Making Paper from Materials That Are Essential to Our Lives/ Making Paper Without Trees Is the New "Must"

Carmen-Alice Teacă

Paper, which is in fact a very complex cellulose-based product derived from different lignocellulosic resources, is usually regarded as a simple omnipresent commodity in our lives. Wood fibers derived from trees are the most employed sources for papermaking purposes. From an environmental protection perspective, and for their essential role in our life (they give us the life itself through their foliar system supporting the photosynthesis process), trees should not be extensively cut down and they should be used less and less for papermaking. Thus, employment of non-woody alternative sources for papermaking could be exploited more as an attractive and feasible option.

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Contact information: "Petru Poni" Institute of Macromolecular Chemistry, Centre of Advanced Research in Bionanoconjugates and Biopolymers, 41A Grigore Ghica-Voda Alley, Iasi, Romania; e-mail: cateaca@icmpp.ro; cateaca14@yahoo.com

Paper – A Particularly Complex Material

Paper is a complex cellulose-based product derived from different lignocellulosic resources (but most usually wood fibers) that are valorized through a range of processing stages. Considering old evidence of hand-craft papermaking procedures (Hubbe and Bowden 2009), it is easy to realize its significance and value (good as gold, one may say) as part of humanity's cultural heritage.

More than thirty years ago, in 1992, as a young student in the science and technology of pulp, paper, and synthetic fibers, during a practical learning stage at Letea SA, Bacău, Romania, I was very surprised to see with my own eyes how paper is made. At that moment, I was astonished by the complexity of all processing stages involved in papermaking technology. Then I realized that trees are really indeed cut-down and debarked for the delignification stage (a chemical cooking procedure using acid and alkaline chemicals), all these also implying the use of large quantities/amounts of water (for easier debarking of trunks, for facilitating the lignin and hemicelluloses removal up to a large extent, in order to ease the further pulp bleaching treatments for papermaking and finished paper-based products). I was convinced on the spot by the inherent harmful pollution caused by such technology employed for pulp production (Hubbe *et al.* 2016). People were working in such tough conditions, but this was their work and they were totally involved in it.

Here, my colleagues and I became familiar with how paper is made for newspapers (from mostly recycled papers; at that moment, here was the most modern machine for making paper for newspaper), cigarettes (from different textile wastes, mainly old clothes *per se* or recycled, preferably having a dominant white color grade, and using a special, round-form boiler for pulping), or specialty paper for banknotes and other official

documents (*e.g.* watermarked secured papers). A part of the watermark paper used for the National Bank of Romania banknotes was first purchased from the Romanian pulp and paper manufactory Letea (Bacău) around 1937 (https://imprimeriabnr.ro/en/history/ - accessed on March 27th, 2023).

I have understood very well how complex paper is as a material especially when I realized how final paper-based products are obtained and when different fillers and additives are employed in the finishing stage for conferring upon it special properties depending on the envisaged applications.

Papermaking Employing Alternative Sources

Certainly, wood fibers are the most employed sources for papermaking purposes. From an environmental point of view, harvesting the trees had and still has a deleterious impact through issues related to some uncontrolled deforestation and further inherent soil erosion, visual appearance of the forest habitat, perturbation of the ecosystem, and even disturbing oxygen and carbon cycles in nature, ultimately impacting human lives. Because trees are the most important component of our living environment, for recreation and mindfulness (as human practices) and for photosynthesis (as main biological function), they must be thoroughly appreciated through respecting their "secret life" as complex living entities (Wohlleben 2016). Trees can be considered as being the "environment's lungs" because they provide the oxygen indispensable to our lives, improve air quality, and ameliorate climate conditions (reduce the rate of global warming acting as an effective carbon sink). Besides all these points, trees conserve water resources and preserve soil (through binding soil to their radicular system thus reducing the soil erosion), protect and support wildlife, and finally, they are unconditioned suppliers for effective raw materials for tools, building, and energy production. These are all reasons supporting why trees should not be extensively cut down and why they should be used less for papermaking.

Efficient protection for the forest habitats can be ensured through employment of alternative sources, non-woody type, for papermaking. One may say that we can make paper from almost any plant that contains cellulose fibers, though the properties of the resulting paper may vary. So, in recent years, there were many studies related to such issues, including obtaining cellulose fibers suitable for papermaking with reduced environmental impact from: (1) stalks from invasive plants such as paper mulberry (*Broussonetia papyrifera*) and common reed (*Phragmites australis*) (Seo and Hwang 2019; https://www.natureupnorth.org/justmynature/vmald17/how-make-paper-invasive-plants - accessed on April 3rd, 2023), (2) agricultural residues: pineapple - crown waste and leaves (Pereira *et al.* 2020); tomato (Jiang and Hsieh 2015), orange (Bicu and Mustaţă 2013), and banana peels (Pelissari *et al.* 2013); sugarcane bagasse (Piñeres *et al.* 2020; Pereira *et al.* 2011); straw from rice, wheat (Malik *et al.* 2020; Varghese *et al.* 2020); (3) bamboo (Chen *et al.* 2019); (4) giant milkweed *Calotropis procera* (Chauhan *et al.* 2013); (5) aquatic plants (Bidin *et al.* 2015); (6) even residual fallen leaves collected mostly from the trees present in urban areas (https://packagingeurope.com/features/this-energy-efficient-technology-turns-fallen-leaves-into-paper/7887.article - accessed on March 30th, 2023). The last alternative source mentioned represents an essential component for the carbon cycle in nature, mainly within forests' ecosystems where they form an essential, vital part of it. Even if leaves represent a small component of the trees, they are the most important and essential element for the photosynthesis process through CO_2 absorption and water transport with their chemical conversion into saccharide compounds using sunlight energy.

Thus, oxygen that helps us to breathe is released as a by-product. So, we have to be thankful for trees' existence and even to hug them in thanks for what they give us, life itself.

Agriculture-derived waste can be used as non-wood materials for paper production. This approach has shown its effectiveness for various paper products. For example, cotton fibers extracted from recycled fabrics (short fibers, but having strength, softness, and flexibility) yield durable paper when combined with other fibers (*i.e.*, linen fibers up to 25%) intended for banknotes (https://www.royaldutchkusters.com/blog/the-five-pros-and-cons-of-cotton-banknotes, accessed: April 10th, 2023). Another approach is the use of agricultural by-products that are not suitable for animal feed (Worku *et al.* 2023) or even seaweed collected from beaches (https://algaeplanet.com/making-paper-from-seaweed. Last accessed: April 10th, 2023). A special type of glossy and durable paper, reusable and photodegradable, has been obtained using small amounts of plastics, even recycled waste, and powdered minerals (up to 80%), by a process having a very low level (if not at all) of water and air pollution (Indriati *et al.* 2020). Recycling and up-cycling in the papermaking are well illustrated by the new 100% recyclable and biodegradable paper made of 10% paper waste, and residues from leather manufacturing that can replace up to 25% wood tree pulp (https://www.favini.com/gs/en/fine-papers/remake/features-applications, accessed: April 10th, 2023). This type of paper has a particular appearance, is soft and velvety, and perfect for luxury printing or packaging. However, at present the paper industry is oriented to recycling old and used papers and books for the manufacturing of various types of paper.

Why Paper Is Good for Us

In a society that is evolving at a fast pace, we have come to depend on information technology to a great extent, in almost all sectors of public and private life. However, we remain tied to paper and the written/printed word both intellectually and emotionally. Paper remains as a keeper of human history, as important as stone (even if not quite as durable), a witness to unique emotions, a mentor and educator, confessor, and a soul friend. This is why we must have paper in our life and, given the up-to-date environmental concerns, we must find alternative, non-woody resources and methods to produce paper for all uses.

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