International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
March-April-2023 Volume 10, Issue-2
Email: editor@ijermt.org www.ijermt.org

EXTRACTION OF CELLULOSE FIBERS FROM DUNG OF INDIGENOUS CATTLE BREEDS OF MAHARASHTRA STATE IN INDIA

Pawar P. H.*, Kodape A.H.[1], Ingole S.D.[2], Gaikwad S.A.[3], Gadegaonkar G.M.[4], Sawant M.N.[5], Gore R.P.[6] & More R.S.[7]

***** Doctorate Research Scholar & Corresponding Author, Department of LPM, MVC, Mumbai.
1 Doctorate Research Guide & Sectional Head, Department of LPM, MVC, Mumbai.
2 Member, Doctorate research advisory committee & Professor, Department of Veterinary Physiology, Bombay Veterinary College, Parel, Mumbai.
3 Member, Doctorate research advisory committee & Associate Professor, Department of Veterinary Anatomy & Histology, Bombay Veterinary College, Mumbai.
4 Member, Doctorate research advisory committee & Assistant Professor, Department of Animal Nutrition, Bombay Veterinary College, Mumbai.
5 Member, Doctorate research advisory committee & Assistant Professor, Department of Veterinary Extension Education, Bombay Veterinary College, Mumbai.
6 Member, Doctorate research advisory committee & Associate Professor, School of Chemistry, Kavayatri Bahinabai Chaudhary North Maharashtra University, Jalgaon (MS).
7. Post-Graduate Research Scholar, LPM, MVC, Mumbai.

ABSTRACT

In the meanwhile, research into the extraction of natural cellulose fibers and the possible applications of these fibers is gaining steam. Environmental and ecological problems that are created by the use of products based on petroleum are on the increase. Through the use of a variety of techniques, such as boiling with hot water, hydrogen peroxide (H2O2), sodium hydroxide (NaOH), and potassium hydroxide (KOH), the purpose of this research is to select cow dung fibers of the best possible quality for use in papermaking while maintaining quality control. Additionally, the cellulose fibers will be extracted from cow dung. Finding a method that is both sustainable and kind to the environment in order to extract the maximum amount of value from renewable biomass feedstock is the primary objective of our study. In accordance with the data, the most effective technique for extracting cellulose fibers is boiling the material in potassium hydroxide (KOH), which results in a yield of 42 percent. There is a tensile index of 26.72 Nm/g, a tear index of 4.83 mNm2/g, and a burst index of 2.48 KPam2/g for handmade paper that has attributes that are comparable to those of manufactured paper. As a consequence of this project, new applications for cow dung are being investigated, and simultaneously, the sources of natural cellulose fibers are being introduced into the mix.

Keyword: - cow dung, fiber, cattle bread, cellulose.

INTRODUCTION

As a result of their inability to biodegrade, plastics that are manufactured from non-renewable petroleum resources contribute to the pollution that occurs in the environment. Research into novel materials that might be used as mulching film, nutrition bowls, and packing bags has been spurred by the need to develop biodegradable alternatives to plastic in a variety of products. lignocellulosic materials have been receiving a lot of attention as of late due to the several advantages they possess, which include being lightweight, affordable, non-toxic, mechanically strong, biodegradable, and biocompatible. These are just few of the many advantages. Cellulose fiber is one of the fundamental components of natural fibers that may be found in plants (such as bananas, palm trees, hemp, coconut husk, flax, cotton, sisal, and so on) and wood (both softwood and hardwood). It is the units of β-1,4-D-glucose that constitute the linear, high-molecular-weight homopolysaccharide that is often referred to as cellulose fiber. Because it contains three free hydroxyl groups per monomer unit, it has a micro fibrillated structure and a very cohesive nature. These hydroxyl groups have the potential to form strong hydrogen bonds. The extraction of cellulose fibers allows for the manufacturing of a broad range of cellulose products, which have found use in a number of industries, including packaging, industrial production, and the construction of various types of infrastructure.

The procedure of extracting cellulose fiber relied heavily on natural plant materials such as seaweed, Phormium tenax, tomato plant waste, and Eleusine indica grass. These were the primary components of the process. Cellulose fibers may also be extracted from waste biomass such as apple core, mulberry leaves, cassava core, bagasse, maize straw, peanut shell, and other waste materials. The scientific community has paid relatively little attention to the concept of reusing cellulose fibers in animal husbandry waste, particularly since cow dung is the most frequent kind of animal husbandry waste. Cows, being ruminants, digest plant-based food by passing it through their four-chambered stomach, which then breaks it down into smaller pieces before they defecate. Cows are able to digest more plant-based foods than other animals. During the time that the meal is being mechanically processed, the digestive enzymes and bacteria that are contained inside these chambers break down the plant fibers, particularly the hemicellulose and pectin component. On the other hand, since the digesting process is not yet complete, cow dung still contains a significant amount of cellulose fiber.

Another significant contributor to pollution in rural areas is cow manure, which is a waste product of animal husbandry. This problem has lately come to the forefront as a significant concern. Consider the fact that Zhangye City, which is situated in the northwest of China, is home to 600,000 cattle, making animal husbandry a major sector there. In spite of the fact that animal husbandry is beneficial to the economy of the region, it brings about a significant challenge in terms of waste management. This is because it generates 6.48×10^1 tons of cow dung year, which is detrimental to both public health and the environment. Therefore, it is essential to do research into the most efficient ways to use biomass derived from animal waste. Many research have been conducted to study the possible applications of cow dung. As an example, cow dung may be used in a variety of ways. For instance, it can be utilized as compost, which improves the health of the soil and enhances crop yields; as a basis for vermicomposting; or as biochar, which prevents the loss of soil nutrients and increases crop yields. In addition, cow dung is used in a variety of applications, including the treatment of sewage, the reinforcement of composite materials, and the production of renewable energy. However, there has been a limited amount of study conducted on the collection of cellulose fibers from cow dung, the description of these fibers, and the use of these fibers in practical applications.

To extract cellulose fibers from cow dung, a sustainable biomass feedstock, this research used four different treatments: boiling with hot water, boiling with hydrogen peroxide, boiling with sodium hydroxide, and boiling with potassium hydroxide. We were able to find the most efficient extraction procedure that does not violate any environmental or sustainable development criteria by comparing the qualities of cellulose fibers that were treated with a variety of different ways. During the first stages of study, the prospect of employing extracted cellulose fibers to manufacture handmade paper was the primary emphasis. A number of different techniques, including scanning electron microscopy (SEM), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA), were used in order to conduct the study of the extracts obtained from cow dung. Alkali solutions, such as potassium hydroxide and sodium hydroxide, have much greater extraction rates than boiling water and hydrogen peroxide. This is due to the fact that these solutions are able to effectively eliminate any lignin and hemicellulose that may still be present in cow manure. Diluting the black liquid that is left behind after the KOH extraction process in order to utilize it as fertilizer is yet another possible use for this liquid residue. As a consequence of this project, new applications for cow dung are being investigated, and simultaneously, the sources of natural cellulose fibers are being introduced into the mix.

OBJECTIVE

1. To prove and show that farmers can use technology that are resistant to climate change in their farms.

2. To enhance the expertise of researchers and other interested parties in agriculture that can withstand the effects of climate change

MATERIALS METHODS

Zhangye City, Gansu Province, China is the location from whence the cow dung was sourced. To begin, the fibers from the cow dung were washed and dried to extract any particles that may have been present. Chengdu Kelong Chemical Co., Ltd. of Chengdu, China, supplied the analytical grade chemical reagents used in the experiment, which included KOH, NaOH, and H_2O_2 (30%).

Procedure for conducting an experiment

After the cow dung was well mixed and rinsed, the pH of the water solution was adjusted to neutral. Sample S1 is the result of drying the collected cow dung fibers at 80 °C for 12 hours and then stabilizing them in a dryer for another 24 hours. The exact treatment technique is depicted in Figure 1. Four distinct treatments were utilized to extract cellulose fibers from crude fiber: hot water, hydrogen peroxide, sodium hydroxide, and boiling extractions with sodium kOH.

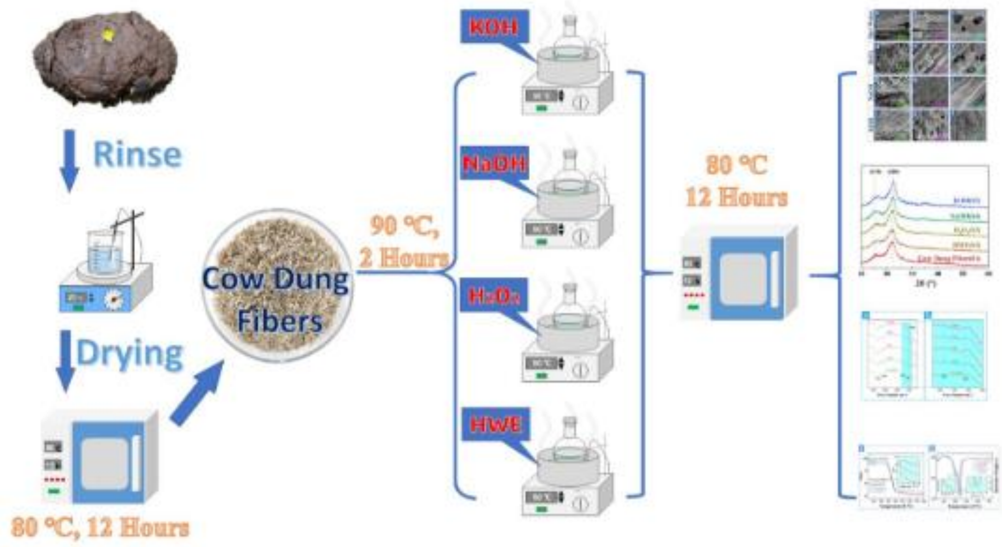

Figure 1. The extraction process of cellulose fibers from cow dung

Hot Water Extraction (S2)

After soaking the quantified crude fibers (5 g) in deionized water for 2 hours at 90 °C, washing them to neutrality, drying them at 80 °C for 12 hours, and finally stabilizing them in a dryer for 24 hours, the same process was repeated. Here is the sample: S2.

Hydrogen Peroxide Extraction (S3).

Drying at 80° for 12 hours and stabilizing in a dryer for 24 hours followed treating 5 g of crude fiber with a 5 wt.% H2O2 solution at 90 °C with stirring for 2 hours. After washing to neutrality, the mixture was further dried. The sample code is S3.

Sodium Hydroxide Extraction (S4).

Using a 5 wt.% NaOH solution, 5 g of crude fiber was heated to 90 °C and stirred for 2 hours. After washing to neutrality, the fiber was dried at 80 °C for 12 hours and then stabilized in a dryer for 24 hours. The sample is known as S4.

Potassium Hydroxide Extraction (S5)

Drying at 80° for 12 hours and stabilizing in a dryer for 24 hours followed treating 5 g of crude fiber with a 5 wt.% KOH solution at 90 °C with stirring for 2 hours. After washing to neutrality, the mixture was further dried. Here is the sample: S5.

RESULTS AND DISCUSSIONS

Extraction of Cellulose fibre from cow dung:

Dung samples from indigenous cow breeds in Maharashtra were studied in this study. Five indigenous cow breeds—Deoni, Dangi, Gaolao, Red kandhari, and Khillar—were discovered throughout the state for future research. We gathered fresh voided excrement from each breed. Cellulose fibers from several indigenous cow breeds' raw dung fibers were isolated and categorized using this study's procedure. Results are described in the following subheadings on the previous pages.

Extraction of cellulose fibre from Dangi Cow:

The specifics of the outcomes achieved in terms of cellulose fiber extraction from Dangi cow manure are detailed in

Table 4.1 Extraction of Raw Cellulose Fibre from Dangi Cow Dung.

Sr. No.	Sample Cow	Age (Years)	Fresh Dung Collected (kg)	Raw Cellulose fibre recovered (gm.)	
				After Washing	After sun drying
1	DAM 1	1	10	5582	586
2	DAF 1	1	10	5550	572
3	DAM 2	2	10	5624	584
4	DAF 2	2	10	5684	592
5	DAM 3	3	10	5785	596
6	DAF 3	3	10	5800	590
7	DAM 4	4	10	5891	610
8	DAF 4	4	10	5820	600
9	DAM 5	5	10	6030	630
10	DAF 5	5	10	5940	628

Average	3	10	5770.6	598.8

Male Dangi cattle aged 1–5 years gave 10 kg of freshly voided manure as Samples DAM1, DAM2, DAM3, DAM4, and DAM5. DAM1, DAM2, DAM3, DAM4, and DAM5 samples produced 5582, 5624, 5785, 5891, and 6030 gms of wet raw cellulose fibers after washing. But the samples were sun-dried. DAM1, DAM2, DAM3, DAM4, and DAM5 samples contained 586, 584, 596, 610, and 630 gms of raw cellulose fiber after sun drying. Why? Clean fibers have far less moisture.Wet cow dung fibers averaged 5782.40 gms from 10 kg of freshly voided Dangi male cow dung. The average dried cow dung fiber weight from 10 kg of freshly voided Dangi male dung was 601.20 gms. Sundried Dangi male dung fibers recovered 6.01%, whereas raw recovered 57.82%.

According to cellulose fiber extraction from Dangi male animal excrement, moisture and other factors produced a 93.9 percentile weight loss in newly voided dung samples.We collected 10 kg of freshly voided manure from female Dangi cattle aged 1–5 years as Samples DAF1, DAF2, DAF3, DAF4, and DAF5. DAF1, DAF2, DAF3, DAF4, and DAF5 samples provided 5550, 5684, 5800, 5820, and 5940 gms of wet raw cellulose fibers after washing.But the samples were sun-dried. Weighing raw cellulose fibers after sun drying. Because washed fibers lose moisture, DAF1, DAF2, DAF3, DAF4, and DAF5 samples have dry masses of 572, 592, 590, 600, and 628 gms.The average wet basis recovery was 5758.80 gms after washing 10 kg of freshly voided Dangi male cow dung. The average dried cow dung fibers from 10 kg of freshly voided Dangi male feces were 596.40 gms. Dangi men recovered 57.58% raw and 5.96% dried dung fiber.The 94.03% percentile weight loss during cellulose fiber extraction from Dangi female animal excrement was due to moisture and other factors.

The recovery of cellulose fibers from cow dung fiber for male and female Dangi animals was not statistically different either wet or dry.Using animals of the same sex and origin fed the same diets and methods may explain the observed occurrences. Dangi cattle's exceptional health enabled us to obtain objective statistics.

Extraction of cellulose fibre from Deoni Cow:

Detailed information on the outcomes of the cellulose fiber extraction process from Deoni cow feces is provided in

Table 4.2 Extraction of Raw Cellulose Fibre from Deoni Cow Dung.

Sr. No.	Sample Cow	Age (Years)	Fresh Dung Collected (kg)	Raw Cellulose fibre recovered (gm.)	
				After Washing	After sun drying
1	DEM 1	1	10	5996	580

2	DEF 1	1	10	6032	581
3	DEM 2	2	10	6068	587
4	DEF 2	2	10	6104	588
5	DEM 3	3	10	6140	596
6	DEF 3	3	10	6176	592
7	DEM 4	4	10	6212	601
8	DEF 4	4	10	6248	596
9	DEM 5	5	10	6284	641
10	DEF 5	5	10	6320	645
Average		3	10	6158	600.7

DEM1–DEM5 samples were 10 kg of freshly voided manure from male Deoni cattle ages 1–5. DEM1, DEM2, DEM3, DEM4, and DEM5 samples provided 5996, 6068, 6140, 6212, and 6284 gms of wet raw cellulose fibers after washing. But the samples were sun-dried. Due to the significant reduction in moisture content of washed fibers, DEM1, DEM2, DEM3, DEM4, and DEM5 samples had sun-dried raw cellulose fiber masses of 580, 587, 596, 601, and 641 gms.The average wet basis fiber recovery was 6140 grams using 10 kilos of freshly voided male Deoni cow dung. The average dry cow dung fiber weight from 10 kg of freshly voided Deoni male feces was 601 gms. Raw dung fiber percentile recovery from a male Deoni was 61.40% and dry recovery 6.01%.When cellulose fibers were extracted from male Deoni animal feces, moisture and other factors produced a 93.9 percentile weight loss.Female Deoni cattle aged one to five years contributed ten kilograms of DEF1, DEF2, DEF3, DEF4, and DEF5 feces samples. DEF1, DEF2, DEF3, DEF4, and DEF5 samples provided 6032, 6104, 6176, 6248, and 6320 gms of wet raw cellulose fibers after washing.But the samples were sun-dried. Weighing raw cellulose fibers after sun drying. DEF1, DEF2, DEF3, DEF4, and DEF5 samples weighed 581, 588, 592, 596, and 645 gms due to washed fibers' moisture loss.The average wet basis fiber recovery was 6176 grams using 10 kilos of freshly voided male Deoni cow dung. 600.40 gms of dried cow dung fibers were averaged from 10 kg of freshly voided Deoni male excrement. Raw dung fiber percentile recovery from a male Deoni was 61.76%, whereas dried recovery was 6.00%.Moisture and other variables reduced newly voided dung samples by 94.0 percentile while extracting cellulose fibers from Deoni female animals' feces.There was no statistical difference in raw cow dung fibers recovered wet and dry for male and female Deoni animals during cellulose fiber extraction.

Extraction of cellulose fibre from Gaolao Cow:

The specifics of the outcomes achieved in terms of cellulose fiber extraction from Gaolao cow manure are detailed in

Table 4.3 Extraction of Raw Cellulose Fibre from Gaolao Cow Dung.

Sr. No.	Sample Cow	Age (Years)	Fresh Dung Collected (kg)	Raw Cellulose fibre recovered (gm.)	
				After Washing	After sun drying
1	GAM 1	1	10	6284	586
2	GAF 1	1	10	6320	572
3	GAM 2	2	10	6269	584
4	GAF 2	2	10	6356	592
5	GAM 3	3	10	6392	596
6	GAF 3	3	10	6428	590
7	GAM 4	4	10	6464	610
8	GAF 4	4	10	6194	600
9	GAM 5	5	10	6258	630
10	GAF 5	5	10	6320	628
Average		3	10	6328.5	598.8

Sample GAM1–GAM5 consisted of 10 kg of freshly voided manure from 1- to 5-year-old male Gaolao cattle. GAM1–GAM5 retrieved 6284, 6269, 6392, 6464, and 6258 wet raw cellulose fibers after thorough washing. But the samples were sun-dried. Raw cellulose was sun-dried and weighed. Washing fibers reduced their moisture content, making GAM1, GAM2, GAM3, GAM4, and GAM5 samples weigh 586, 584, 596, 610, and 630 gms. Moisturized fibers from 10 kg of freshly voided gaolao male cow dung averaged 6333.4 gms. The average dried cow dung fiber weight from 10 kg of freshly voided Gaolao male dung was 601.2 gms. Raw dung fiber percentile recovery from Gaolao males was 63.33% and dried 6.01%.When cellulose fibers were extracted from Gaolao male feces, moisture and other factors produced a 93.9 percentile weight loss. Female Gaolao cattle aged one to five years contributed ten kilogram of feces samples GAF1, GAF2, GAF3, GAF4, and GAF5. Wet raw cellulose fibers from GAF1, GAF2, GAF3, GAF4, and GAF5 samples weighed 6320, 6356, 6428, 6194, and 6320 gms after washing. But the samples were sun-dried. GAF1, GAF2, GAF3, GAF4, and GAF5 samples weighed 572, 592, 590, 600, and 628 gms after sun drying raw cellulose fibers. Why? Clean fibers have far less moisture. The average wet basis recovery was 6323.60 gms after washing 10 kg of freshly voided gaolao male cow manure. The average dry fiber content of 10 kg of recently voided Gaolao male feces was 596.40 gms. Dried dung fiber percentile recovery from Gaolao males was 5.96% and raw 63.23%. During cellulose fiber extraction from Gaolao female animals' feces, moisture and other variables produced 94.04% percentile weight loss in newly voided dung samples. Wet and dry raw cow dung fiber recovery was similar for male and female Gaolao animals during cellulose fiber extraction.

Extraction of cellulose fibre from Khillar Cow:

The specifics of the outcomes achieved in terms of cellulose fiber extraction from Khillar cow dung are detailed in

Table 4.4 Extraction of Raw Cellulose Fibre from Khillar Cow Dung.

Sr. No.	Sample Cow	Age (Years)	Fresh Dung Collected (kg)	Raw Cellulose fibre recovered (gm.)	
				After Washing	After sun drying
1	KHM 1	1	10	6292	618
2	KHF 1	1	10	6300	628
3	KHM 2	2	10	6254	641
4	KHF 2	2	10	6226	618
5	KHM 3	3	10	6385	638
6	KHF 3	3	10	6391	629
7	KHM 4	4	10	6354	620
8	KHF 4	4	10	6298	643
9	KHM 5	5	10	6452	633

10	KHF 5	5	10	6288	610
Average		3	10	6324	627.8

KHM1–KHM5 samples used 10 kg of freshly voided manure from male Khillar cattle aged 1–5 years. After complete washing, KHM1, KHM2, KHM3, KHM4, and KHM5 samples yielded 6292, 6254, 6385, 6354, and 6452 wet raw cellulose fibers. But the samples were sun-dried. KHM1, KHM2, KHM3, KHM4, and KHM5 samples weighed 618, 641, 638, 620, and 633 gms after sun drying raw cellulose fibers. Why? Clean fibers have far less moisture. Wet cow dung fibers averaged 6347.40 gms from 10 kg of freshly voided male Khillar cow dung. The average dried cow dung fibers from 10 kg of freshly voided male Khillar dung were 630 gms. Male Khillar dung fiber percentile recovery was 63.47% raw and 6.30% dry. When cellulose fibers were extracted from male Khillar feces, moisture and other factors produced 93.70% weight loss. Samples KHF1, KHF2, KHF3, KHF4, and KHF5 included 10 kg of freshly voided manure from 1–5-year-old female Khillar cattle. After thorough washing, KHF1, KHF2, KHF3, KHF4, and KHF5 wet raw cellulose fibers were 6300, 6226, 6391, 6298, and 6288 gms.But the samples were sun-dried. Due to the significant moisture decrease of washed cellulose fibers, samples KHF1, KHF2, KHF3, KHF4, and KHF5 weighed 628, 618, 629, 643, and 610 gms.Wet cow dung fibers averaged 6,300.60 gms from 10 kg of freshly voided male Khillar cow dung. The average dried cow dung fibers from 10 kg of freshly voided male Khillar dung were 625.60 gms. Male Khillar dung fiber percentile recovery was 63.000% raw and 6.25% dry. Thus, moisture and other factors caused 93.75% of newly voided dung samples to lose weight during Khillar female animal excrement cellulose fiber extraction. Wet and dry raw cow dung fiber recovery was similar for male and female Khillar animals during cellulose fiber extraction.

CONCLUSION

Because of the damage that petroleum-based products do to the environment, there has been a lot of focus on the production and use of natural fibers. This experiment used four distinct methods to recover cellulose fibers from cow dung, an underutilized resource up until now. The best-performing fibers were then used to manufacture handmade paper. The study's findings reveal that cellulose fibers, which are abundant in cow dung, may be most effectively removed by KOH boiling procedures. Paper made from fibers recovered from cow dung using potassium hydroxide (KOH) showed excellent mechanical qualities, including a tear index of 4.83 mNm2/g, a tensile index of 26.72 Nm/g, and a burst index of 2.48 KPam2/g. The procedure of extracting cellulose from cow dung is eco-friendly and sustainable since the residual black liquor may be utilized as fertilizer. This research delves into an innovative approach of harnessing the potential of cow manure. Soil contamination from plastic mulch may be mitigated in the future by making use of cow dung paper as a raw material for mulch manufacture based on paper. Additional investigation into optimizing extraction parameters such solution concentration, extraction duration, and temperature is warranted because of the wide variety of variables that could influence the final product.

REFERENCES

1. Sumesh, K.R.; Kanthavel, K.; Kavimani, V. Peanut Oil Cake-Derived Cellulose Fiber: Extraction, Application of Mechanical and Thermal Properties in Pineapple/Flax Natural Fiber Composites. Int. J. Biol. Macromol. 2020, 150, 775–785. https://doi.org/10.1016/j.ijbiomac.2020.02.118.
2. Gharehkhani, S.; Sadeghinezhad, E.; Kazi, S.N.; Yarmand, H.; Badarudin, A.; Safaei, M.R.; Zubir, M.N.M. Basic Effects of Pulp Refining on Fiber Properties—A Review. Carbohydr Polym 2015, 115, 785–803. https://doi.org/10.1016/j.carbpol.2014.08.047.
3. Khawas, P.; Deka, S.C. Isolation and Characterization of Cellulose Nanofibers from Culinary Banana Peel Using High-Intensity Ultrasonication Combined with Chemical Treatment. Carbohydr. Polym. 2016, 137, 608–616. https://doi.org/10.1016/j.carbpol.2015.11.020.
4. Alotaibi, M.D.; Alshammari, B.A.; Saba, N.; Alothman, O.Y.; Sanjay, M.R.; Almutairi, Z.; Jawaid, M. Characterization of Natural Fiber Obtained from Different Parts of Date Palm Tree (Phoenix Dactylifera L.). Int. J. Biol. Macromol. 2019, 135, 69–76. https://doi.org/10.1016/j.ijbiomac.2019.05.102.
5. Vilaseca, F.; Del Rey, R.; Serrat, R.; Alba, J.; Mutje, P.; Espinach, F.X. Macro and Micro-Mechanics Behavior of Stifness in Alkaline Treated Hemp Core Fibres Polypropylene-Based Composites. Compos. Part B Eng. 2018, 144, 118–125.
6. Jeetah, P.; Jaffur, N. Coconut Husk, a Lignocellulosic Biomass, as a Promising Engineering Material for Non-Wood Paper Production. J. Nat. Fibers 2021, 19, 5622–5636. https://doi.org/10.1080/15440478.2021.1889428.
7. Zykova, A.K.; Pantyukhov, P.V.; Mastalygina, E.E.; Chaverri-Ramos, C.; Nikolaeva, S.G.; Saavedra-Arias, J.J.; Popov, A.A.; Wortman, S.E.; Poletto, M. Biocomposites of Low-Density Polyethylene Plus Wood Flour or Flax Straw: Biodegradation Kinetics across Three Environments. Polymers 2021, 13, 2138. https://doi.org/10.3390/polym13132138.
8. Wang, H.Q.; Li, J.C.; Zeng, X.H.; Tang, X.; Sun, Y.; Lei, T.Z.; Lin, L. Extraction of Cellulose Nanocrystals Using a Recyclable Deep Eutectic Solvent. Cellulose 2020, 27, 1301–1314. https://doi.org/10.1007/s10570-019-02867-2.
9. Raymond, P.; Mshandete, A.M.; Kajumulo Kivaisi, A. Production of Oxidative and Hydrolytic Enzymes by Coprinus Cinereus (Schaeff.) Gray from Sisal Wastes Supplemented with Cow Dung Manure. Biotechnol. Res. Int. 2015, 2015, 650543.
10. Klemm, D.; Philipp, B.; Heinze, T.; Heinze, U.; Wagenknecht, W. Comprehensive Cellulose Chemistry: Volume I: Fundamentals and Analytical Methods; Wiley: Hoboken, NJ, USA, 1998; p. 37.
11. Thomas, B.; Raj, M.C.; Athira, K.B.; Rubiyah, M.H.; Joy, J.; Moores, A.; Drisko, G.L.; Sanchez, C. Nanocellulose, a Versatile Green Platform: From Biosources to Materials and Their Applications. Chem. Rev. 2018, 118, 11575–11625. https://doi.org/10.1021/acs.chemrev.7b00627.
12. Pickering, K.L.; Efendy, M.G.A.; Le, T.M. A Review of Recent Developments in Natural Fibre Composites and Their Mechanical Performance. Compos. Part A Appl. Sci. Manuf. 2016, 83, 98–112. https://doi.org/10.1016/j.compositesa.2015.08.038.
13. Niu, X.; Liu, Y.; Song, Y.; Han, J.; Pan, H. Rosin Modified Cellulose Nanofiber as a Reinforcing and Co-Antimicrobial Agents in Polylactic Acid /Chitosan Composite Film for Food Packaging. Carbohydr. Polym. 2018, 183, 102–109. https://doi.org/10.1016/j.carbpol.2017.11.079.

14. Wahlstrom, N.; Edlund, U.; Pavia, H.; Toth, G.; Jaworski, A.; Pell, A.J.; Choong, F.X.; Shirani, H.; Nilsson, K.P.R.; Richter-Dahlfors, A. Cellulose from the Green Macroalgae Ulva Lactuca: Isolation, Characterization, Optotracing, and Production of Cellulose Nanofibrils. Cellulose 2020, 27, 3707–3725.
15. Di Giorgio, L.; Salgado, P.R.; Dufresne, A.; Mauri, A.N. Nanocelluloses from Phormium (Phormium Tenax) Fibers. Cellulose 2020, 27, 4975–4990.
16. Kassab, Z.; Kassem, I.; Hannache, H.; Bouhfid, R.; Qaiss, A.; El Achaby, M. Tomato Plant Residue as New Renewable Source for Cellulose Production: Extraction of Cellulose Nanocrystals with Different Surface Functionalities. Cellulose 2020, 27, 4287– 4303. https://doi.org/10.1007/s10570-020-03097-7.
17. Khan, A.; Vijay, R.; Singaravelu, D.L.; Sanjay, M.R.; Siengchin, S.; Verpoort, F.; Alamry, K.A.; Asiri, A.M. Extraction and Characterization of Natural Fiber from Eleusine Indica Grass as Reinforcement of Sustainable Fiber Reinforced Polymer Composites. J. Nat. Fibers 2021, 18, 1742–1750. https://doi.org/10.1080/15440478.2019.1697993.
18. Saeed, H.A.M.; Liu, Y.; Lucia, L.; Chen, H. Evaluation of Sudanese Sorghum and Bagasse as a Pulp and Paper Feedstock. Bioresources 2017, 12, 5212–5222.
19. El-Sayed, E.S.A.; El-Sakhawy, M.; El-Sakhawy, M.A.-M. Non-Wood Fibers as Raw Material for Pulp and Paper Industry. Nord. Pulp Pap. Res. J. 2020, 35, 215–230.
20. Braun, U. Ultrasonographic Examination of the Reticulum, Rumen, Omasum, Abomasum, and Liver in Calves. Vet. Clin. North Am. : Food Anim. Pract. 2016, 32, 85–107.