Novel *Achillea wilhelmsii* C. Koch Nanocomposite Fabrication with Extraordinary Physical and Chemical Properties

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Abstract

In this paper, we utilized two techniques, steam extraction and Soxhlet extraction, to obtain the active components of *Achillea wilhelmsii* C.Koch. These active substances were then used to create composite nanofibers using an electrospinning machine. The morphology of the resulting nanocomposite was examined using a FESEM, and the results demonstrated that the electrospinning method and conditions were suitable. Additionally, we investigated and analyzed the anti-inflammatory efficacy of the nanocomposite produced through both methods. Furthermore, we compared and analyzed the strength, abrasion resistance, moisture content, and water supply of the samples we produced according to certain standards. Overall, the nanocomposite derived from Achillea Wilhelmsii C.Koch exhibited promising properties that could be utilized in various industries.

Keywords: Achillea wilhelmsii C.Koch; Composite; Nanofiber; Anti-inflammatory; Abrasion resistance

Introduction

Achillea Wilhelmsii C.Koch is a fascinating herbaceous perennial that has been used for centuries for its medicinal properties. This plant is native to the Middle East and has been highly valued in traditional medicine for its numerous health benefits. What makes Achillea Wilhelmsii C.Koch so special is its unique combination of compounds that have been found to possess anti-inflammatory, antioxidant, and antimicrobial properties. These properties make it a valuable herb in treating various ailments and promoting overall well-being. From treating digestive disorders to relieving menstrual cramps, Achillea Wilhelmsii C.Koch has a wide range of uses. Achillea Wilhelmsii C.Koch also has ecological advantages. This plant is known to attract pollinators such as bees and butterflies, making it an excellent addition to any garden or natural landscape. Its beautiful flowers, ranging in color from white to pink to yellow, add a touch of vibrancy wherever they bloom [1-3]. Momtaz et al. [4] in a study intended to verify whether Achillea Wilhelmsii C.Koch is able to improve colitis via mediating inflammatory cytokines. They treated animals with the hydro-alcoholic extract of Achillea Wilhelmsii C.Koch at different concentrations and the result show the extract downregulated pro-inflammatory mediators in the colon tissue.

One of the technologies that has this power to revolutionize various industries, from healthcare to electronics is nano fiber electrospinning. Electrospinning is a process that uses an electric field to produce polymer fibers. These fibers can be used in tissue engineering, drug delivery systems, filtration, sensors, and so much more. One of the most exciting applications of electrospinning nano fibers is in the field of regenerative medicine. These fibers can be used as scaffolds to support tissue regeneration, helping damaged organs or tissues heal and restore their function. The small diameter of the fibers mimics the natural extracellular matrix, promoting cell adhesion and growth. This could potentially lead to groundbreaking advancements in the treatment of injuries and diseases. This method is used to produce nano composites that are also extracted from natural materials [5-15]. For example, in a research, Ghiasi et al. [16] used this method to extract the effective elements of wheat bran and produce its nanocomposite. They announced that by producing this composite ship, which of course also contained nanomaterials, they obtained good anti-ultraviolet and anti-bacterial properties. On the other hand, in a study, Zohoori et al. [17] used effective materials of palm in combination with carbon mesoporous nanoparticles in the production of nanocomposite, which was done by electrospinning method. This research has shown the use of electrospinning in the production of nanocomposites and its results have indicated the improvement of the properties of this nanocomposite. The other research was done by Asakereh et al. [18] which used electrospinning in order to produce nanocomposites of hazelnut green shell. In this paper the researchers produced gelatin/hazelnut green shell nano composites with special properties. There are many applications of nano composites and nano membranes which can improvement in features such as hydrophilicity, permeability, salt rejection, antifouling, and stability [19].

Experimental

Materials and Devices

The *Achillea wilhelmsii* C.Koch was prepared from Alborz Mountain (Persia). Toluene, ethanol, acetic acid, tri-fluoro acetic acid and sodium chlorite was purchased from Merck. Soxhlet extractor device model EV6, 230V, 50-60Hz (Deutschland), Steam Lab Distillation Apparatus Kit (Deschem), a Euronda ultrasonic bath model Eurosonic 4D, 350 W, 50/60 Hz (Italy) was used. The morphology of nano fiber and nano materials was studied using FESEM (Field Emission Scanning Electron Microscope) (MIRA3-TESCAN). A double-head system of rotary platform was done in order to investigate the abrasion resistance through ASTM D-3884-09. The tensile strength was determined by tabletop uniaxial testing apparatus (INSTRON 3345).

Method

In this paper, two extraction methods (steam method and Soxhlet method) were performed and their characteristics were compared. In the first method (which produced sample A), steam is used to gently extract the volatile compounds from the plant material through steam lab distillation. The steam passes through the plant material, causing the essential oils and other valuable components to be released and carried away in the steam. The steam and volatile compounds are then condensed and collected, resulting in a concentrated extract. This extract contains the potent ingredients of Achillea Wilhelmsii C.Koch, which can be electrospun in next step. One of the key benefits of this extraction method is its ability to preserve the natural properties of Achillea Wilhelmsii C.Koch. Through careful processing and handling, we ensure that the extract retains its original qualities and benefits. This means that when we use products made from this extract, we are experiencing the full power and potency of Achillea Wilhelmsii C.Koch. In the second method (which produced sample B), the Achillea Wilhelmsii C.Koch of 10 grams was measured and scoured with distilled water. Milling was carried out to eliminate any wax and pollution. Then scoured with toluene/ethanol (1/2 volume percent) for 8 hours in a Soxhlet extractor apparatus. Then the solution was rested for a day at room temperature. Then, sodium chlorite, (with a pH range of 4.5 - 5.5) was added with acetic acid in order to eliminate the lignin. Then the solution was neutralized with distilled water and ethanol.

Then the obtained solution from both methods was separately dissolved in tri-fluoro acetic acid and subjected to ultrasonic bath. Afterwards, a blunt needle syringe of each solution was setup to the electrospinning apparatus and electrospun nanocomposite produced. Table1 demonstrate the electrospinning conditions.

Table1.

Eleven male Wistar rats were selected and they were all kept under the same conditions for 24 hours. All experiments and tests were done pursuant to animal rights laws. Then the hair cover on the back of the rats were shaved and covered with prepared composites and tied stoutly (in order to reduce laboratory error, five rats were tested for each composite. One sample was covered with Indomethacin cream as a control sample).

Results and Discussion

Morphological Analysis

The morphological analysis of electrospinning nano fibers involves a comprehensive investigation into their physical characteristics at the microscopic level. It allows us to study the arrangement and distribution of nanofibers, as well as their size, shape, and surface features. Through advanced imaging techniques like scanning electron microscopy (SEM) we can capture high-resolution images that showcase the intricate details of these fibers. This in-depth analysis enables us to understand how different parameters, such as polymer concentration, voltage, and solvent composition, influence the morphology of the electrospun nanofibers. The scanning electron microscopy image of the samples is depicted in Figure1. The nano composite's diameter, as observed in Figure1, measures approximately 39nm. Additionally, Figure1 reveals that the nano fibers are created via electrospinning. Upon closer examination, it is evident that the thickness of the nano fibers and their beads does not exceed 50nm, which is highly satisfactory. Due to the achieved images, we come to conclusion that the electrospinning parameters was good because we have not any necking in SEM.

Figure1.

Strength and Abrasion Properties

Fabrics/fibers are subjected to different forces and stressors within their longevity. Nano fibers, with their minuscule size and exceptional durability, have become a game-changer in various industries. In this test, rubbing test of 30 cycles was done and the discrepancy in sample mass after and before abrasion was studied for each sample. As shown in Table 2, the abrasion resistance of both samples produced from Achillea Wilhelmsii C.Koch is very good and even after 30 rubbing cycles, they still show a resistance higher than 90%. By comparing the abrasion resistance of two samples A and B, it can be seen that there is no significant difference between these two samples, and therefore it can be said that the abrasion resistance of both samples is almost the same. It is worth mentioning that the abrasion resistance of both produced samples is much higher compared to other similar cellulosic fibers [20] and it can be concluded that the use of Achillea Wilhelmsii C.Koch in the production of nano fibers can lead to the production of fibers with high abrasion resistance.

On the other hand, in order to investigate the strength of the samples, the produced nano fibers were subjected to tension. The results showed that the strength of both produced samples is very high and of course almost the same. This is despite the fact that the strength of these nanofibers is much higher compared to cellulose nanofibers [21]. The strength of these nanofibers can be attributed to its unique molecular structure and composition. The fibers are composed of long chains of organic molecules that are tightly packed together, creating a dense and strong material. This molecular arrangement allows the nanofiber to withstand high levels of stress and strain without breaking or deforming. Furthermore, the nanofiber's abrasion resistance is also remarkable. Abrasion resistance refers to the ability of a material to resist wear and tear caused by friction. In the case of Achillea Wilhelmsii C.Koch nanofiber, its high abrasion resistance can be attributed to several factors. Firstly, the dense molecular packing provides a strong barrier against external forces that could cause abrasion. Additionally, the nanofiber's surface is smooth and free from irregularities, reducing friction and minimizing the likelihood of abrasion. The reason behind the strength and abrasion resistance of Achillea Wilhelmsii C.Koch nanofiber can also be linked to its natural properties. Achillea Wilhelmsii C.Koch is a plant that grows in harsh environments, such as arid regions. To survive in these conditions, the plant has developed mechanisms to protect itself from external stressors. These mechanisms translate into the nanofiber's exceptional strength and durability. Moreover, the presence of certain compounds within Achillea Wilhelmsii C.Koch nanofiber may contribute to its strength and abrasion resistance. These compounds could include lignin, cellulose, and other organic substances that enhance the material's mechanical properties. The combination of natural adaptations and chemical composition makes Achillea Wilhelmsii C.Koch nanofiber a robust and resilient material. In conclusion, the strength and abrasion resistance of Achillea Wilhelmsii C.Koch nanofiber can be attributed to its unique molecular structure, smooth surface, natural adaptations, and chemical composition.

Table2.

Anti-inflammatory Analysis

Inflammation is a natural response of the immune system to injury or infection, but when it becomes chronic, it can lead to a range of diseases, including arthritis, asthma, and inflammatory bowel disease[22-24]. This test was done based on Winter technique [25]. A digital caliper was used in order to measuring the diameter of hind paw, before and after injection of carrageenan. This calculation was repeated every 30min for 5hours. As the results show in edema diagram (Figure2), the edema reduction of the sample A and B are clearly visible after 60 minutes, while this property is present in the control sample from the very beginning and after about 240 minutes, the effects of samples A and B and the control sample were very close to each other. This is while sample A reached its best effect earlier than the control sample, i.e. after 210 minutes (the control sample reached this point after 240 minutes). By comparing samples A and B, we come to the conclusion that both samples have a relatively similar effect and both samples work the same, but sample A works a little better than sampleB.

This study has demonstrated that Achillea Wilhelmsii C.Koch nanofibers can effectively suppress the production of pro-inflammatory molecules, such as cytokines and chemokines. These molecules play a key role in the inflammatory process by recruiting immune cells to the site of inflammation and promoting tissue damage. By inhibiting their production, Achillea Wilhelmsii C.Koch nanofibers help alleviate inflammation and reduce associated symptoms. The anti-inflammatory effects of Achillea Wilhelmsii C.Koch nanofibers are attributed to the presence of bioactive compounds, such as flavonoids and terpenoids, which have been shown to possess anti-inflammatory activity. These compounds modulate the activity of inflammatory mediators and enzymes, suppressing the inflammatory response and promoting tissue repair.

Figure2.

Moisture Content and Water Supply

Proper hydration is essential for maintaining healthy skin. When the skin becomes dehydrated, it can lead to dryness, flakiness, and a compromised skin barrier. This not only affects the appearance of the skin but also increases the risk of various skin conditions, such as eczema and dermatitis [26-29]. The moisture content and water supply of the produced nanocomposites were investigated and measured through the AATCC-20A standard as equation1, where Wh is the weight of the composites after being exposed to moisture and Ws is the weight of the samples after dehumidification.

$$\mathrm{TH}\ (\%) = \frac{\mathrm{Wh}-\mathrm{Ws}}{\mathrm{Ws}} \times 100 \qquad \text{Eq.1}$$

Both samples A and B were subjected to this test five times each one (due to the elimination of laboratory error) and the average data indicates that the moisture content of samples A and B are very close to each other, 18.65% and 18.48%, respectively. This difference is small and negligible. Therefore, it can be said that the wettability of both produced composites is similar. Meanwhile, according to previous research [17], the moisture content of cellulose sample (which are cellulosic and the same as these two samples) is about 11%. Achillea Wilhelmsii C.Koch nanofibers offer strong water supply benefits, making them an excellent choice for individuals looking to improve skin hydration. The nanofiber structure of Achillea Wilhelmsii C.Koch allows for the retention of a high amount of water, creating a moist environment that helps prevent trans epidermal water loss. In addition to their water retention properties, Achillea Wilhelmsii C.Koch nanofibers also promote the absorption of moisture from the environment. This means that even in dry conditions, the nanofibers can continuously supply water to the skin, ensuring optimal hydration levels.

Conclusion

The findings presented in this study indicate that both Soxhlet extraction and steam extraction of *Achillea wilhelmsii* C.Koch yield similar outcomes in terms of the final properties of the nanocomposite fiber. However, the steam method appears to have a slight advantage. The interaction between bioactive compounds, such as terpenoids and flavonoids, with skin cells leads to an increase in the anti-inflammatory properties of the samples. These compounds, including lignin, cellulose, and other organic substances, enhance the strength and abrasion resistance of the produced samples, contributing to their mechanical properties. On the other hand, the moisture content and water absorption of the produced nanocomposite are higher compared to other cellulosic materials. Overall, while the effects of Soxhlet and steam extraction are similar, the steam method shows slightly better results. In this particular case, the research not only provides valuable data and insights to the nano composite production sector, but it also advances our understanding of how various methods can fundamentally change the properties of composite textiles. This contribution is essential for the industry as it helps propel advancements in the field of composite material production.

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Availability of data

Data available on request from the authors

Conflict of Interest

All authors declare that they have no conflicts of interest.

Research ethics

Not applicable

Author contributions

MM designed this study, and done the experimental work. The author read and approved the final manuscript.

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Figure Captions

Figure1. SEM of samples (right: sample A, left: sample B)

Figure2. Inflammatory diagram of samples

Table1. Electrospinning conditions

Feeding rate (ml/h)	Drum speed (rpm)	Collector-needle distance (cm)	Traverse speed (m/min)	Voltage (kV)
0.4	135	15	0.3	20

Table2. Abrasion resistance and tensile strength of samples

Sample	Fabric weight before abrasion (g)	Fabric weight after abrasion (g)	Abrasion resistance (%)	Tensile strength(MPa)
Raw			~84	~0.694
A	5.634	5.147	91.35	1.365
B	5.496	4.991	90.81	1.374

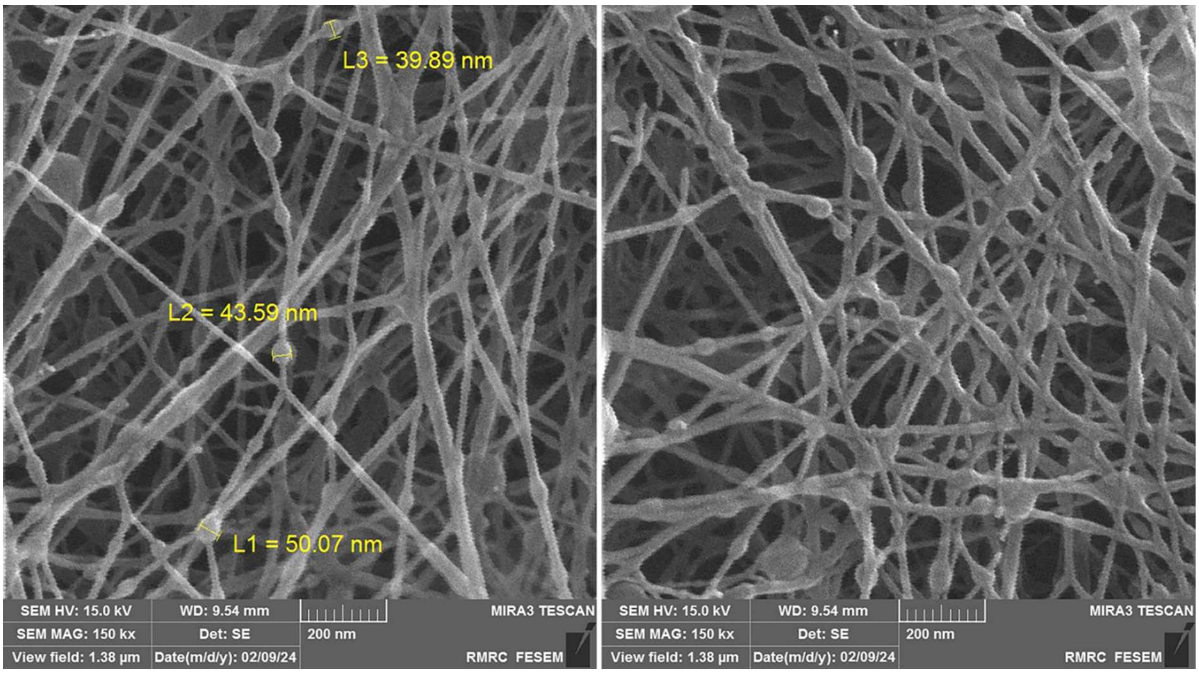
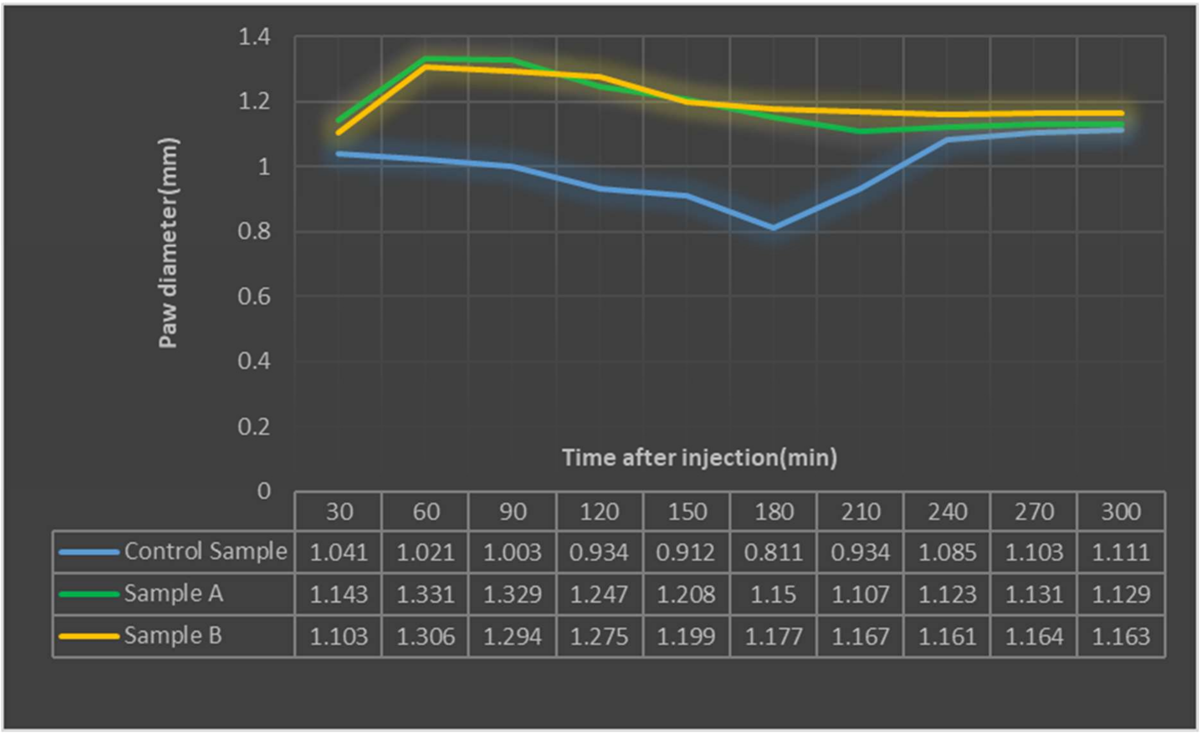

L3 = 39.89 nm
L2 = 43.59 nm
L1 = 50.07 nm
SEM HV: 15.0 kV
WD: 9.54 mm
MIRA3 TESCAN
SEM MAG: 150 kx
Det: SE
200 nm
View field: 1.38 μm
Date(m/d/y): 02/09/24
RMRC FESEM
SEM HV: 15.0 kV
WD: 9.54 mm
MIRA3 TESCAN
SEM MAG: 150 kx
Det: SE
200 nm
View field: 1.38 μm
Date(m/d/y): 02/09/24
RMRC FESEM

Figure 1



	30	60	90	120	150	180	210	240	270	300
Control Sample	1.041	1.021	1.003	0.934	0.912	0.811	0.934	1.085	1.103	1.111
Sample A	1.143	1.331	1.329	1.247	1.208	1.15	1.107	1.123	1.131	1.129
Sample B	1.103	1.306	1.294	1.275	1.199	1.177	1.167	1.161	1.164	1.163

Figure 2