Rigid packaging from bark

Bark – an underutilized resource and potential game changer in rigid bio-packaging

Biobased composites made from a fossil matrix with e.g. flax fibres or wood particles (WPC, wood plastics composites) have been researched extensively and found their way into the market a long time ago. Bark is a side stream from the wood processing industries, from which active compounds can be extracted. It lends itself also as filler in fully biobased composites, thereby offering a route to rigid packaging with biodegradability and low carbon footprint. While current research and application of biopolymers focused on flexible packaging, rigid packaging is still a big niche for implementation. Bark has a huge potential as a filler for biopolymers for the production of rigid packaging solutions, due to excellent strength and durability, but also temperature stability. This work examines the potential use of bark in biopolymer-based composites.

Today, in our global economy, packaging and transporting of goods is essential, both for food and non-food items. Half of the annual production of fossil-based plastics, e.g. HDPE, LDPE, and PP, which have a carbon footprint in the order of 2 kg of CO_2/kg of product, is used for (mostly short-lived, single-use) packaging. The externalized costs of fossil plastics are huge, and they are estimated at 3.17 trillion USD/year for plastic packaging [1]. This corresponds to 18.5 USD/kg = 17.3 EUR/kg of plastic, or 1.7 Eurocent for 1 single plastic bag alone, which means that the externalized costs of plastic packaging exceed its market price by more than 2.5 times. Sustainable alternatives and substitutes have to offer comparable properties in terms of mechanics and price, and be biobased, biodegradable, reusable and/or recyclable, to enable several end-of-life options. They should preferably be made from waste raw materials and side streams, and not from primary agricultural produce like sugar, which also comes with a disadvantageous footprint, e.g. due to land use (change), demand for fertilizer and water, and feed/food competition.

Broadly speaking, packaging can be categorized into single-use and reusable forms (e.g. carbonated soft drink cans versus 20ft shipping containers) and flexible versus rigid materials (e.g. plastic bags versus plastic boxes). Most research on bioplastics in packaging has focused on flexible packaging (film). Flexible packaging, often layered, is commonly used for the protection of various low-value products, while rigid packaging typically employs sturdier materials such as glass, metal, wood, cardboard, and hard plastics. Rigid packaging serves purposes like safeguarding fragile items (for fall protection). It furthermore conveys a sense of luxury, as high-value products are frequently enclosed in robust *shells*. For a concise overview of rigid packaging, please refer to Table 1.

Only 9 % of plastics are recycled today [3]. The recycling rates of other materials (glass, paper/cardboard, metals) are higher, yet there are also environmental issues associated with the products (e.g. finite resource consumption, extra energy demand for transportation due to weight). Thus, there is a need for more sustainable packing solutions, particularly also for rigid packaging.

Table 1: Characteristics of rigid packaging [4].

Pros of Rigid Packaging	Cons of Rigid Packaging
Superior strength – Made from hard plastics and other materials.	**Material Cost** – Notably more expensive in most cases
Associated with quality – Glass, for example, suggests luxury.	**Sustainability** – Significantly higher carbon footprint
Unlikely to affect the flavour of food – This is due to the lack of soft plastics.	**Logistics** – Much higher shipping costs
Recyclability – E.g. glass and hard plastic	**End of Life** – If not recycled, takes up more space in landfills

One alternative,bioplastics, such as PLA (polylactic acid) and PHA (polyhydroxyalkanoates), are biobased and/or biodegradable, and the industry promotes their compostability. However, these materials can be controversial. Composters in many countries can have negative attitudes towards them as some products don't break down within one composting cycle (either due to a mismatch between standards such as EN 13432 and local composting practices, or products being altogether uncertified), leaving behind residue considered contamination. In addition, bioplastics do not yield valuable compost themselves, they simply mineralize to CO_2 and H_2O. Another highly contentious aspect of bioplastics is the discussion about the use of primary agricultural products, which could lead to undesired effects (e.g. competition with feed/food, energy consumption for fertilizer, direct and indirect land use change, etc). There are also plastics products with biobased fillers, so-called WPC (wood plastic composites). Such products, which are a mix of fossil, non-biodegradable plastics (PP, PVC, etc), and sawdust (also often imported materials, such as in BPC, bamboo plastic composite), give long durability, e.g. for deckings and facades, and they have reached a market volume of 4 million tonnes per year [4]. However, WPC as post-consumer waste is, as is the case with most composite materials, mostly downcycled. For foamed plastics, such as expanded polystyrene (EPS), a replacement with cardboard – moulded pulp – has been developed. Various deposit schemes as well as collection and sorting programmes try to collect packaging waste for recycling. Reuse of packaging is likewise difficult to implement in a non-industrial, standardized setting, given the broad diversity of packaging in shape, material, and use. It works well in many countries for PET bottles or large LDPE containers. For a review on bioplastics composites, see here [5].

Bark – a side stream with little usage today: Bark is an abundant and underutilized resource. Bark is the outermost layer of stems and roots of woody plants such as trees, it stands for about 10 % of the volume of a log. In Europe, approx. 45 million m³ of wood waste (incl. bark and sawdust) is produced per year [8], and globally that number is estimated to be up to 4 billion m³. Currently, more than half of the bark in Europe is incinerated or landfilled, where it aggravates climate change due to CH_4 emissions, and the remainder of the bark is mainly used as a cheap source of energy in saw/pulp mills [9]. In other parts of the world, it is often mismanaged by landfilling. Due to the high nitrogen content, combustion produces nitrous oxides, and the ash will be low-melting, increasing the risk of fouling. There are only a few areas where bark is being utilized, for instance as substrate in biofilters [10], in gardening, and as soft material on playgrounds (bark chips). Such materials also find use in terrariums. However, bark at large contains various extractable compounds, which could be utilized as a renewable source of chemicals, particularly tannins and other aromatic chemicals [11], which is only a niche market today. Various studies were made to extract compounds of interest from bark. For instance, tannins have anti-parasitic, antimicrobial, and antioxidative properties [12, 13].

Bark in packaging: Active packaging from poly(hexamethylene furanoate) and bark extracts was described previously [14]. PLA-based composites of Bael bark with potential biomedical applications [6] and high bark content (up to 60 wt%) in a PLA matrix [7] were studied recently [15]. Valorization of Larix decidua Mill. bark by functionalizing bioextract onto chitosan films for sustainable active food packaging was also reported before [16]. Sonoextraction of antioxidants from tree barks of Hungarian woodlands for potential food applications was studied as well [17]. All these components are obtained using different chemical treatments and (usually) harmful chemicals, increasing the environmental impact of biobased compounds obtained this way.

Bark itself has a low thermal stability, which has prevented its use as filler in plastics compounds in the past. Ground bark particles can be used in plastics composites, too. A study from 2018 concluded that swelling and water absorption properties were improved by 80 % compared to WPC [18]. Figure 1 shows a prototype of a rigid container made from 70 % (weight) of bark in a thermoplastic starch matrix (TPS). Glycerol was used as plasticizer in the TPS. The matrix was modified using proprietary technology to obtain water stability as well as to enhance barrier properties. The item (2 mm in thickness) was found to be compostable. Bark-derived packaging, when being biodegraded, will not completely mineralize like a biopolymer, but contribute to the formation of compost, thereby storing some of the carbon and providing a growth substrate for plants. Bark-based rigid packaging is an innovation that has yet to be explored for its potential. Bark, as a waste stream, has the potential to be upcycled to rigid packaging with a low carbon footprint and biodegradability. However, a different standard than EN 13432 would be required to describe its end-of-life performance.

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This article wants to raise awareness for rigid packaging from fully biobased materials. Let's work on defossilizing that section of the packaging industry.

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Figure 1: Prototype of bark-based packaging, containing TPS as binder and 70 % bark powder.

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