Fractionation Stream Components of Wood-based Biorefinery: New Agents in Active or Intelligent Primary Food Packaging?

Nanci Ehman, Agustina Ponce de León, and María Cristina Area

Active and intelligent packaging production helps to improve the food value chain, granting reliability to consumers. According to these two premises, these packaging concepts were born. Sustainability and food protection criteria are two fundamental aspects that can be achieved with wood components.

DOI: 10.15376/biores.18.4.6724-6726

Keywords: Wood-based; Active food packaging; Lignin; Wood extractives; Nanocellulose

Contact information: IMAM, UNaM, CONICET, FCEQYN, Programa de Celulosa y Papel (PROCYP), Félix de Azara 1552, Posadas, Argentina; email: nanciehman@gmail.com

Preservation before consumption is a vitally important factor in the useful life of food. Environmental factors that accelerate the deterioration of food are humidity, oxygen, light, dirt, and microbial agents. Currently, the principal function of a food container is to isolate food from the environment. Common food containers on the market include plastic materials with a high barrier performance, which prevents the passage of oxygen, water vapor, and liquids. However, health-related events (such as SARS-COVID) and environmental pollution (plastic pollution in the ocean) have changed consumer packaging demand. People are not only looking for more environmentally friendly food packaging but also for their food to have fewer preservatives and, in turn, to be well protected from external agents that could threaten its conservation. These circumstances set the stage for the appearance of innovative food packaging systems in the market.

Passive, Active, Intelligent, and Smart Primary Food Packaging

Passive or traditional primary food packaging only fulfills the property of isolating the food from its environment. It is currently the dominant form of packaging on the market and has lower costs. Plastic is the most widely used material as traditional primary food packaging due to its high barrier properties. From there, it is possible to find packages with specific functionalities, giving birth to the concepts of intelligent, smart, and active packaging (Fig. 1).

Going up toward a more sophisticated scale in food packaging, we find *active* food packaging. It contains substances that make it possible to increase the conservation of food or maintain its quality before consumption. The most common active components are applied to regulate humidity or moisture absorption, reduce scavenger components, or provide antimicrobial properties to the container. Some food packaging options also include elements that directly or indirectly control or monitor the packaged product: sensors, indicators, or data carriers, turning the container into food *intelligent* packaging. Besides systems control, these elements help to show the product history: RIFD technology or QR codes. Finally, *smart* packaging encompasses both of the above-mentioned packaging elements (active + intelligent).

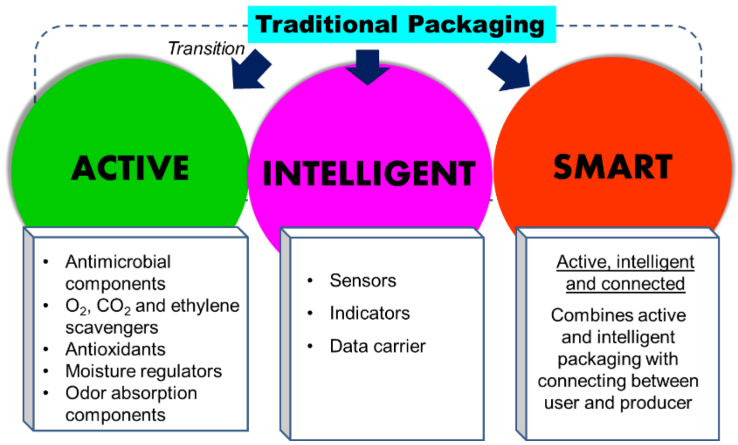

Fig. 1. Food packaging classification according to functionalities

Can biorefinery wood components be incorporated into active packaging?

It is a possibility. Fractionation operations in wood-based biorefinery schemes allow wood components to be separated into streams of extractives, hemicelluloses, lignin, and cellulose. Each fraction that is sequentially extracted contains wood components that show active properties for use as agents in active packaging. Some extractive phenolic-based components could improve the capacity of food packaging to avoid the precursors of pathogens (*E. coli*, *Salmonella*, *L. monocytogenes*, *Staphylococcus* species), leading to an antimicrobial system. Flavonoids (flavanones, flavones, flavonols, isoflavones, anthocyanidins, *etc*.) act as antibacterial agents, suppressing cellular functions and inhibiting bacterial growth. Condensed tannins can pass through the bacterial cell wall up to the internal membrane, interfering with cell metabolism. Also, several wood stilbenes derivatives (*e.g.*, pinosylvin) exhibit antimicrobial and cytotoxic activity. Finally, the extractives stream phenolic acid (gallic, ferulic, caffeic, and coumaric acid) can be incorporated in active packaging as radical scavenging agents (antioxidants).

The chemical heterogeneity of lignin components allows different properties: UV light absorption, good hydrophobicity, microbial growth inhibitory activity, and thermal stabilizer when combined in composite materials.

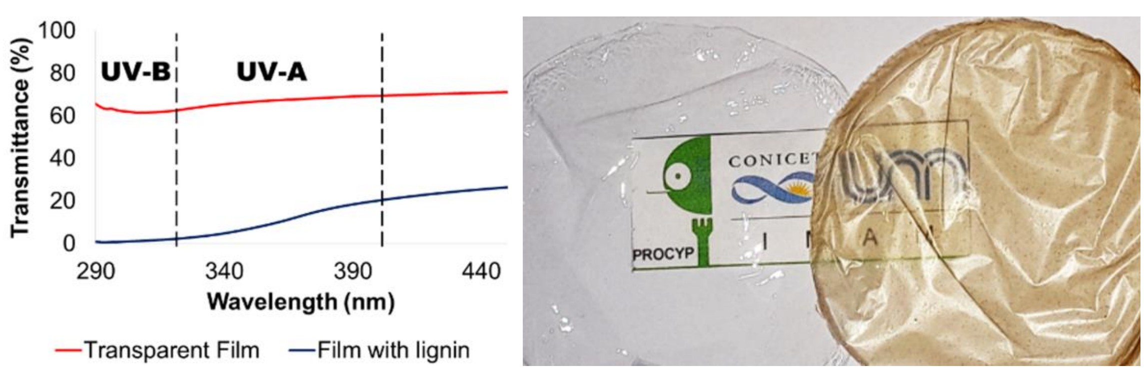

Fig. 2. Films based on wood components (nanocellulose + lignin) (own image)

The UV light absorption by lignin components would be of relative interest in the film's creation for food with some light-sensitive ingredients such as vitamins, fats, or flavorings of nuts, oils, milk, or wines. Our laboratory studies showed that the addition of at least 10% precipitated lignin in films allows blocking the passage of UV rays in the UV-B zone (280 to 320 nm) by up to 100% and gradually reduces the light transmission in the UV-A zone (320 to 400 nm) (Fig. 2).

As an antimicrobial agent, the lignin derivatives that contain a double bond in the side chain are the most effective inhibitors against bacterial species. The existence of phenolic monomers grants lignin antioxidant properties. Some characteristics of lignin will allow an increase or decrease in the antioxidant capacity (methoxy, phenolic hydroxyl, or aliphatic hydroxyl groups, and molecular dispersity).

Lignin could also be the main component in intelligent packaging when used as a Quantum Dot (QDot). QDots are particles used as sensors for detecting specific analytes such as pesticides, unsuitable food additives, veterinary drugs in meat food, and toxins. This detection is due to the photoluminescence activity that QDots have when bound to some chemical agents. In addition to the ability to detect specific analytes, QDots have antimicrobial and antioxidant activity. Their applicability in smart packaging could be promising for food safety.

Finally, the most studied option for cellulose-based materials in active packaging is nanocellulose as a barrier-active agent, which can be applied to fruit or vegetables as a coating. However, nanocellulose incorporation in active packaging is mostly as a matrix or reinforcing agent.

What are the opportunities for wood components applications in active and intelligent packaging?

The wood components obtained by biorefinery fractionation could present an opportunity for several current challenges in active and intelligent packaging to extend food shelf-life, quality, and safety. Some aspects that could be covered in primary food packaging by wood-based materials are as follows:

- *Sustainability*. Biobased and biodegradable packaging. Lignocellulosic raw materials obtained from another process could be the best option: pine sawdust from sawmills and sugarcane bagasse extracted during sugarcane production.
- *Strong and* lighter (even flexible). Packaging with less weight but that maintains sufficient strength to contain the food dry, wet, or at high temperatures. Due to their high mechanical strength properties, modified nanocellulose or microfibrillated cellulose are promising candidates.
- *Food safety*. Inclusion of components that prevent food deterioration: antimicrobials and antioxidants, oxygen, and light barriers. Flavonoids derived from wood extractives and even recovered lignin are promising candidates.
- *Reliability*. Sensors and intelligent indicators. Sensors for seeing the state of the food before its purchase. The applicability of lignin-based sensors is a future trend.

Despite these novel systems, there is still a long way to go to research active agents' overall and specific migration from the packaging to the food. Additionally, current regulations should be discussed, mainly when incorporating materials with nanometer-scale dimensions.