2018)
Activated Carbon	32.1	(Hillier et al., 2020)
Activated Carbon	90	
Graphene	81.7	(Liu et al., 2012)
Graphene	40	(Yuning Meng et al., 2013)
CNT	22	(Pushparaj et al., 2007)
MnO_2	141.8	(Lu et al., 2013)
MnO_2	29.8	(He et al., 2013)
Polyprrole	114	(Zhao et al. 2015)
Thyme Sediment (0-0.5V)	101.04	This Study
Thyme Sediment (0-1V)	50.54	
Thyme Sediment (0-2V)	25.25	

In Table-1, the capacitive performance comparison of thyme sediment with the most commonly used electrode types in the literature is given. As a result of the comparison in Table-1, it was determined that the capacitive performance of thyme sediment electrodes was at good levels and even had higher capacitance values than many toxic and environmentally harmful electrodes. In addition, literature studies show that capacitive performance can be increased by changing the electrolyte types used in capacitors (LiOH, H_2SO_4, NaCl etc.). As a result of the potential energy and power calculations that the capacitors produced with thyme sediment electrodes can have; It can deliver ~19 mW/s of power per gram in the 0-2 V range, ~3.8 mW/s in the 0-1 V range and 0.12 mW/s in the 0.-0.5V range. Although these levels seem low, the amount of power to be produced can be increased by changing the sizes of the capacitors to be created and connecting them in series. Figure 3-d shows how this situation changes, especially when using 100 grams TS.

3.2. Agricultural economics benefit

Thyme is generally used in many areas such as health, cosmetics and food. Obtaining Thyme extracts is of great importance, especially for its use in areas such as health and cosmetics. For example, in the extraction of thyme essential oil, dried thyme is boiled in water and the essential oil is evaporated with boiled water and condensed and liquefied in the next room. As the last process, essential oil is obtained by using the density difference. So, what to do after these procedures? How much oil can be obtained from a Thyme flower? A large amount of Thyme plant is used for the essential oil obtained at an average level of 3%. At the end of this process, a large amount of Thyme sediment remains. At this point, it is of great importance to evaluate thyme sediment as an alternative product. We wonder how the use of thyme sediment in energy systems, which is one of today's current issues, can be beneficial for agricultural producers? As a result of literature research, 2-tons dried thyme can be obtained per hectare. When we analyze this situation at the oil extraction level, 60 kg of thyme essential oil per hectare can be produced with a maximum essential oil yield of 3%. Within the scope of our study, an average of 1 gram of Thyme sediment was used as electrode active material for each capacitor produced. When evaluated commercially, it is noticeable how light today's battery systems are. For example, a phone battery; Considering that the current weight of a mobile phone is 200 grams, the battery accounts for an average of 50 grams of this weight. This 50-gram weight includes the battery case and other plastic equipment. In other words, the rate of active substance that stores energy is generally around 20 grams. These figures, which are very low and ideal for industrial production, when analyzed in terms of agricultural economy, show that agricultural producers' investment in thyme production can provide economic benefits in the long term. Because while benefiting from the contents of the thyme plant, also benefiting from its sediment stands out as one of the factors that can increase the value of thyme.

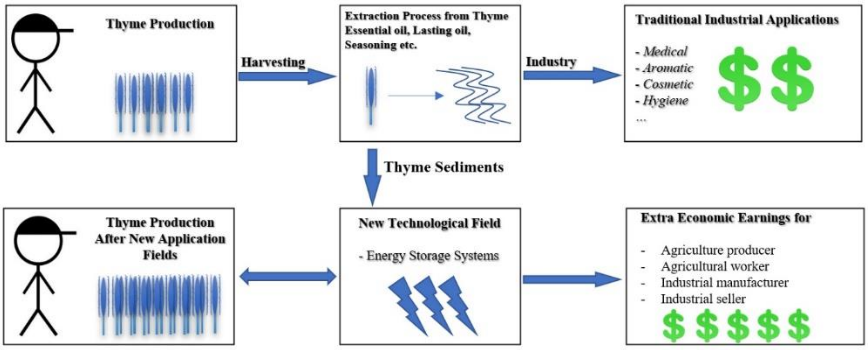

Figure 4. Creating an alternative and economic growth with the use of thyme sediment

Figure 4 is actually a picture of the basic logic we tried to explain above. The alternative created by a new field can make great contributions to both agricultural producers, agricultural workers, industrial workers and employers. Moreover, with the use of sediment, there will be a chance to leave a more beautiful world to future generations by making today's toxic energy storage systems more environmentally friendly.

The utilization of thyme sediment as an alternative electrode material not only presents a novel avenue for energy storage systems but also holds significant implications for agricultural economics. By repurposing thyme sediment, agricultural producers stand to benefit from additional revenue streams derived from the by-products of thyme extraction processes. This presents an opportunity for diversification of income sources within the agricultural sector, thereby enhancing resilience against market fluctuations and contributing to overall economic sustainability. Furthermore, the integration of thyme sediment into energy storage systems has the potential to enhance the value proposition of thyme cultivation for agricultural producers. As highlighted in our study, the lightweight nature of thyme-based energy storage solutions presents a favorable scenario for industrial production, aligning with contemporary trends towards more sustainable and efficient technologies.

Moreover, by incorporating thyme sediment into energy storage systems, agricultural producers can actively contribute to environmental conservation efforts. The reduction in reliance on traditional, potentially toxic energy storage materials in favor of eco-friendly alternatives not only mitigates environmental impact but also fosters a more sustainable agricultural ecosystem for future generations. In summary, the utilization of thyme sediment as an alternative electrode material represents a multifaceted opportunity for agricultural economics, encompassing additional revenue generation, enhanced market competitiveness, and environmental stewardship.

4. Conclusions

Thyme, which is used in many different areas, was used as an electrode in energy storage systems for the first time, using the sediment that emerged after the extraction of essential oil in the literature. For this purpose, thyme sediment coated on platinum foils and a cellulosic membrane and capacitor formula are available. Electrochemical CV measurements were made for irrigation analyzes based on energy storage performance. The results obtained show that thyme sediment, an organic product, can store energy at 2V in its capacitors and a supercapacitor can be created with a capacitance of ~101 F g^{-1}. The electrochemical electrode feature discovered for thyme sediment may create an alternative sales area for management authorization. Having thyme sediment as an alternative electrode material for capacitors will enable significant economic developments for both the energy sector and agriculture. In light of the results of this study, we recommend that policymakers consider incentivizing investments in the utilization of thyme sediments for energy storage applications. Given the organic nature of thyme sediment and its demonstrated capability to store energy effectively, there exists a significant opportunity to capitalize on this renewable resource for sustainable energy solutions. Policymakers could explore the implementation of support mechanisms such as research grants, tax incentives, and regulatory frameworks to encourage investment and innovation in this emerging field. Furthermore, fostering collaboration between research institutions, industry stakeholders, and government agencies can facilitate the development and commercialization of thyme-based energy storage technologies. By leveraging the potential of thyme sediments as an alternative electrode material, policymakers can contribute to both the growth of the energy sector and the promotion of sustainable agricultural practices, thereby fostering economic development and environmental sustainability.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

Acknowledgment

The datasets generated and/or analyzed during the current study are not publicly available for data protection reasons but are available from the corresponding author upon reasonable request.

References

2023 Thyme global market overview today. Retrieved 7 November 2023, from https://www.tridge.com/intelligences/thyme1/

Coşge Şenkal, B., 2020. The role of secondary metabolites obtained from medicinal and aromatic plants in our lives. *ISPEC Journal of Agricultural Sciences*, 4(4): 1071–1079.

Demirel, A.N.Ş., Bagi, F., Yildirim, B., Demirel, S., 2023. A new technological application field for lavender and economic profit analysis for agricultural producers. *Journal of the Institute of Science and Technology*, 13(3): 2185–2194.

Demirel, S., 2020. Bloedite-type $N_{a2}X(SO_4)_2$ (X = Ni, Mg) as novel alternative aqueous electrolyte materials for supercapacitors. *Journal of Materials Science: Materials in Electronics*, 31(22): 19809–19818.

Doğan, D.B., Kirar, N., Bilal, O., Daş, A., Avci, M., Bozkaya, F., Tufan, T., 2022. The effect of sumac supplementation on egg yield and egg quality in layer quails. *ISPEC Journal of Agricultural Sciences*, 6(4): 657–666.

Ege, G., Kalaycıoğlu, H., 2019. Türkiye'de kekik (Thymus spp.) yetiştiriciliği ve üretim teknikleri. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, 28(2): 212-220.

Feng, S., Fu, Z.H., Chen, X., Zhang, Q., 2022. A review on theoretical models for lithium–sulfur battery cathodes. *InfoMat*, 4(3): e12304.

Habekost, A., 2016. Experimental investigations of alkaline silver-zinc and copper-zinc batteries. *World Journal of Chemical Education*, 4(1): 4–12.

He, Y., Chen, W., Li, X., Zhang, Z., Fu, J., Zhao, C., Xie, E., 2013. Freestanding three-dimensional graphene/MnO_2 composite networks as ultralight and flexible supercapacitor electrodes. *ACS Nano*, 7(1): 174–182.

Hillier, N., Yong, S., Beeby, S., 2020. ScienceDirect The good, the bad and the porous: A review of carbonaceous materials for flexible supercapacitor applications.

Hou, X., Liu, X., Wang, H., Zhang, X., Zhou, J., Wang, M., 2023. Specific countermeasures to intrinsic capacity decline issues and future direction of $LiMn_2O_4$ cathode. *Energy Storage Materials*, 57: 577–606.

Jost, K., Perez, C.R., McDonough, J.K., Presser, V., Heon, M., Dion, G., Gogotsi, Y., 2011. Carbon coated textiles for flexible energy storage. *Energy & Environmental Science*, 4(12): 5060–5067.

Liu, W.W., Yan, X. Bin, Lang, J.W., Peng, C., Xue, Q.J., 2012. Flexible and conductive nanocomposite electrode based on graphene sheets and cotton cloth for supercapacitor. *Journal of Materials Chemistry*, 22(33): 17245–17253.

Lu, X., Yu, M., Wang, G., Zhai, T., Xie, S., Ling, Y., Li, Y., 2013. H-TiO_2@MnO_2//H-TiO_2@C Core–Shell Nanowires for High Performance and Flexible Asymmetric Supercapacitors. *Advanced Materials*, 25(2): 267–272.

Ma, W., Chen, S., Yang, S., Chen, W., Weng, W., Zhu, M., 2016. Bottom-Up fabrication of activated carbon fiber for all-solid-state supercapacitor with excellent electrochemical performance. *ACS Applied Materials and Interfaces*, 8(23): 14622–14627.

Olabi, A.G., Onumaegbu, C., Wilberforce, T., Ramadan, M., Abdelkareem, M.A., Al – Alami, A.H., 2021. Critical review of energy storage systems. *Energy*, 214: 118987.

Pushparaj, V.L., Shaijumon, M.M., Kumar, A., Murugesan, S., Ci, L., Vajtai, R., Ajayan, P. M., 2007. Flexible energy storage devices based on nanocomposite paper. *Proceedings of the National Academy of Sciences of the United States of America*, 104(34): 13574–13577.

Raihan, A., 2023. A review of the global climate change impacts, adaptation strategies, and mitigation options in the socio-economic and environmental sectors. *Journal of Environmental Science and Economics*, 2(3): 36–58.

Sarihan, B., Tonçer, Ö., 2021. The impact of drying methods on product quality of *Rosmarinus officinalis* L. *ISPEC Journal of Agricultural Sciences*, 5(2): 411–417.

Schmidt, E., 2020. Production of Essential Oils. *Handbook of Essential Oils*, 125–160.

Shahrajabian, M.H., Sun, W., 2023. Seed Biology and Pharmacological Benefits of Fennel, Lavender, Thyme and Echinacea Species.

Şeker, M.A., Özçelik, M., 2017. Determination of essential oil yields and quality characteristics of thyme (*Thymus vulgaris* L.) grown in different regions of Turkey. *Turkish Journal of Agriculture - Food Science and Technology*, 5(4): 446-451.

Tamboli, F.A., 2021. Medicinal plants used in cosmetics for skin and hair care. *Article in International Journal of Pharmaceutical Chemistry and Analysis*, 8(2): 36–40.

Tandrayen-Ragoobur, V., 2023. Going beyond the Covid-19 pandemic: climate change remains the biggest threat for small island developing states. *Developments in Corporate Governance and Responsibility*, 20: 71–94.

Yong, S., Owen, J., Beeby, S., 2018. Solid-State Supercapacitor Fabricated in a Single Woven Textile Layer for E-Textiles Applications. *Advanced Engineering Materials*, 20(5).

Yuning Meng, C., Zhao, Y., Hu, C., Cheng, H., Hu, Y., Zhang, Z., Shi, G., 2013. All-graphene core-sheath microfibers for all-solid-state, stretchable fibriform supercapacitors and wearable electronic textiles. *Advanced Materials*, 25(16): 2326–2331.

Zhang, J.C., Liu, Z.D., Zeng, C.H., Luo, J.W., Deng, Y. Da, Cui, X.Y., Chen, Y.N., 2022. High-voltage LiCoO2 cathodes for high-energy-density lithium-ion battery. *Rare Metals*, 41(12): 3946–3956.

Zhao, C., Chai, B., Chen, X., 2015. An improved convergence rate of A-P reconstruction algorithm and application in signal processing. *Journal of Computational and Applied Mathematics, 287*: 12–19.

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