Nanocellulose Market: Unlocking Growth Opportunities for Startups

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Synthetic polymers, especially those derived from polyolefins, offer a wide range of advantages that have contributed to their extensive use in various industries and applications. Over the past half-century, plastic production has increased by 20-fold, and an estimated 9200 million metric tons of plastic has been produced worldwide (Walker & Fequet, 2023). A global plastic production of 1.1 billion tons is predicted by 2050 (Lai & Lee, 2022). The major concern related to their non-biodegradable nature and prevailing low rate of recycling shifts focus towards developing biodegradable materials to address the environmental and sustainability concerns.

Cellulose, the most abundant bio-based raw materials in nature, is widely regarded as one of the most suitable materials for the synthesis of sustainable, green products (Felgueiras et al., 2021). Scientific pursuit aimed at developing eco-friendly materials from renewable resources have increasingly focused on cellulose and materials derived from it as they exhibit exceptional properties in terms of biodegradability, biocompatibility, cost-effectiveness, and ease of disposal. Factually, a diverse range of cellulosic feedstocks, varying widely in composition, have been used to produce cellulose. These include plants, marine animals, marine biomass, certain amoeba, fungi, bacteria, and invertebrates (Teodoro et al., 2021). The primary and most obvious sources of cellulose are derived from lignocellulosic biomass, representing the primary reinforcement component of the cell wall of plants.

Nanocellulose is gaining popularity since the previous decade, its potential is expanding manifolds thanks to advancements in production techniques. Nanocellulose has gained significant attention due to its low density, high strength, stiffness, and high aspect ratio, along with its renewability, non-toxicity, biodegradability, colloidal stability, and often low cost (Barhoum et al., 2022).

Nanocellulose is mainly categorized into three forms: Cellulose Nanocrystals (CNC), Cellulose Nanofibrils (CNF), and Bacterial Nanocellulose (BNC). The dominant forms are CNF and CNC. CNC are commonly known as nanocrystalline cellulose, crystallites, whiskers, rod like cellulose microcrystals while CNF are termed as microfibrillated cellulose, nanofibrils and microfibrils, nanofibrillated cellulose (Dhali, Ghasemlou, et al., 2021). BNC also referred to as microbial cellulose or bio cellulose, is typically obtained from the fermentation of glucose or other carbohydrate feedstocks by bacterial pathways (Islam et al., 2017).

Future sustainable technologies will increasingly depend on renewable materials to create innovative products with enhanced environment-friendly attributes. Due to its renewable and biodegradable nature, nanocellulose is gaining momentum in a wide range of fields, including packaging, paper and pulp, energy storage, biomedical applications, environmental remediation, optoelectronics, and coatings (Dhali, Ghasemlou, et al., 2021). Its non-toxicity and versatility have also paved the way for its use in environmental remediation, such as flocculants, photocatalysts, adsorbents, and membranes.

Much like anything else, nanocellulose does not come without its limitations, and there are some challenges hindering their market growth. Isolating nanocellulose from bulk or crude cellulose is a complex process. Extensive research has focused on developing optimal methods that would incur minimal or prevent any damage to the crystalline structure of nanocellulose. It is undeniable that the production cost remains relatively high and energy-intensive. Often, the process requires significant establishment costs and sophisticated equipment, which can limit its widespread adoption, particularly in low-cost applications. Continuous research is being conducted to produce nanocellulose in the most innovative way that cater to desired end applications. In terms of scalability, achieving commercial-scale production of nanocellulose while maintaining its quality and ensuring a favourable cost-benefit ratio remains a major hurdle.

The usage of nanocellulose at commercial scale is rapidly expanding in the food, cosmetics and biomedical applications where it faces stringent regulatory hurdles, particularly regarding safety standards and testing. Often "nano" materials are labelled as potential health and environmental risks, hindering their adoption. There is a need for enhanced campaigns in India to educate industries about the rapid growth of the global nanocellulose market and to raise awareness of the diverse opportunities for potential applications, driven by its unique properties. A consolidated effort by researchers, academics, and government agencies of our country is essential to establish protocols for nanocellulose applications, particularly in sectors involving human health concerns. The lack of standardized regulations and quality benchmarks significantly complicates its acceptance in various markets.

However, the advantages of the nanocellulose market, driven by its applications across key sectors far outweigh its limitations (Klemm et al., 2005; Tayeb et al., 2018). In recent years, the production of nanocellulose has experienced significant growth, fuelled by the growing global demand for sustainable materials. Commercial-scale production plants are being established, Finland leads in innovation investments, followed by Sweden and the United States making significant contributions to nanocellulose production (Garcia et al., 2024).

Analysts estimate the value of the global nanocellulose market at $350 million in 2022 (Market Research Future, 2023). Recent forecasts predict the nanocellulose market to grow at a compound annual growth rate (CAGR) of 20% over the next 5-7 years, reaching an estimated value of approximately $628 million by 2028. Projections further suggest the market could surpass $1.1 billion by 2030 (Market Data Forecast, 2023).

In the mid-1980s, a Swedish company, STFI AB (presently known as Innventia AB), began working with MFC, aiming to utilize the nanomaterial in paper applications (Lindström et al., 2014). There are several commercial entities that produce nanocellulose at industrial scale, of which the most prominent are American Process Inc. (USA), CelluForce Inc., (Canada), Tecnaro GmbH (Germany), InnoTech Alberta (Canada), Blue Goose Biorefineries Inc. (Canada), FPInnovations (Canada), CelluComp Ltd. (UK). Furthermore, its multifunctionality has been investigated by established companies like Innventia (Sweden), UPM Kymmene and VTT Technical Research Centre (Finland), Borregaard (Norway), Rettenmaier (Germany), Weidmann (Switzerland) and innovative ones such as GranBio (Brazil) and Finecell (Sweden). In Asia, Japan stands out for its significant investment in nanocellulose production, with major contributions from industries such as Nippon Paper Industries (Japan) Chuetsu Pulp & Paper Co. Ltd. (Japan), Dai-ichiKyogo (DKS) (Japan), Daicel (Japan). Along with Japan, China and the United States of America emerged as the most active countries in industrial research.

Accurately estimating the end-use product cost is challenging due to the confidentiality of financial details within commercial entities. However, based on the raw material cost (approximately USD 0.5 per kilogram) and production expenses, the cost of CNFs is anticipated to range between USD 7 and 12 per kilogram of dried material. Currently, CNCs with diverse structural properties and surface chemistries are available for purchase at prices ranging from USD 4 to 10 per kilogram (de Assis et al., 2017). The nanocrystalline cellulose market is projected to grow further, driven by technological advancements and increased investment in expertise and the development of new equipment to implement innovative strategies for future commercial opportunities.

Conclusion

Now is the ideal time to invest in developing the nanocellulose market in our country. Given its unique attributes, nanocellulose has significant potential across various enterprises, and this potential must be fully explored. Awareness campaigns should be launched to educate stakeholders about its benefits and applications. Targeted marketing strategies need to be implemented to highlight the specific advantages of nanocellulose in key sectors. Collaboration between industries is essential to establish a robust framework. This will not only facilitate the production of nanocellulose but also support the establishment of advanced facilities that create innovative materials, using nanocellulose as an eco-friendly alternative. Such efforts will play a crucial role in combating plastic pollution and promoting environmental sustainability. To support this emerging sectors, government-backed funding through subsidies or incentives should be provided to reduce costs and encourage the growth of nanocellulose-based startups. These initiatives align with Prime Minister's vision of fostering inclusive growth, sustainability, and infrastructure development. They complement national missions like Swachh Bharat Abhiyan (Clean India Mission), Make in India, and Startup India.

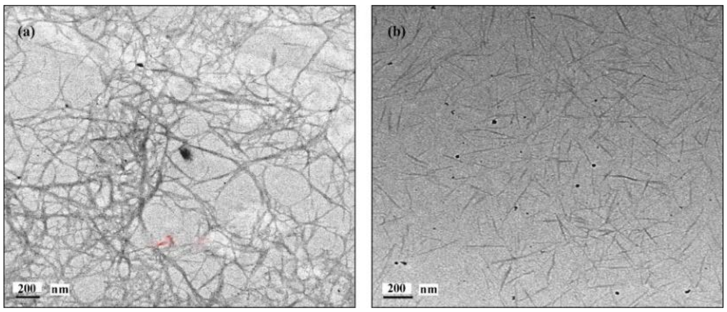

Fig. 1. Transmission electron micrographs (TEM) images of negatively stained with 2% uranyl acetate, (a) mechanically treated fibers (CNFs) and (b) acid hydrolyzed nanocrystals (CNCs). Reproduced from (Dhali, Daver, et al., 2021).

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