Starch as a Filler in HDPE

Key Words:

filler, starch, mechanical properties, biodegradability

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ABSTRACT

Emphasis is placed in this paper on experiments designed to elucidate the mechanisms by which starch–polymer interactions result in composites with properties markedly different from the unfilled polymer properties. In particular, attention has been directed towards increasing our understanding of the thermal and mechanical properties of starch filled HDPE.

INTRODUCTION

Organic plastic additives offer several advantages to the plastics processor, the user and society as a whole. A wide range of these additives may be used to give plastic products improved mechanical properties, better surface quality for some applications and, when desired, biodegradability [1-3]. Additional benefits may include lower product cost and longer life for processing machines.

Starch, a natural polymer produced by plants, has been known and used in a variety of forms for diverse purposes for centuries. Recent studies have revealed its important potential in the plastics field, especially as an economic filler which, when used with familiar polymers to produce composites, can impart valuable properties which polymers alone do not have.

The use of these additives makes it possible to replace part of a polymer, which is an increasingly costly petrochemical product, by starch, an easily renewable natural resource available worldwide. In many cases the user benefits from a product which is lower in price and has an improved appearance.

Some of the additives are formulated to trigger and accelerate the biodegradation process of plastic bags and other disposable items after they are buried underground, disposed of in refuse dumps or simply discarded as litter.

Starch in its usual commercial form is totally unsuited for use with plastics. The starch must first be selected for the appropriate grain size according to the application for which it is intended. Then it must be carefully dried and rendered hydrophobic. The excellent compatibility of these additives with many different plastics and the ease and simplicity of processing make it possible to use starch in a variety of ways on different polymers. Specially treated starch has been tested in polyethylene, polypropylene, polystyrene, polyurethane, ethylene vinyl acetate copolymers, polyester, P.V.C. and A.B.S. Plastics containing additives have been made into film for bags, mulch film, injection moulding, blow moulding, sheets for thermoforming and foam. Each new application must be carefully examined to find the proper balance of physical and chemical properties, appearance, material and processing costs, and other required factors.

Starch particles from different plants have varied sizes and shapes making it possible to choose the best suited type of starch for each use. For very thin film, small particle size starches such as rice or taro may be needed, whereas wheat and maize starch give good results with most blown films.

Serveral detailed investigations of the properties of starch-filled plastics have been carried out [4,5].

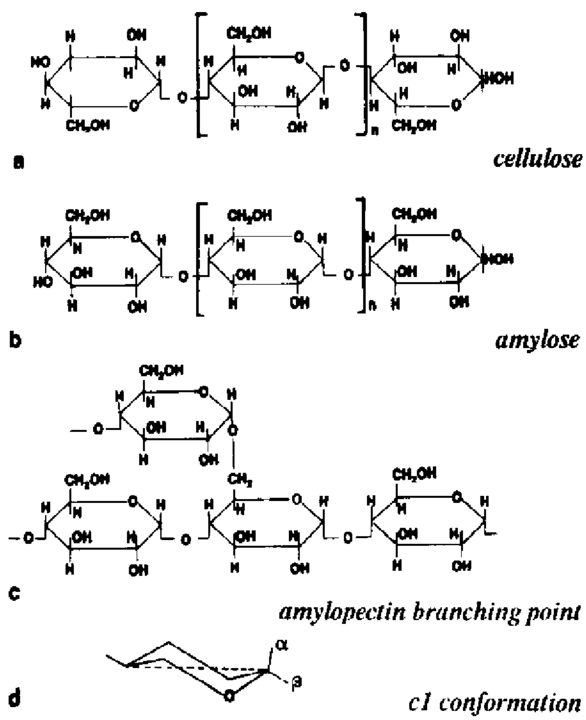

***Figure 1:** Amylose is a linear polymer of 1-4 linked α-D-glucose residue in the C1 conformation whereas amylopectin contains additional α-(1-6)-glycosidic branching link.*

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STRUCTURE OF STARCH

Starch and cellulose are both naturally occurring polymers composed of the same structural unit: D-glucose (Figure 1).

Their physical and chemical properties have been studied extensively [6, 7]. In starch the units are α – linked whereas in cellulose they are ß – linked. Consequently the polymer structures are different in conformation. Most starches consist of two chemically distinct components: amylose and amylopectin, and these are present in varying amounts in starch from different botanical sources.

STARCH VARIETIES

Apart from well-known starches like potato, tapioca, maize and rice, there are several other starches including taro (Genus colocasia).

Dry slices of taro starch were obtained from the Department of Food Science and Technology of the University of Hawaii, Honolulu: The U. S. Department of Agriculture Field Station at Kawai. These taro starches were extracted and purified [8]. Out of 112 different taro starches examined, four could be manufactured commercially from taro cultivates currently grown as commercial crops. These are:

- Colocasia esculenta var. Bun Long
- Un–named cultivar ex W. Samoa
- Colocasia esculenta var. Lehua Maoli
- Colocasia esculenta var White Maoi

These taro starches were examined by optical and electron microscopy in order to characterize shape, surface and granule size distribution.

Particle size measurement was carried out using an Image Analyzer (Plates 1 - 4), and compared with S.E.M. photo-plates (Plates 5, 6). Tables 1–4 show particle size distribution of starch used in HDPE.

The granules of rice starch are small (see Plate 1). Table 1 shows particle size distribution. The central helum is difficult to observe and the hilum is visible only after treatment with dilute acid. Compound grains comprising several granules are sometimes observed owing either to inadequate steeping or to improper drying during manufacture and have relatively low birefringence.

Of the 112 taro starches available, Bun Long, White Maoi, Lehua Maoli and West Samoa were observed under optical and S.E.M. microscope (see Plates 2, 3 and 4). The reason for choosing these starches is that they can be produced commercially. Bun Long (Plate 2) is the smallest among these four. Table 2 shows particle size distribution. The granules are mostly polygonal. The granules of Lehua Maoli (Plate 3) are very similar to those of Bun Long and have polygonal shape. Table 3 shows particle size distribution of Lehua Maoli. White Maoi (Plate 4) is very similar to Lehua Maoli. The granules are mostly polygonal. Table 4 shows particle size distribution of White Maoi.

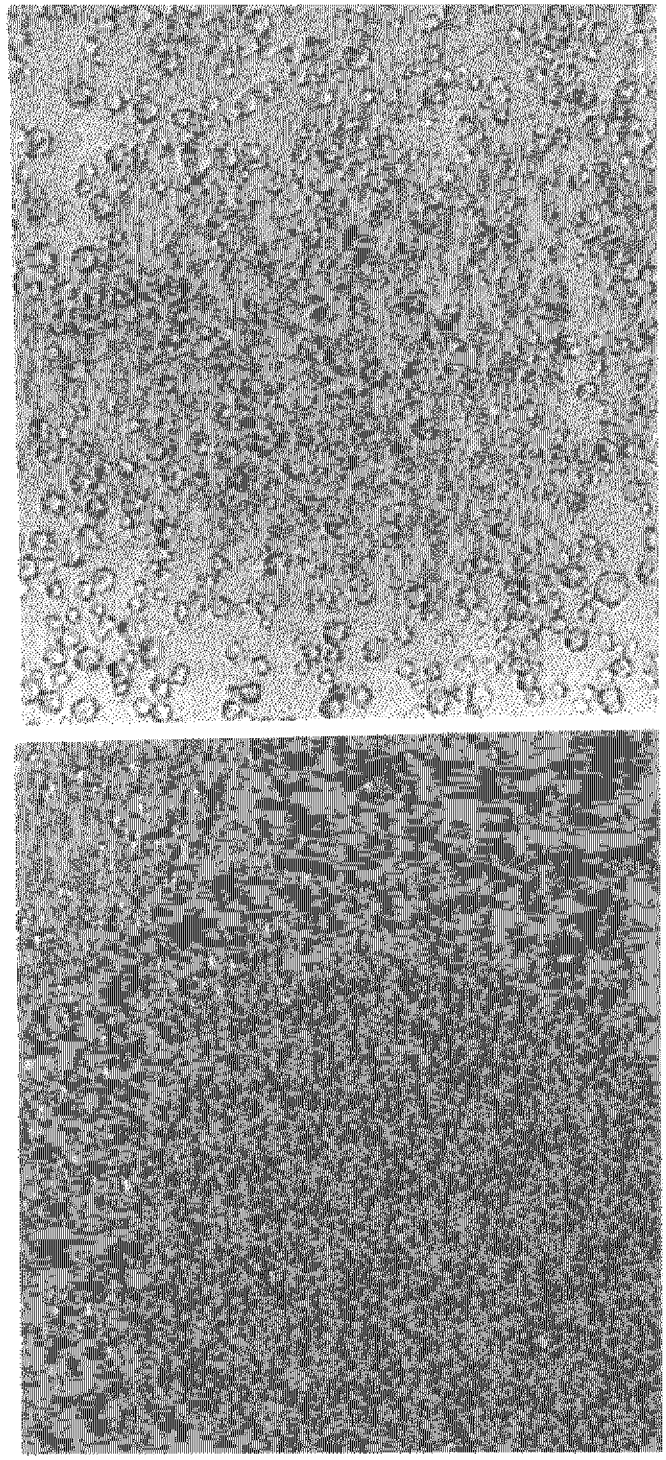

Plate 1: Optical photomicrograph of starch granules from rice starch (c420)
(top): normal light (bottom): polarized light Mountant was glycerol / water (1:1)

Experimental

SURFACE TREATMENT OF STARCH

In order to achieve compatibility of starch with HDPE,