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Using Nanocellulose as Ibuprofen Delivery System

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Abstract

The preparation of green organic nanomaterials is one of the newly adopted methods in the fields of sustainable environmental health. This paper aims to use nanocellulose produced from laboratory starch, in reduce the medicine released in simulation conditions of the human body. A Fourier-transform infrared spectroscopy (FTIR) was used to identify the structure of starch and their nanocellulose. The presence of nanocellulose structure was confirmed by FTIR spectra, which detected many functional groups such as (-OH) wide (3100-3600 cm^{-1}), (C-H) (2800-3000 cm^{-1}), (C-H) symmetric bending (1400 cm^{-1}), and (C–O–C) stretching (856 cm^{-1}), The primary distinctive peaks were found in the fingerprint region of the absorption band (856 cm^{-1}), which is attributed to the stretching of the (C-O-C) group at β-(1→4)-glycosidic connections. Atomic force microscopy showed nanoscale of prepared nanocellulose, but with significant nature and low surface roughness, were confirmed by showing the mean diameter (21.8 nm) whereas, an arithmetic mean height (17.08 nm). When using nanocellulose in an adsorption of Ibuprofen, from resulting the mean diameter increased to limits (71.3) instead of (21.8 nm) for nanocellulose alone, accompanied by a noticeable decrease in roughness and increased in mean height to reach (179.7 nm). The difference was clear with the variation of surface roughness parameters produced after adsorption with Ibuprofen. It is noted that prepared nanocellulose deviated in its values with Ibuprofen by leaving nanoscale, which may be attributed to chemical structure of Ibuprofen.

Keywords: Environmental Health, Ibuprofen Delivery System, Nanocellulose

1. Introduction

Environmental contaminants harmful effects on animals and human have become a growing source of health worries in recent years.[1-4] Finding solutions that could quickly and easily lower pollution levels to risk-free levels is urgently needed. In the new studies offer new way to clean the environment and enhance the efficiency of existing technologies by using green nanotechnology and limiting the release of contaminants or halting their development, this technique is also being using for use in health pollution control.[5,6]

With its unique chemical properties and thermal stability, low cost, and high degrading activity, green nanotechnology has the potential to enable production of desirable materials for environmental health treatments.[7-9]

Green chemistry is a new emerging field that aim to work at the molecular level to synthesize products and processes that are beneficial to human health and the environment and to achieve sustainability and provide a strong solution to disposal of harmful waste and decompose chemicals after use in order to prevent pollution and reduce waste risks by using biomass-derived compounds, which have a lower CO_2 footprint.[10] The field has received widespread interest in the past decade due to its ability to harness chemical innovation to meet environmental health and economic purpose simultaneously.[11]

In recent years, nanocellulose synthesis and application has achieved remarkable growth as polymer reinforcement in order to create high-performance biomaterials.[12] It is one of the most plentiful organic molecules generated from plant biomass.[13] Wood, bast fibers, grasses, seed fibers, marine animals, algae, fungus, invertebrates, and bacteria are all sources of cellulose, which can be derived from a variety of sources.[14,15]

Nanocellulose and its applications have been discovered to be a major controlling material in both research, medicine and industry this is due to their various properties, which include high surface area, natural properties with (100%) environmental friendliness, outstanding mechanical properties, and a large number of hydroxyl groups for modification.[16,17]

The hydroxyl surface groups of cellulose can become readily accessible and provide rich chemistry possibilities such as plenty of exchangeable protons and high catalytic activity. Therefore, it is possible to deals with innovative approaches to prepare new sustainable usable materials in terms of super colloidal and super molecular modifications.[18]

It was found that various therapeutic agents can be bound and released using some modifications. Therefore, nanocellulose has been used in several medicine delivery experiments.[19,20]

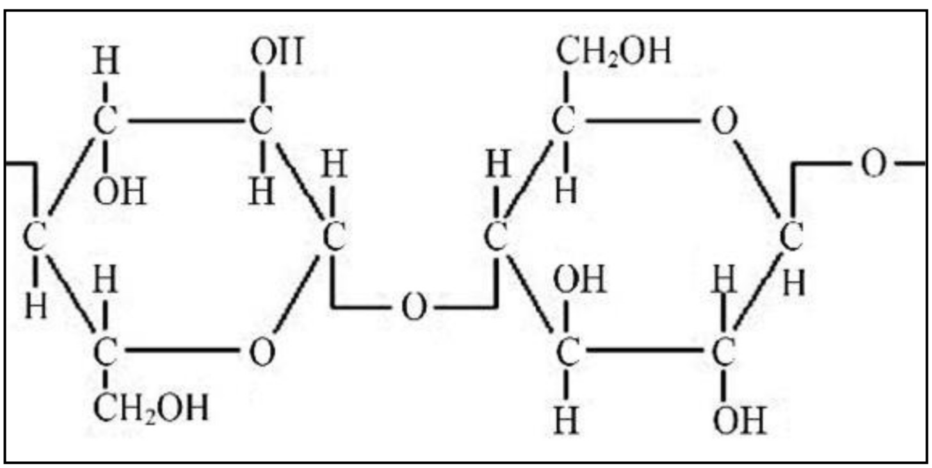


Figure 1. Chemical Structure of Cellulose ($C_6H_{10}O_5$).[21]

Ibuprofen is (2RS)-1[4-(2-methyl propyl) phenyl] propionic acid is ibuprofen. In 1969, the first propionic acid derivative, Ibuprofen, was developed as a better alternative to Aspirin. Gastric discomfort, nausea, and vomiting are the most prevalent side effects. However, they are less common than aspirin or indomethacin.[22]

Ibuprofen is the most often used and prescribed non-steroidal anti-inflammatory drug (NSAID).[23,24] It is a non-selective cyclo-oxygenase-1(COX-1) and cyclo-oxygenase-2 inhibitor (COX-2).[25]

It has a notable analgesic and antipyretic function, despite its anti-inflammatory characteristics being less than those of several other NSAIDs. Its actions are attributed to inhibitory effects on cyclooxygenases, which play a role in the production of prostaglandins. Prostaglandins play a critical part in the development of pain, inflammation, and fever.[26]

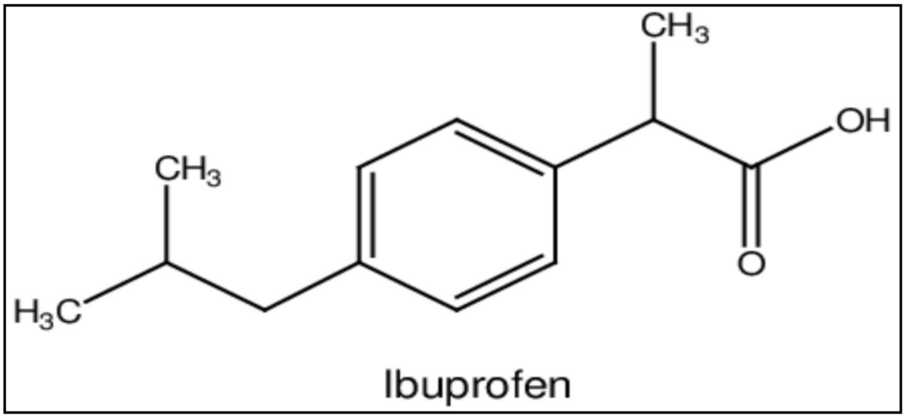


Figure 2. Chemical structure of Ibuprofen ($C_{13}H_{18}O_2$).

Ibuprofen, on the other hand, has side effects.[27] The effects on the gastrointestinal tract (GIT), the kidney, and the coagulation system are among the most serious side effects.[28]According to clinical study data, major GIT reactions such as hematemesis, peptic ulcer,[29] and severe stomach discomfort led to therapy cessation.[30]

This paper will include the subject of the susceptibility of nanocellulose, which was prepared from laboratory starch in a green friendly way, in its great adsorption and loading of Ibuprofen on its surface as a carrier and preservation system and its follow-up with technique of an atomic force microscopy and the impact of medicine loading on the nanoscale of the carrier.

2. Work Methods

1. Preparation procedure of nanocellulose [31]

It can be use lab-starch after filtration step can be taken to dry it. Heated to 50 Cº for (1 hour) after making a solution from starch and (50 ml) de-ionized distilled water. Add (3) drops from citric acid (extract of lemon juice) were added to the extracted sample Figure (3). Isolate the powder by centrifugation step (10 minutes) at (6000 rpm), and then filtered through Whitman filter paper 42 (2.5 μm). Evaporation and washed with de-ionized distilled water to get dry nanocellulose at room temperature.

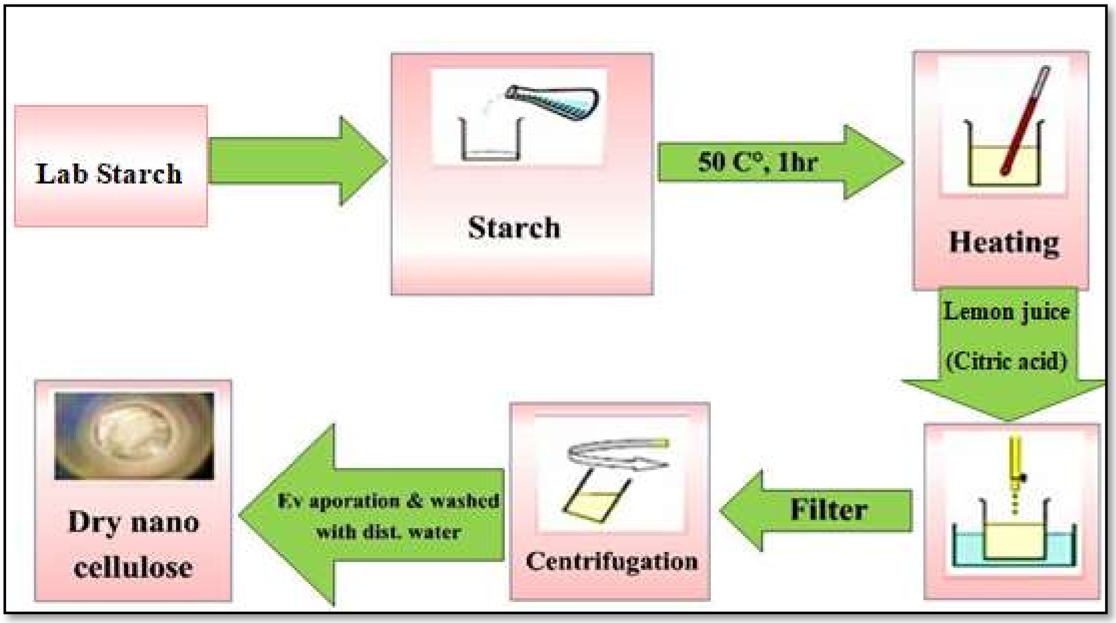


Figure 3: Scheme for preparation of cellulose nanocrystals[32]

2. Mixture nanocellulose and Ibuprofen

The purpose of this adsorption is to determine if nanocellulose has an ability to be used as a pharmaceutical carrier for Ibuprofen. The mix was made by take (10 mg) of nanocellulose prepared from lab starch and with used medicine (Ibuprofen) in volume (50 ml of 611 ppm) de-ionized water, through stirring reaction for (5 min) and then titrated against a sodium hydroxide. After that, the mixture was leave it to evaporate water by rotary evaporator under vacuum to isolate powder mix and prepare the samples to AFM measurements.

3. Results and Discussion

1. Fourier-Transform Infrared Spectroscopy (FTIR)

The stretching of the (-OH) group caused an absorption peak to appear in the range of (3600-3100 cm^{-1}) on the FTIR spectrum, and the stretching of the (C-H) group caused a peak to occur at (3000-2800 cm^{-1}). The band was seen at (1651 cm^{-1}) across from the water absorptions bending (H-O-H) at(1400 cm^{-1}), the (C-H) group underwent symmetric bending.

The primary distinctive peaks were found in the fingerprint region of the absorption band (856 cm^{-1}), which is attributed to the stretching of the (C-O-C) group at β-(1→4)-glycosidic connections. Figure (4). shows FTIR spectra that supported the existence of nanoscale of the cellulose.

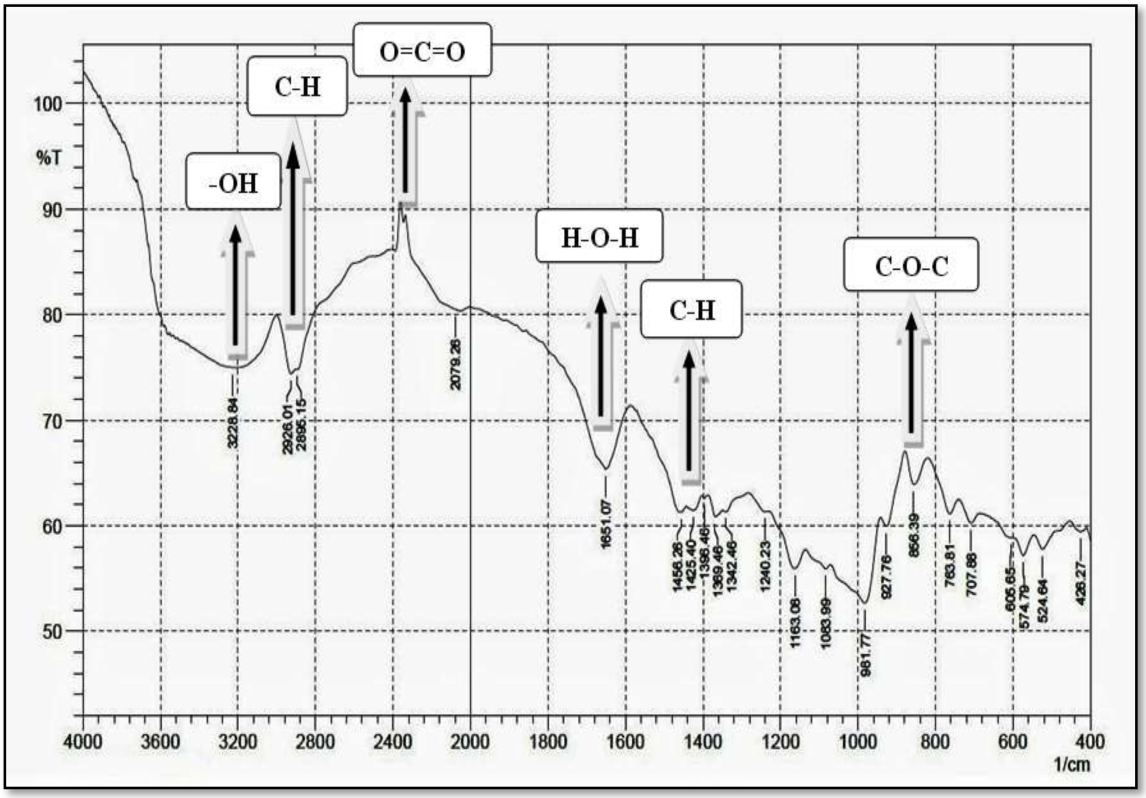


Figure 4. FTIR spectra for lab starch-based nanocellulose.

It appears clearly observation after mixing the Ibuprofen medicines an attempt of adsorption with nanocellulose from lab starch.

The distinctive peaks found in the fingerprint region of the absorption band (937 cm^{-1}), which is attributed to the stretching of the (C-O-C) group at β-(1→4)-glycosidic connections This is due to the mixing with nanomaterials. The Figures (5 and 6) showed that.

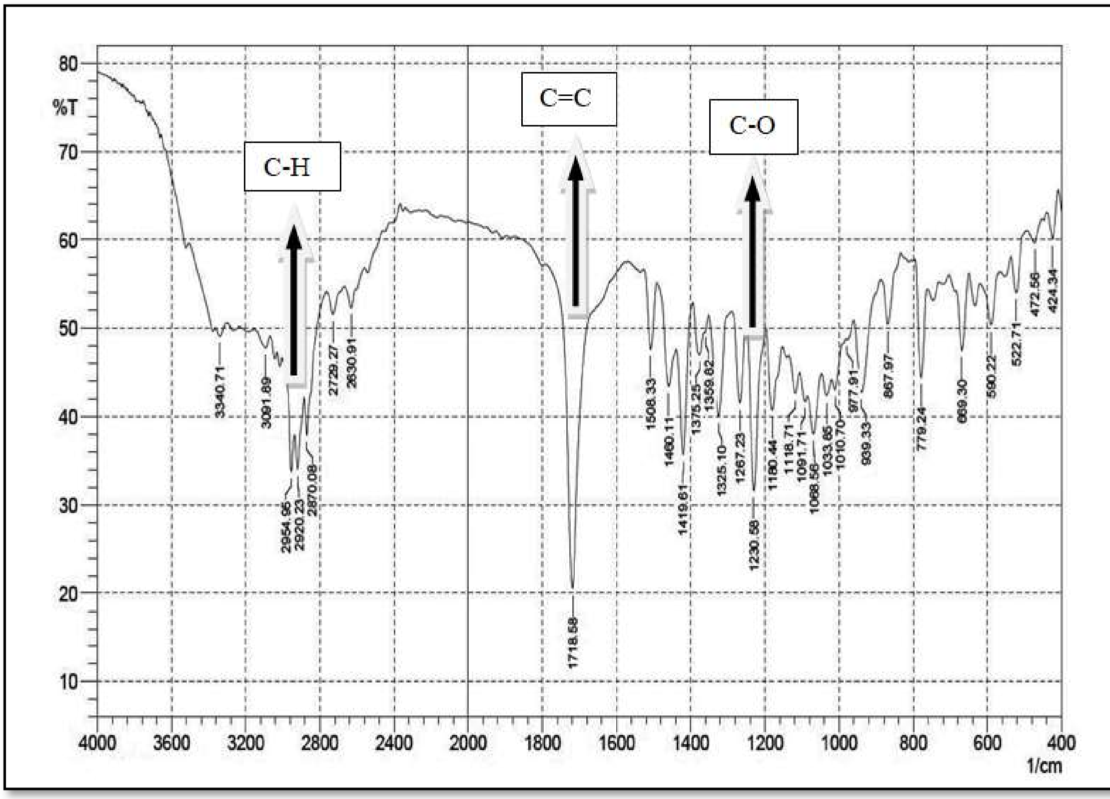


Figure 5. FTIR spectra for Ibuprofen medicine without nanocellulose.

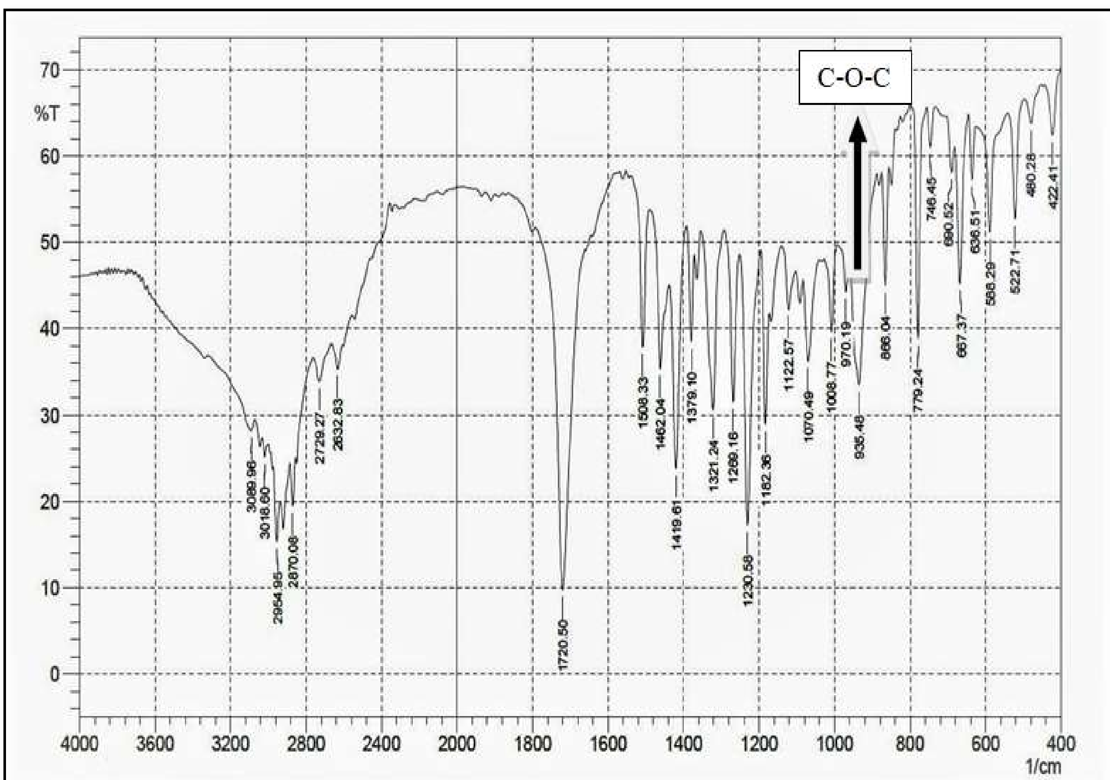


Figure 6. FTIR spectra for Ibuprofen with prepared nanocellulose.

The peaks of nanocellulose appear clearly at limits of (1500-400 cm^{-1}) that prepared from lab nanocellulose. While its observe after mixing Ibuprofen with nanocellulose, the peaks were clear, as shows in Table (1).

Table 1: FTIR peaks of the studied samples

No.	IR-absorption frequency	Ibuprofen	Lab starch	Prepared Nanocellulose	Ibuprofen with nanocellulose
1	4000-2500 cm^{-1}	3340.71 3091.89 2954.95 2920.23 2870.08 2729.27 2630.91	3388.93 3271.27 2929.87	3228.84 2926.01 2896.15	3089.96 3018.60 2632.83
2	2500-1500 cm^{-1}	1718.58 1506.33 1460.11 1419.61 1375.25	2046.47 1647.21	2079.26 1651.07	1720.50 1508.33
3	1500-400 cm^{-1}	1359.82 1325.10 1267.23 1230.58 1180.44 1118.71 1091.71 1068.56 1033.85 1010.70 977.91 939.33 887.97 779.24 669.30 590.22 522.71 472.56 424.34	1460.11 1423.47 1369.46 1303.88 1238.30 1161.15 1083.99 987.55 927.76 856.39 793.81 709.80 605.65 578.35 574.79 524.64 478.35 428.20 420.48	1458.26 1425.40 1396.46 1342.46 1240.23 1163.08 981.77 763.81 707.88 426.27	1462.04 1379.10 1321.24 1269.16 1182.36 1122.57 1070.49 1008.77 970.19 935.48 866.04 746.45 690.52 667.37 636.51 588.29 480.28 422.41

2. Atomic force microscopy (AFM) measurements

Atomic force microscopy (AFM) measurements of nanoscale of cellulose prepared from lab starch, were confirmed by showing the mean diameter (21.8 nm) but with different significant nature and clear lower surface roughness, as observed in the surface images of nanocellulose Figure (7).

This is due to the origin of the prepared material source and its different chemical structure. Whereas, an arithmetic mean height was (17.08 nm), according to topology parameters of surface roughness.

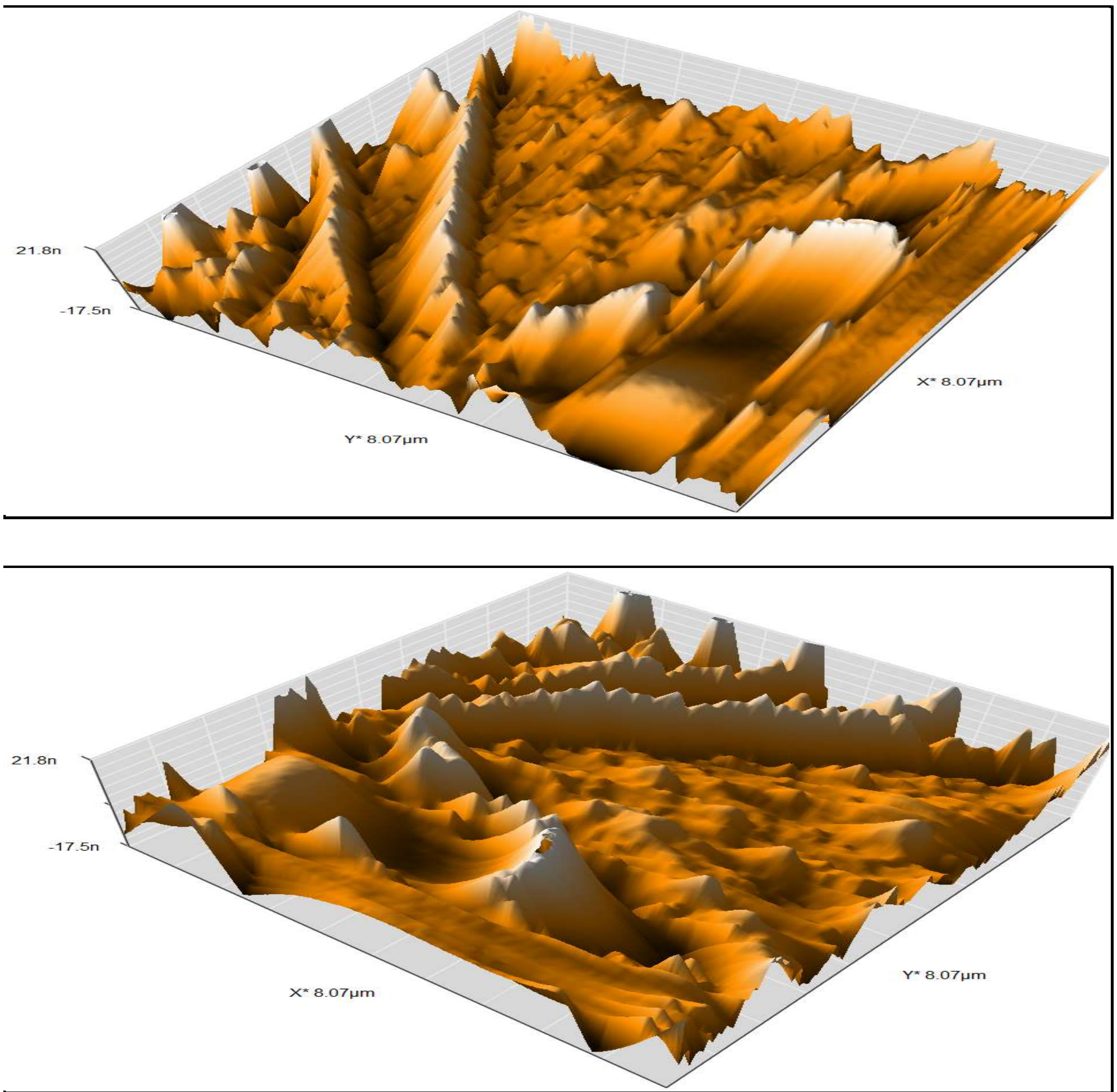


Figure 7. Surface images of lab-based nanocellulose.

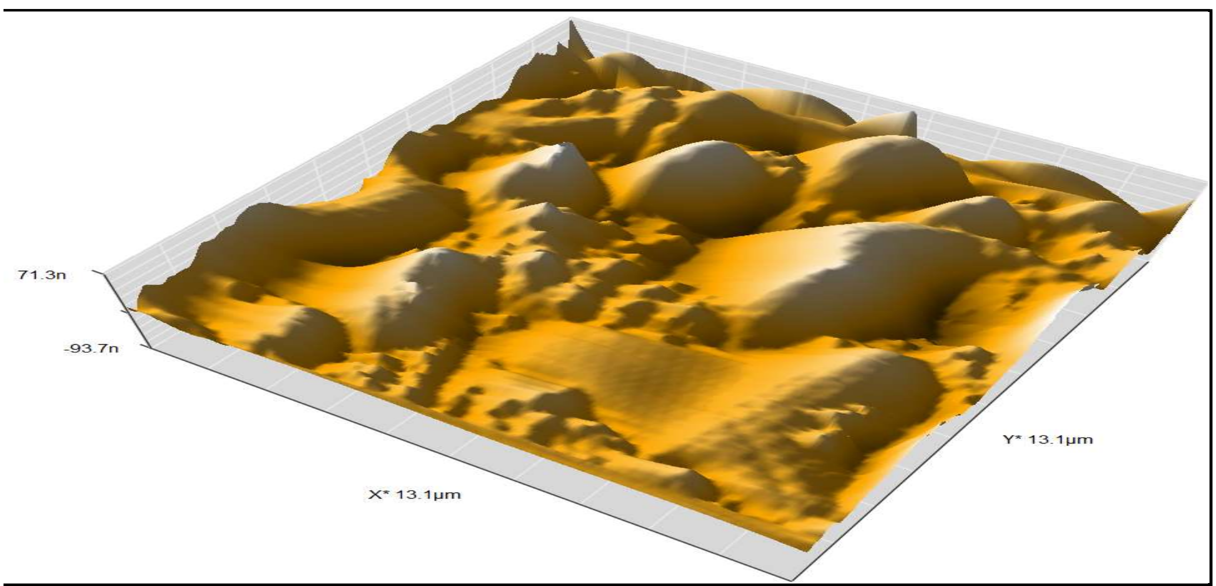
From the surface images above of the nanocellulose sample nature of the surface of the lab starch-based nanocellulose, which was characterized by low interesting in the roughness of the surface and the disappearance of the sharp peaks, which makes it take a shape closer to the sand hills in the desert.

These properties and Nano-parameters of the surface topology of prepared nanocellulose which is the required useful green tool with low nanoscale, large surface area, good crystallization, biodegradability, and application in various vital processes such as nutrition, adsorption or encapsulation of medicines, decomposition of toxic organic compounds, sensors for pathogens in water, absorbents for oil spills in water and sequestering carbon dioxide in the atmosphere, nanocellulose membranes which are used to remove various heavy metals, oil, and pharmaceuticals that still pose a threat to aquatic life and thus for human and environment.[33-35]

A cellulose nanomaterial with unique physicochemical properties has been applied as modern multifunctional smart tool in many vital fields.[36-40]

3. Ibuprofen adsorption by lab starch-based nanocellulose

When using lab starch-based nanocellulose in the process of adsorption and loading of Ibuprofen, it was observed from the resulting surface images that the Nano-sized diameter increased to reach the limits of (71.3) instead of (21.8 nm) for nanocellulose alone, accompanied by a noticeable decrease in roughness. as in the Figure (8).



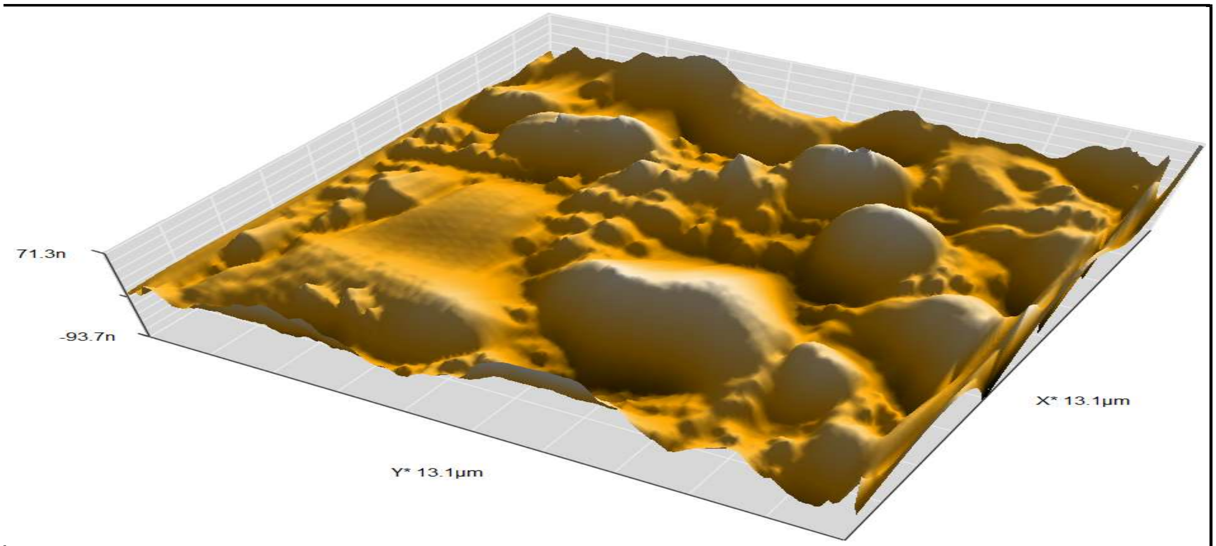


Figure 8. Surface images of prepared nanocellulose and Ibuprofen.

In order to gain some useful information about the height, functional, and hybrid of topology parameters regarding the prepared Nano-surface of prepared nanocellulose and adsorption with medicine (Ibuprofen).

The difference was clear with the variation of the values for the surface roughness parameters produced before and after adsorption with medicine. It is noted that prepared lab starch-based nanocellulose deviated in its values with Ibuprofen by leaving the nanoscale range, which may be attributed to the chemical structure of the Ibuprofen as well as the type of nanocellulose used, as described in Table (2).

Table 2. AFM measurements for Ibuprofen adsorption by nanocellulose

Parameters	Lab starch-based nanocellulose	Nanocellulose and Ibuprofen
Root-mean-square height (nm)	24.96	337.2
Skewness	1.508	2.844
Kurtosis	10.75	20.17
Arithmetic mean height (nm)	17.08	179.7
Inverse areal material ratio (nm)	29.6	183.7
Material ratio height difference (nm)	53.12	478.3
Developed interfacial area ratio	1.578	20.21

4. Conclusions

1. Cellulose nanocrystals were successfully produced from lab cellulose using a green analytical method in which citric acid (lemon juice) was used as a substitute for other concentrated acids used in the hydroacidification method such as (HCl, H_2SO_4, and CH_3COOH).
2. The adsorption capacity of those organic nanocrystals were tested with Ibuprofen to see if they could successfully encapsulate it with such carrier.
3. The preparation and adsorption processes were followed up with FTIR technique, as a results showed disappearance and emergence of new peaks, a qualitative indication of a reaction and a change in the structure and nature of the previous or new chemical bonds.
4. The adsorption and mechanism of drug carrier system were followed up by AFM technique, showed surface images of carrier system and parameters of surface topology, a great variation in it after the adsorption process and before it, which resulted in the surface of the carrier leaving the nanoscale as a result of the accumulation of drug molecules on it and chemical adsorption with hydrogen bonds (inter and intra).

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Conflicts of Interest: The authors declare no conflict of interest.

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