

# Sweet potato starch/clay nanocomposite film: new material for emerging biodegradable food packaging

## Abstract

Environmental pollution caused by excessive waste from packaging materials driven the researches to develop biodegradable food packaging systems. One possible solution may be the utilization of a range of naturally derived materials. Sweet potato starch (SPS) is a low cost and abundant biodegradable polymer that may be used for packaging. However, starch films are inherently brittle and lack the necessary mechanical integrity for conventional packaging. The incorporation of additives can potentially improve the mechanical properties and process ability of starch films. Biopolymer-clay nanocomposites are new classes of packaging systems with potentially improved mechanical properties. This review discusses the possible uses of natural materials such as clay nanofillers with SPS to develop biodegradable nanocomposite packaging films to address issues of environmental impact, and agricultural sustainability.

**Keywords:** sweet potato starch, nanocomposite film, food packaging

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**Abbreviations:** SPS, sweet potato starch; MMT, montmorillonite

## Introduction

Packaging materials based on polymers that are derived from renewable sources may be a solution to environmental pollution concern and problems posed by non-degradable synthetic polymers. These types of packaging materials were first reported as early as 1950.<sup>1</sup> Such polymers include naturally existing ones such as proteins, cellulose, and starches. These renewable polymers are biodegradable under normal environmental conditions.<sup>2</sup> Interest and research activity in the area of biopolymer packaging films have been especially intensive over the past ten years.<sup>3</sup> Among all biopolymers, starch is one of the leading candidates as it is abundant and cheap.<sup>4</sup> Moreover, starch is known to be completely degradable in soil and water and can promote the biodegradability of a non-biodegradable plastic when blended, thus they are safe as food packaging materials. As films or bag, starch could be employed in many types of applications such as packaging for fruits and vegetables, snacks or dry products.<sup>5</sup>

Starch as a renewable source, appears to be the best raw material of biodegradable polymer with low cost.<sup>6</sup> Starch exhibits thermoplastic behavior.<sup>7</sup> Thus, since the 1950's starch from different sources has been widely studied as a potential film-forming agent. This review aims to discuss the application of sweet potato starch (SPS) for food film fabrication.

## Discussion

### Sweet potato starch

Sweet potato (SP) (*Ipomoea batatas* Lam) is an inexpensive and readily available vegetable which is cultivated extensively for its nutritious value across many regions of the world. In the past 15 years, the U.S. sweet potato production has significantly increased. Due to storage difficulties and inefficient processing, up to 15 % of SP is discarded every year due to decay.<sup>8</sup> Discoloration is the major

problem in the quality of the products and arises from two different sources. The first is the formation of brown discoloration caused by the oxidase reaction of polyphenol groups by enzymes; the second is the non-enzymatic browning (at high temperatures) when reducing sugars condense with amino groups. Thus, sweet potato starch (SPS) could be an alternative use of SP in the market.<sup>9</sup>

SPS with 58-76% starch content (on a dry basis), have properties similar to those of potato starch.<sup>10</sup> SPS has also exhibited bacteriostatic activity against pathogenic *Escherichia coli*, *S. Typhimurium*, and *S. aureus*.<sup>11</sup> In the food industry, SPS is used to impart "functional" properties to processed foods such as thickening, binding and filling. For instance, SPS has been successfully used to thicken chocolate pudding at Tuskegee University.<sup>12</sup>

For packaging purposes, moisture content and color properties of the starch is important. Liu<sup>13</sup> reported a 4.4±0.2%, 5.0±0.2% and 6.0±0.3% moisture content for starch extracted from three SP cultivars. They also reported that L\* color values of SPS are comparable of corn starch. Furthermore, in contrast to the other biopolymers used for film fabrication, SPS does not impart any allergenicity, since these materials may migrate to the edible food from packaging. However, SPS does not have the mechanical and barrier properties matching those of plastics.

### Reinforcement of starch based film

Unfortunately, the use of starch as food packaging materials has some limitations, when compared to the conventional non-biodegradable materials made from petroleum. It has limited mechanical properties such as thermal, and barrier properties. In particular, because of the hydrophilicity of the starch the performance changes during and after processing, due to the water content changes.<sup>14</sup>

In order to overcome this limitation, there have been several attempts to enhance the end-use properties of starch in biodegradable packaging. Therefore, it is possible to improve the properties of starch

by filling a thermoplastic starch matrix with nanofillers. The addition of nano-scale particles into starch can change the crystallization kinetics, the crystalline morphology, the crystal forms, and the crystallite size. As a result, it may improve the mechanical and barrier properties of starch.<sup>15</sup> By far the most promising nanoscale fillers for biodegradable packaging are montmorillonite (MMT) nanoclays. The popularity of MMT nanoclays in food contact applications derives from their low cost, effectiveness, and high stability.<sup>16</sup> The nanoclays have an average thickness of ~1nm and average lateral dimensions ranging between a few tenths of a nm to several  $\mu\text{m}$ . This is desired because bio-nanocomposites depend on the high surface area of the nanosized fillers which results into a large interface between the matrix or biopolymer and nanofiller. The large interface enabled improves its physical properties, thermal, and barrier properties of the bio-nanocomposites.<sup>17</sup> Especially for food packaging applications, bio-nanocomposite materials are usually designed to have the ability to endure the mechanical and thermal stress during food processing, transportation, and storage.<sup>8</sup>

In some studies, the safety of packaging materials made with nanoclays was investigated. The main risk of consumer exposure to nanoclays packaging is through migration of nanoparticles or other substances from packages into packaged foods which are then eaten. However, migration studies are few in number. Avella et al.<sup>18</sup> showed that vegetables in contact with clay/starch nanocomposite films exhibited no trends in their iron and magnesium content. Their results demonstrated either no appreciable migration of the constituent elements of the clay nanoparticles into the food, or migration within the limits set forth by the current food regulations.

Shen Wu et al.<sup>19</sup> found poor mechanical and water vapor barrier properties for SPS as compared to plastics. To alleviate this problem, McGlashan and Halley<sup>17</sup> incorporated MMT nanoclays in the starch-based packaging materials. Tensile strength is an important indication of mechanical properties of packaging which expresses the maximum stress developed in a film during tensile testing. Their results showed that the addition of nanoclay (from 0 to 5 wt %) significantly improved both the processing and tensile properties over the original starch blends. Avella et al.<sup>18</sup> also showed a good increase in modulus and tensile strength for starch-nanocomposites prepared from cast film dispersions of MMT into plasticized potato starch.

The incorporation of nanofillers may not only enhance the mechanical properties of the biopolymers but also provide other desired functions and exploited in the field of various industries including packaging sector, such as antimicrobial agent, biosensor, and oxygen scavenger. The incorporation of nanofillers that exhibit antimicrobial properties could improve food safety by controlling the growth and invasion as well as killing bacteria and pathogenic microorganisms in the food. Generally, the large surface area of nanofillers permits more microorganisms to attach to the nanofillers thus increase the antimicrobial efficiency of nanocomposite materials.<sup>9</sup>

Furthermore, many studies have demonstrated that antimicrobial function has long been recognized for some nanofillers or nanoparticles (e.g. MMT, chitosan, silver, ZnO), which are favorable for food packaging applications.<sup>6</sup>

The success of the above studies indicates that nanoclays show much promise in improving the mechanical and barrier properties of starch-based packaging materials as well as exhibited other desired functions and applications in food packaging.

## Conclusion

This paper succinctly reviewed the possible fabrication of a biodegradable nanocomposite (bio-nanocomposite) packaging film from sweet potato starch (SPS) which may provide an alternative biodegradable source of starch for packaging without an allergenic compound as there is no report of any allergenicity of SPS.

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## Conflict of interest

The author declares no conflict of interest.

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