



### Short Review Paper

## Recent progress in Bio-based renewable food packaging with advancement in barrier property enhancement and traceability a complete state of the art

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### Abstract

Recently, progress in food packaging materials has increased tremendously. From mineral based materials to biodegradable or renewable materials for continued food security and protection especially in enhancing barrier properties. This paper x-rays the technologies/techniques available for modern food storage/packaging and the comparative advantages derivable from their applications over the conventional methods. In this case, ways are suggested to ensure the substitution of olefin based polymers with renewable and compostable polymers, even edible polymers to suit recent technological advancements. With the recent age of globalisation, food packaging is receiving more and better attention. Aside just food safety and better quality by strict monitoring, adoption of polymer nanotechnology can avail new materials for packaging. The self-assembly of polymers and nanoparticles into a variety of nanostructures and nano patterns at interfaces can be utilised in this concept. For instance, by the adoption of bottom-up self-assembly and self-organisation methodologies from liquid phases. This would create thin and ultra-thin films of polymers and nano particles; which are fabricated by simple methods like dip coating, spin-coating, casting and droplet evaporation. With these, directed and controlled fabrication of thin-film based nanostructures and nano patterns on surfaces are developed. These materials exhibit enhanced mechanical and other improved barrier properties, coupled with nanosensors and the use of internet of things for tracking food condition while in storage and on transit.

**Keywords:** Bioplastics, sustainability, barrier properties, nanotechnology, food packaging, biopolymer.

### Introduction

For there to be the satisfactory management of food production and supply, there is bound to be good packaging and logistics activities which would eventually encourage good consumer behaviour. Therefore every stage of the food chain has to be meticulously done and monitored to ensure food safety. Food safety system is involved in food production processes, packaging, storage and transportation from point to another. The scope of this work is within its packaging, distribution/transportation and storage.

Nowadays, the application of polymer nanotechnology has improved the quality of food processing and packaging, health benefits, hygiene and shelf life thereby satisfying shoppers and consumers' demand. There has already been recorded success in the use of nanotechnology in various scientific fields, like physics, chemistry, biology and other aspects of engineering. Their potentials are big and foreseen to bring many benefits to many areas of research and development; like medicine, food industry, agriculture and various fields of engineering. With particular reference to the food packaging area, some significant advances have been made in the nano reinforcement of bio based materials. This has made the necessary enablement

towards growing the economic and technological competition between renewable polymers for different uses<sup>1</sup>. Hence, various packaging functions can be successfully and sustainably implemented by polymer nanotechnology<sup>2</sup>. There is a broad range of potential applications where nanotechnology could offer innovative solutions to the food and food packaging industry (Table-1)<sup>3</sup>.

**Table-1:** Major areas where nanotechnology is applied in the food related industry.

Materials	Processing	Product	Product Safety
Nano particles	Heat and Mass Transfer	Controlled Delivery	Nano Sensors
Nano-emulsions	Reaction Engineering	Formulation	Nano Tracers
Nano composites	Biotechnology	Packaging	
Nano structured Materials	Molecular synthesis		

The inclusion of nanomaterials into food packaging offers some unique advantages to food packaging: Resistance to barrier, Inclusion of active components for functionality and Information sensing.

This development enables preservation of taste, colour, texture, consistency, and nutrients. Due to the essence of food traceability and monitoring during storage and transport, new technology with embedded nano sensors are incorporated so that the food environmental conditions would be tracked throughout the supply chain<sup>3-5</sup>.

**Food packaging:** Food packaging is a technology that encloses and protects food products for preservation, distribution, usage and marketing purposes. It is an industrial process which may be used along with food preservation with the intent of reducing or completely avoiding spoilage that would otherwise exhibit loss of textural quality, taste, or nutritional value of food<sup>6</sup>.

The food package serves as a protection to the product from deterioration and spoilage caused by heat, light, presence or absence of moisture, microorganisms, pressure, etc. Packaging constitutes products of different sizes and shapes and provides consumers with greater ease of usage and conveniently save time<sup>4</sup>. Various innovations in technology, also Internet of Things (IoT) have moved the packaging market from the well known conventional packaging to interactive, aware, and intelligent packaging<sup>7</sup>.

Smart packaging systems are based on the correlation between environment where the packaging is done and the food to provide adequate security to it<sup>4,8</sup>.

**Biobased Packaging:** This is the application of biodegradable materials in food packaging. As a result of economic abundance, petrochemical plastics have been much in use for packaging because of their qualities. Petrochemical products have barriers such as high cost, non-renewability, non-biodegradable thereby causing environmental pollution. Bioplastics have proffered a solution to the existing threats on the environment caused by petrochemical materials<sup>9</sup>. From a greenhouse perspective, it seems biodegradability is a viable option to minimise and ensure plastics wastes reduction. Therefore, the adoption of biobased sustainable materials (bioplastics) seems to be the only viable option in future as fossil fuel deposits might get exhausted perhaps<sup>10-13</sup>. This has created a shift in attention from the biodegradable/compostable materials to completely biobased products<sup>14</sup>.

**PLA:** Known as polylactide belongs to the biodegradable thermoplastic polyester family and appears as a transparent material in nature. It is derived from bio resources, and today it is serving as one of the most promising polymers for commercial application which would replace conventional polymers. The production process goes through corn conversion to dextrose, some other carbohydrates like rice, sorghum etc can be adopted as well, then fermentation of dextrose into lactic

acid. It can be processed using the following techniques- Injection moulding, blow moulding, thermoforming and extrusion overcast film extrusion<sup>10,15-19</sup>.

**Starch:** Another natural resource largely available and also biodegrades easily. Water and plasticisers like glycerol and sorbitol are required in large quantities for the production of starch based-films that are in the form of plastics. Due to the application of heat and mechanical energy, they are referred to as plasticised materials called thermoplastic starch (TPS). They serve as good alternatives where polystyrene is used. Starch-based thermoplastics like the blends of thermoplastic starch with synthetic polymer materials like polyvinyl alcohol, polyethylene, vinyl alcohol or polycaprolactone, are progressively used for extrusion applications, blow and injection moulding, even foaming and film blowing<sup>20,21,10</sup>.

**PHA:** Most commonly grouped under naturally occurring organism-based bioplastics known as polyhydroxyalkanoate, and belongs to the biodegradable thermoplastic polymer hence derived from microorganism. PHA is applied in polymer science for the production of composites, a common example is polyhydroxybutyrate (PHB)<sup>10,22</sup>.

**Cellulose:** A biodegradable polysaccharide and a natural polymer. It is obtained from the process of delignification from cotton linters or wood pulp. With the introduction of additives, cellulose esters like cellulose diacetate and cellulose triacetate can form thermoplastic materials; and they can be processed using extrusion or injection moulding processes. Ethyl cellulose can be applied for extrusion, laminating or moulding when plasticisers have been introduced to it or other polymers. These derivatives, albeit their expensive nature for bulk use, exhibit excellent film forming properties<sup>10,23</sup>.

## Barrier Property Improvement on Bioplastics

In recent times, there have been numerous studies investigating several possible ways by which barrier properties of bioplastics can be improved as regards food packaging.

**Coating:** Biobased films for food packaging applications are usually coated as a viable option to improve their general properties especially barrier. The coating is either biobased or non-biobased and entails the application or deposition of a thin layer of material on top of the biobased films<sup>24,32</sup>.

**Blending via Nanotechnology:** Nanotechnology may be visualised as a new area blending chemistry, material science, electronics, and biosciences together. It is a fascinating technology of the 21<sup>st</sup> century. It is the development and utilisation of materials with at least one dimension in the nanometer length scale ( $10^{-9}$ m)<sup>10,13</sup>. Nanoengineered polymeric materials are of great importance, rapidly developing a new class of materials optional to conventional filled polymers. The introduction of nanoparticles and nanodevices to biopolymers in food packaging is another state of the art phase in property

modification and improvement. This could be classified into three groups, namely: Improved packaging, Active packaging, and Intelligent/Smart packaging.

**Active Nanopackaging:** Active nanopackaging includes oxygen scavengers, antimicrobial, carbon dioxide controllers, antioxidants, flavour controllers, odour controllers, humidity regulators etc that blends with food and the surroundings and play a flexible role in preserving food.

**Intelligent/Smart Packaging:** Nanodevices present in the polymer matrix keeps a close watch and scrutinizes the factors affecting food packaging in the environment and secures against substandard products. Nanosensors respond to environmental variations that monitors the degradation products or microbial contamination. Also the new advances in electronic tongue technology will help enhance the smart packaging<sup>33-42</sup>.

**Inclusion of Biopolymer Cellulose:** The introduction of biopolymer cellulose to biobased fibers was observed to significantly develop the desirable properties of films, such as water vapour permeability<sup>10</sup>. The cellulose incorporated becomes well cemented to the polymer matrix. This arrangement confers the merits of good behaviour towards water permeability on the starch-based film, harnessing the hydrophobic and highly crystalline nature of the fibre<sup>43,44</sup>. For nano-clays, the inclusion of cellulose fibres reduces the vapour transmission rate by increasing the tortuous path, when turned around, a condition called congregation is achieved<sup>43,45</sup>.

**Hybridisation of Biopolymers:** This technique enables the synergistic utilisation of the inherent separate properties of these different materials which obviously overrides the single property of each for a particular defined objective. Therefore, blends of two or more different biobased materials have great potentials. Compatibility factor remains one of the greatest challenges during materials blending. To improve this compatibility for immiscible polymers, it is wise to introduce reactive functional groups via chemical modification<sup>46-48</sup>. Albeit the incompatibility/immiscibility of certain polymers, some positive effects of mixing are obtained. For instance: a blending of PLA with polycaprolactone (PCL) was observed to exhibit a reduction in brittleness of PLA film, a slight increase in thermal stability. However, the barrier property decreased in accordance with the proportion of PCL added this barrier property loss by the addition of kaolinite nano clays<sup>10</sup>. The brittleness of polylactic acid (PLA) can be diminished when combined with plasticisers (glycerol/sorbitol), starch, or other degradable polymers<sup>42,49-51</sup>.

According to Wu, Y.G.<sup>52</sup>, there was an improvement on the microstructure of starch film when blended with agar, water vapour permeation (WVP) and mechanical properties were also improved. Similarly, Fama, L.G.<sup>53</sup> reported that when starch was blended with wheat bran, the water vapour permeation (WVP) of the film was reduced and with increasing wheat bran fibre content, the mechanical properties were improved.

**Modification of Biopolymers:** Modification through either chemical or physical means affects positively the properties of biopolymers, especially water vapour permeation (WVP) and mechanical properties. It can also enhance biopolymer compatibility. In this case, starch is very promising as studies have proven that the hydrophobicity of starch can be improved through modification, which makes them have similar properties with other materials<sup>10</sup>.

## Food Safety, Monitoring, and Transportation

Food safety entails a number of routine scrutiny at every level of the process which should be imbibed to avert hazards. It is a scientific field indeed. Therefore, in order to ensure and enhance food safety, every stage of the process ought to be carried out and strictly monitored. Food Safety Management Systems (FSMS) is a network of interrelated elements such as set goals that combine to get rid of potentially dangerous health hazards<sup>4</sup>. In order to achieve food delivery without reducing quality, environment devoid of contamination risks and other possible hazards should be available. Also the need to build and implement a comprehensive and well-designed food contaminants monitoring systems. Barcodes (QR codes or similar matrix barcodes), universal product codes, and radio frequency identification labels allow automated information management in logistics at retailing. Packaging might be recognised or distinguished by the use of visible registration marks and other printing calibration/troubleshooting cues. Safe movement or transportation of food is a very vital key step to ensuring its safe arrival to customers, which is the ultimate objective, and that it remains of the highest quality with packaging untampered. Improper and unhygienic transportation could lead to breaking food safety circle, perhaps food poisoning or spoilage<sup>54-61</sup>. In accordance with the EU law, traceability entails following up food, feed, or animals alike that would be involved in production, processing and distribution<sup>62</sup>. Growth and upgrading in information and communication technology systems really improved food tracking. To ensure safe delivery in accordance with adequate standards, embedded technologies has been developed to be applied in these process<sup>63</sup>.

## Conclusion

In recent times, biobased materials have been mostly used in packing easily perishable products that rarely needs oxygen. Hence, the need to implement Internet of Things (IoT) which involves the combination of electronic and smart devices to track products and develop a flexible relationship with sensors and network in a food traceability system. This would ensure the safety of food materials and increase-consumer's faith in the food itself.

## Recommendations

The current use of bioplastics for product packaging that requires limited oxygen calls for the up scaling of these

materials in commercial scale. Therefore, there is need to drift our concentration from agro crops to wild and/or underwater crops. A good example is water hyacinth. This water hyacinth is considered one of the most notorious aquatic weeds which proliferate rapidly in lakes, dams and irrigation channels. It has been shown that water hyacinth and some other aquatic weeds have a rich source of carbohydrate and is promising in biodegradable plastics production.

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