

Evaluation of the Metachromatic Effect on Broom Weed (*Sida acuta*) Fibre Production

Mikyitsabu Ago Atoshi and Ataitiya Hyelalibiya

Department of Chemical Sciences,

Federal University, Wukari, Taraba State, Nigeria

Corresponding Author: agomikyi@gmail.com

ABSTRACT

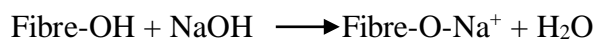
Fibre extraction process is the process of separating fibres from plant parts (stems, fruits, leaves, bark, and roots). In this work, natural fibre was extracted from *Sida acuta* stem bark using both alkaline and acidic treatments. The moisture content and weight absorption were determined. The functional groups of *Sida acuta* were confirmed using the FTIR analysis and the metachromatic effect on the extracted fibre was evaluated. The study showed that moisture content was 14.46% and weight absorption was determined to be 36.2% for the natural fibre extracted. An elongated broad absorption of O-H stretching vibration in alpha-cellulose and hydrogen bond of the hydroxyl group was observed. The peak was at 2918 cm^{-1} which relates to aliphatic C-H stretching vibration from CH and CH₂ of methyl. The metachromatic effect observed for NaOH solution extraction of the fibre showed colour change, from yellow to green and to blue colouration whereas, the fibres extracted in acidic solution became reddish brown with increasing concentration of hydrochloric acid. The fibre treated with both alkaline and acidic solutions showed metachromatic changes with changes in concentrations. This means that natural fibres can change colour in different alkaline solutions of different concentrations.

Keywords: Extraction, metachromatic, *Sida acuta*, Broom weed.

INTRODUCTION

Sida acuta is a shrub that belongs to the family, Malvaceae (the same family with *Corchorus olitorius*—known as *Ewedu* in Yoruba speaking part of Nigeria). Though perceived to be a weed, it has found both recognition and use in healthcare dispensation in many parts of the world. It is called *Isekotu* in Yoruba. Some research reports have shown that the ethanol extract of the plant is effective against the venom of certain snake species [1]. Natural fibre-based manufacturing plants can control the emission of hazardous chemical and non-degradable waste generation during the manufacturing over the synthetic fibres-based manufacturing plant [2]. The fibre covers cellulosic semisolid flush which is reinforced by the fibre [3]. The fibres are eco-friendly,

inexpensive, available in nature, renewable and therefore the determination of the fibre potential characteristics to the technical arena is essential. Alkaline treatment or mercerization is one of the best used chemical treatments for natural fibres [4]. Due to alkali treatment, there is an increase in the amount of amorphous cellulose at the expense of crystalline cellulose. By this treatment there is a removal of hydrogen bonding in the network structure. Reaction which takes place during this treatment is shown:



The type of treatment with alkali such as KOH, LiOH, NaOH and its concentration will influence the degree of swelling and degree of lattice transformation into cellulose [5]. Mishra *et al* reported that 5% NaOH treated fibre reinforced polyester composites have better tensile strength than 10% NaOH treated composites, because at high concentration, there is delignification of natural fibre taking place and as a result damage of fibre surface [6]. The tensile strength of composite decreased drastically after certain optimum NaOH concentration. Alkali solution not only affects the cellulosic components inside the plant fibre but also affect the non-cellulosic components such as hemicellulose, lignin and pectin [7]. Examination on the effect of NaOH at concentrations 0.5, 1,2,4 and 10% for treating Sisal fibre reinforced showed that maximum tensile strength resulted from the 4% NaOH treatment at room temperature.

Sida acuta is a weed plant which exhibit a metachromatic characteristic when extracted in different alkaline and acidic solutions of different concentrations.

Therefore, this work is aimed at evaluating the metachromatic potentials in *Sida acuta*.



Plate 1: Broom weed plant (*Sida acuta*)

MATERIALS AND METHODS

Broom weed plants, Digital weighing balance, NaOH, pH meter, Nikon Eclipse ME 600 microscope, Universal testing machine (model UTM: M500-50), Thermo Scientific Nicolet iS5-iD1 machine for FTIR spectroscopy.

Collection and Preparation of Plant Material

Broom weed stem bark was gotten within the premises of the Federal University, Wukari, Nigeria. The stem bark was soaked in different concentrations of both acid and base.

The following steps were followed:

- i. Sample collection and Handling: Samples collected were properly labeled to preserve their identity when treated with both acid and base at different concentrations.
- ii. Reagent purity: All chemicals used were of analytical grade.

Metachromatic Effect on Extraction of the Fibre

Broom weed plants stem bark was obtained and the stem bark cut into equal parts of four each weighing 0.1kg. Sodium hydroxide solutions of 0.1 M, 0.05 M, 0.01 M and 0.00 M were prepared and also hydrochloric acid solution of 0.1 M, 0.05 M, 0.01 M and 0.00 M were also prepared each poured into labeled containers. The broom weed stem barks were completely immersed into the eight labeled containers and covered. The stem bark was allowed to stay in the solution for 2 weeks and the pH change was monitored daily using a pH meter. The colour intensity was studied for the broom weed stem bark in various solutions. The metachromatic change that appeared on each fibre is evaluated using the dye found in the solution after the fibre has been removed.

Determination of moisture content

The moisture content of the broom weed stem bark was determined after the final weight of the various trunks (which were dried in the oven for 72h) was measured. The moisture content was calculated using:

$$MC = \frac{M1 - M2}{M1} \times 100$$

Where MC is the moisture content, M1 is the initial weight of broom weed trunk before drying and M2 is the final weight of broom weed stem bark after drying.

Determination of weight absorption

Weight absorption was measured by immersing the broom weed stem bark in distilled water and left for 24 h. The weight difference was measured and the total water uptake was calculated using:

$$WA = \frac{M3 - M4}{M4} \times 100$$

Where WA is the weight absorption, M3 is the weight of broom weed stem bark after absorption of H₂O and M4; the weight of broom weed stem bark before submerging into H₂O.

The fibre yield was also calculated. A cross sectional area of the fibre obtained via retting was viewed using Nikon Eclipse ME 600 microscope.

Fourier transform infrared spectroscopy (FTIR) analysis

The FTIR analysis is an important indicative on the possibility of fibre integration with the polymer matrices. FTIR Spectroscopy was carried out on the treated and untreated broom weed stem bark fibre samples to identify the constituents of the fibre [8]. The analysis was carried out using Thermo Scientific Nicolet iS5-iD1 machine for FTIR analysis in the Department of Chemistry, Federal University, Wukari, Nigeria.

RESULTS AND DISCUSSION

Metachromatic effect of alkaline on broom weed stem bark extraction

Figure 1 shows the result for NaOH concentrations on fibre extraction. The higher concentration of alkaline treatment during extraction of the fibre from *Sida acuta* was of a great interest. A higher concentrated aqueous solution of strong base produces a great swelling with resultant changes in the fine structure, dimension, morphology and mechanical properties of the *Sida acuta*. The important modification resulting from alkaline treatment is the network structure thereby increasing surface roughness. The metachromatic effect observed for NaOH solution extraction of the fibre shows colour changes, from yellow to green and to blue colouration. This is in agreement with the colour arrangement in the visible region of the electromagnetic spectrum. The natural fibre when extracted in the absence of HCl and NaOH is shown on Plate 2. The metachromatic effect as observed under alkaline treated extraction is shown on Plate 3. The is in agreement with the Uv/visible colour spectra arrangement.

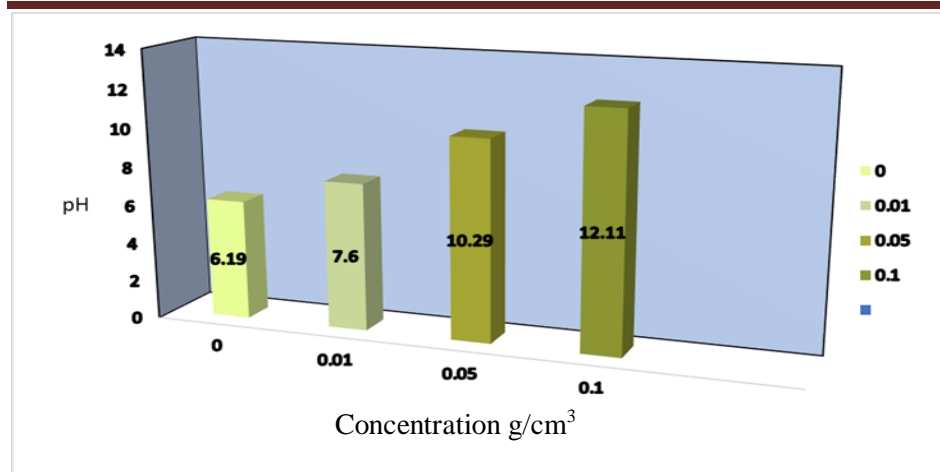


Figure 1: Metachromatic effect of alkaline on broom weed stem bark extraction

Metachromatic effect of HCl on broom weed stem bark extraction

Figure 2 shows the results in HCl concentrations on fibre extraction. From Plate 4, the fibres extracted in acidic solution become reddish brown with increasing concentration of hydrochloric acid. The process shows an increasing reddish coloration with natural tendency of metachromatic effect. The fibre changes from green at 0.0 HCl solution which is the natural color of the fibre to brownish at 0.01 and 0.05 and to reddish colour was observed at 0.1 g/cm³. The odour observed for both acidic and alkaline extractions was a pleasant odour with increasing days of extraction.

The treatment removes a certain amount of lignin, wax, and oil covering the external surface of the fibre cell wall. Alkaline treatment not only increases the surface roughness resulting in better mechanical interlocking but also increases the amount of cellulose exposed on the fibre surface, thus increasing the number of possible reaction site. Consequently, alkaline treatment greatly improves the mechanical behavior of the broom weed especially its strength and stiffness and mechanical properties of the resulting composite [9].

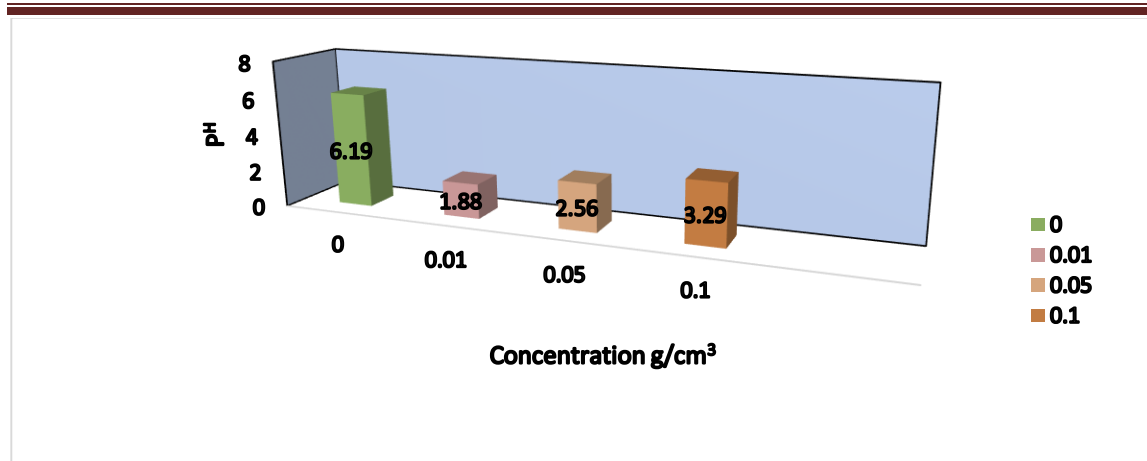


Figure 2: Metachromatic effect on broom weed stem bark extraction when treated with acid (HCl) at different concentrations



Plate 2: Extracted fibre



Plate 3: Extracted fibre at different concentrations of NaOH



Plate 4: Extracted fibre at different concentrations of HCl

Determination of moisture content of broom weed stem bark

The analysis of the moisture content is essential to natural fibre, as a control for the quality of the natural fibre extracted. Moisture content is used for the determination of the amount of water that the *Sida acuta* contain. It influences the physical properties of a substance, including weight, density, viscosity and conductivity. It is generally determined by weight loss upon drying. The result of moisture content determined is shown in Figure 3. The alkaline treatment for the moisture content was 14.63, 14.35, 14.42 and the mean average was calculated as 14.46 while for acidic treatment the moisture content was 14.00, 14.38, 14.59 and the mean average was calculated to be 14.32. Also, that of 0.00 M was calculated to be 15.72. As it was observed, mean average for the fibre extracted in the acidic solution absorb moisture content higher than the alkaline treatment. This is for the most part due to the hydrophilic nature of the natural fibres and the hydrophobic nature of the biopolymers. Therefore, in order to improve the compatibility between the natural fibre and the biopolymer matrix, the natural fibre is usually immersed in an alkaline solution such as sodium hydroxide for a specific time duration at a specific temperature [10]. It has been noted that the immersion of the natural fibres in an alkaline solution does not only improve the compatibility at the fibre-matrix interface, but it also reduces the degradability of the resultant biopolymer composites. Thus, a balance between improving the mechanical performance and maintaining the degradability of the biocomposites should be maintained during alkaline treatment [11].

From Figure 3, moisture content for acidic and alkaline extracted fibre shows an accelerated decrease in moisture content uptake. A shape slit was observed between 0.05 g/cm³

and 0.1 g/cm^3 . This shows that there was a slight increase for the alkalinity.

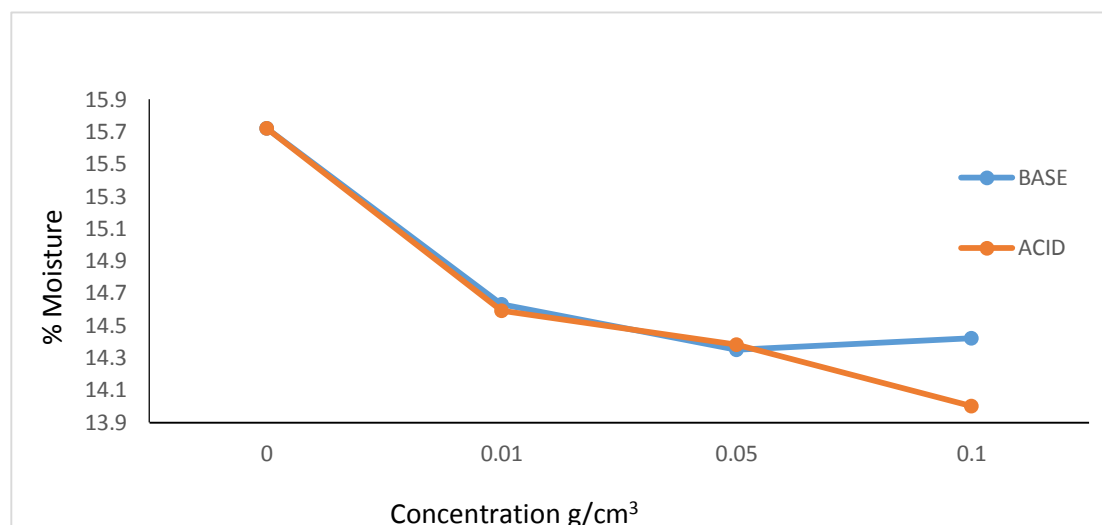


Figure 3: Determination of moisture content of broom weed stem bark when treated at different concentrations

Determination of weight absorption of broom weed stem bark

Weight absorption is used to determine the amount of water absorbed under specified condition. In this study, NaCl salt was used. The weight absorption of the *Sida acuta* was determined and shown in Figure 4 to be 36.2% (that is the amount of water that can be absorbed by *Sida acuta*, without any influence of acid or alkaline). Natural fibre-based materials offer various advantages compared to synthetic fibres. However, their applications are limited mainly due to their hygroscopic properties, which are affected by their chemical composition, microstructure and the porosity of the plant cells of which the fibre is composed [12].

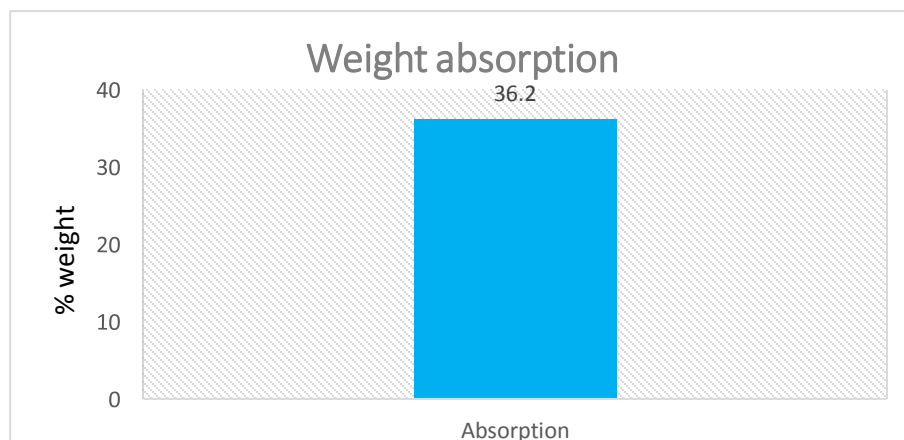


Figure 4: Determination of weight absorption of broom weed stem bark

The Fourier Transform Infrared Spectroscopy

The Fourier Transform Infrared Spectroscopy also known as FTIR Analysis or FTIR spectroscopy is an analytical technique used to identify organic, polymeric, and in some cases inorganic materials. The functional group of the *Sida acuta* spectrum are shown in Figure 5 an elongated broad absorption signal at 3800-3418 cm^{-1} represents the characteristic of O-H stretching vibration in alpha-cellulose and hydrogen bond of the hydroxyl group. The peak at 2918 cm^{-1} which relates to aliphatic C-H stretching vibration from CH and CH_2 of methyl group ensure the presence of cellulose and hemicellulose components. The two peaks at 1748 and 16338 cm^{-1} are indicative of carbonyl group C=O stretching vibration of linkage of carboxylic acid in lignin or ester group in hemicellulose, which is notorious with organic ester linkage of hemicellulose and p-coumaric acid of lignin. The bond observed at 1366 cm^{-1} in the spectrum indicates the bending vibration of C-H and C-O stretching of the aromatic ring in polysaccharides. The strong absorption peak at 1034 cm^{-1} is attributed to CO and O-H stretching vibration which belongs to polysaccharide in cellulose that renders the crystalline structure of the *Sida acuta*.

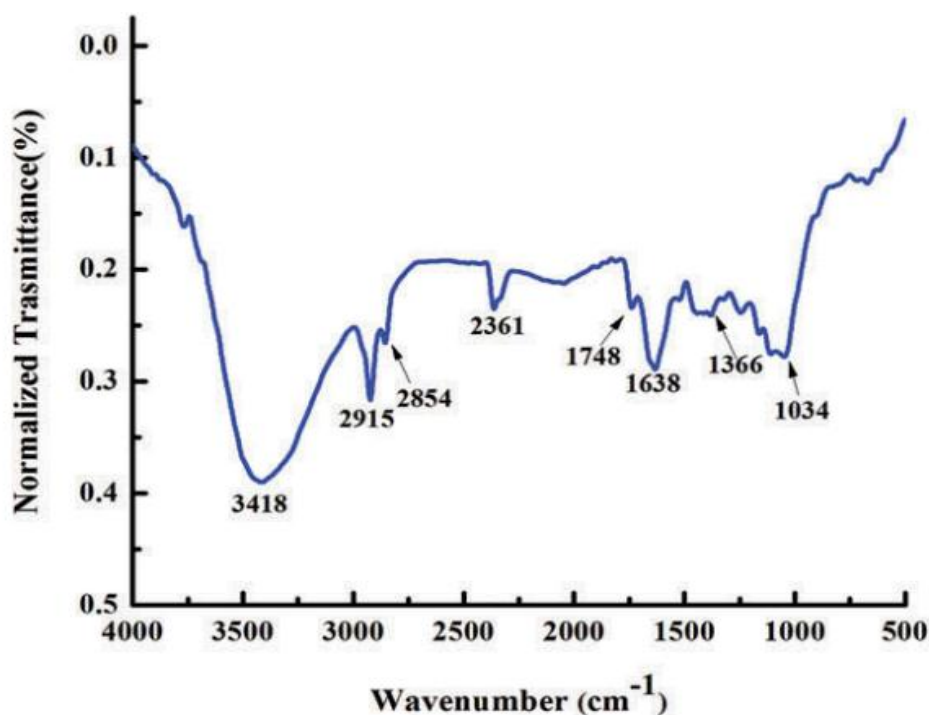


Figure 5: Fourier transform infrared absorption peaks *Sida acuta*

Table 1: Functional group present in each peak

| ABSORPTION BAND CM ⁻¹ | FUNCTION GROUP |
|----------------------------------|----------------|
| 1034 | CO, O-H |
| 1366 | C-H, C-O |
| 1638 | C=O |
| 1748 | C=O |
| 2915 | C-H |
| 3800-3418 | O-H |

CONCLUSION

The stem bark of *Sida acuta* has been used to obtain natural fibre with better strength and elongation. Alkaline treatment (NaOH) depolymerizes cellulose structure and exposes short length crystallites. It also increases the surface roughness of fibre. Alkaline and acids used during natural fibre extraction can also cause metachromatic effect on the extracted fibres. This can be further studied to understand the modifications that should be done in other to exhibit the best colour intensity. Further studies and more attention should be given in the area of using natural fibre for better efficiency and yield.

REFERENCES

1. Selvadurai, S. & Shanmugapandiyam, P. (2021). Comparative Pharmacognostical Studies of Leaves of *Sida Acuta* Burm.F., *Sida Cordifolia* Linn. and *Sida Rhombifolia* Linn. (Malvaceae Family). *International Journal of Pharmaceutical Research*, 13(2), 2916-2926. DOI:[10.31838/ijpr/2021.13.02.325](https://doi.org/10.31838/ijpr/2021.13.02.325).
2. Vijay, R., Singaravelu, D. L., Vinod, A., Sanjay, M. R. & Siengchin, S. (2021) Characterization of alkali-treated and untreated natural Fibres from the stem of parthenium hysterophorus. *J. Nat. Fibres* 18(1), 80–90.
3. Gurukarthik-Babu, B., Winston, D. P., Senthamarai Kannan, P., Saravanakumar, S. S. & Sanjay, M. R. (2019) Study on characterization and physicochemical properties of new natural fibre from *Phaseolus vulgaris*. *J. Nat. Fibres* 16(7), 1035–1042.

4. Desai, R. H., Krishnamurthy, L., Shridhar, T.N. (2016), Effectiveness of Areca (Betel) Fibre as a Reinforcing Material in Eco-friendly Composites: A Review, *Indian Journal of Advances in Chemical Science* S1. 27-33.
5. Kumar, R., Obrai, S. & Sharma, A. (2011) Chemical modifications of natural Fibre for composite material. *Der Chemica Sinica*, 2(4), 219-228.
6. Mishra, S., Misra, M., Tripathy, S. S., Nayak, S. K. & Mohanty, A. K. (2002). Natural Fibre Filled Thermoplastic Composites. *Journal of Science and Engineering*, 23 (2), 164-234.
7. Weyenberg, I. V., Truong, T. C., Vangrimde, B. & Verpoest, I. (2006). Improving the properties of UD flax Fibre reinforced composites by applying an alkaline Fibre treatment. *Composites Part A: Applied Science Manufacturing* 37 (9), 1368-1376.
8. Adeniyi, A.G., Onifade, D.V., Ighalo, J.O., Abdulkareem, S.A. & Amosa, M.K. (2020). Extraction and Characterization of Natural Fibres from Plantain (*Musa paradisiaca*) Stalk Wastes A. *Iranian (Iranica) Journal of Energy & Environment*. 11(2), 116-121,
9. AL-Ola, F.M. (2021). Performance trends and deteriorations of lignocellulosic grape Fibre/polyethylene biocomposites under harsh environment for enhanced sustainable bio-materials. *Cellulose*, 28, 2203–2213.
10. Castoldi, R.D. S., de Souza, L.M.S., Souto, F., Liebscher, M., Mechtcherine, V., Silva, F.D.A. (2022). Effect of alkali treatment on physical–chemical properties of sisal Fibres and adhesion towards cement-based matrices. *Construction and Building Materials*, 345, 128363, <https://doi.org/10.1016/j.conbuildmat.2022.128363>
11. Magagula, J.S. Sefadi, M.J. Mochane, T.H. Mokhothu, T.C. Mokhena, G.G. Lenetha. (2022). The effect of alkaline treatment on natural Fibres/biopolymer composites. Surface Treatment Methods of Natural Fibres and their Effects on Biocomposites. *Woodhead Publishing in Composites Science and Engineering*, 19-45
12. Sweygers, N., Depuydt, D.E.C., Eyley, S., Thielemans, W., Mosleh, Y., Ivens, J., Dewil, R., Appels, L. & Vuure, A.W.V. (2022). Prediction of the equilibrium moisture content based on the chemical composition and crystallinity of natural fibres. *Industrial Crops and Products*. 186, 115187