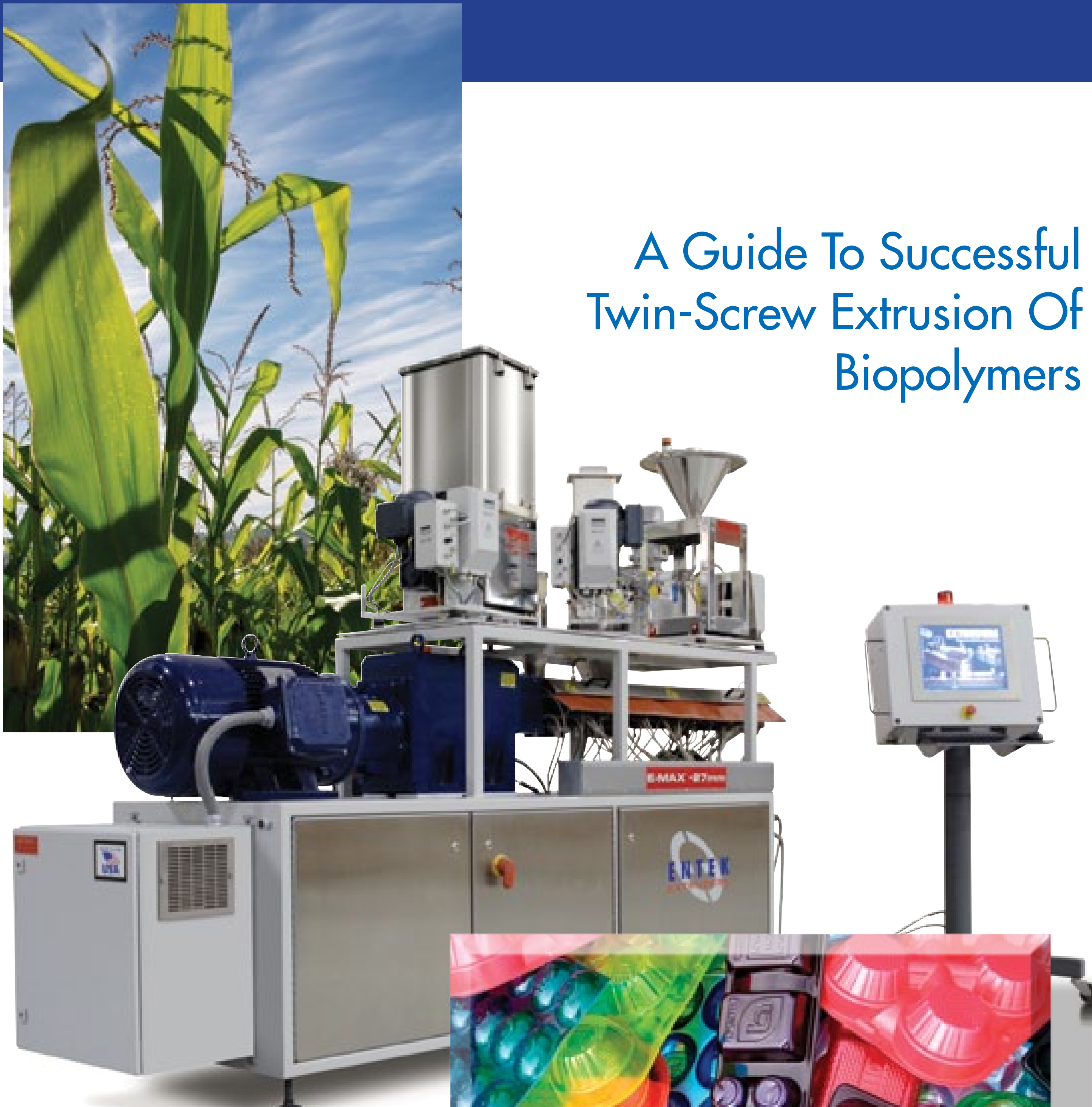
A Guide To Successful Twin-Screw Extrusion Of Biopolymers



ENTEK EXTRUDERS™

Processing biopolymers with twin-screw extruders can be challenging. This article addresses what we at ENTEK have learned about the various types of biopolymers, the challenges of processing them, and what it takes to be successful.

By Dean Elliott, Laboratory Manager, ENTEK Extruders – Lebanon, Oregon USA

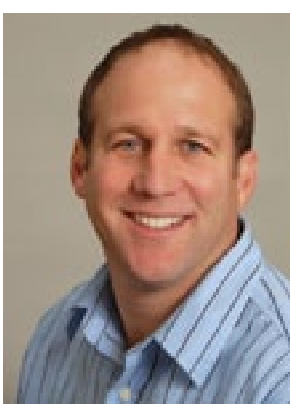


FIG. 1 Biodegradable food packaging trays from Plantic Technologies Ltd.

Introduction

Biopolymers are an emerging market, and one of the very bright spots in the polymer processing industry. Research estimates that the global market for biodegradable plastics reached 541 million pounds in 2007 and is expected to reach 1.2 billion pounds by 2012. We at ENTEK have seen first-hand evidence of this trend. In 2006, only three years ago, ENTEK ran a grand total of zero trials in our company's in-house development lab involving biodegradable resin compounding. Today, biopolymer processing makes up approximately 1/3 of all our twin-screw extrusion trials.

ENTEK was actually a very early participant in bioresin processing; one of the pioneers in the industry, Plantic Technologies Ltd. of Australia, initially came to ENTEK in 2003 for assistance in developing their proprietary material formulas. Today, their patented food packaging products are commercially successful and in use worldwide (see Figure 1).

Many new players have emerged in the industry and new materials and formulations are arriving at our company weekly. Co-rotating twin-screw extruders such as those supplied by ENTEK provide excellent material mixing capabilities for biopolymers (see Figure 2). And as our customers have learned, the success of mixing the key materials in any biopolymer formulation is most critical to achieving the best end results.

FIG. 2 ENTEK E-MAX™ 27mm Co-Rotating Twin-Screw Extruder Configured for processing Bio-Based Blends

Our goal as a machinery supplier and development partner is to achieve our customers' goals for melt quality, production rates, and other parameters regardless of the material formulation. These goals are the same for biopolymers and any other materials. A certain amount of trial and error is inevitable in the process development for new material applications. Some biopolymer formulations are successful from the start; others need more work to become commercially viable.

In this article we will define the types of biopolymers that are on the market, examine the challenges of processing them, and share some of our processing knowledge gained from several years of hands-on experience.

Types of Biopolymers

Based on numerous material trials over the past few years we have categorized the broad field of 'biopolymers' into three key areas:

- Reactive bio-based materials (starch-based materials and plasticizers)
- Bioresin materials (PLA, PHA, PSM etc.)
- Bio-based blends (bioresins or starches blended with thermoplastics)

Each of these categories of materials has its own processing challenges and requires different co-rotating twin-screw extruder configurations for successful processing (see Table 1).

Options	**Reactive Families (Starch & Plasticizers)**	**Bioresins (PLA, PHA, PSM)**	**Blends (Bioresins or Starches & Plastics)**
Feeders	2–4 loss-in-weight 1 liquid	2 minimum	4–8 dry Possible liquid
Venting	Available	2 vacuum	2 vacuum
Die	Strand or Sheet	Strand or Sheet	Strand, Sheet, Underwater Pelletizer
Downstream Equipment	Air Belt or Calender	Air Belt or Calender	Air Belt, Calender and various Pellet Drying Options
Screw Configuration	48:1 typ.	40:1 minimum	48:1 typ.

Co-Rotating Twin-Screw Extruder Processing Techniques for Biopolymers

One of the main requirements of a co-rotating twin-screw extruder, especially when processing biopolymers, is flexibility. By that we mean the flexibility to run with a wide variety of screw and barrel configurations, as no two biopolymer formulations are the same.

Successful processing of many types of biopolymers requires maximized residence time for optimum end product quality, while maintaining limited shear rates to control extrudate temperature. This can often be done by utilizing long extruders (52:1 L/D).

Also, you must optimize the screw design to achieve the right levels of dispersive and distributive mixing. This involves selective placement of dispersive mixing elements, distributive style screw elements and reverse screw elements along the screw. In the case of Bioresin/Thermoplastic Blends, the screw geometry is set up into segregated zones of high shear for polymer introduction and a low shear zone for biopolymer inclusion. In some instances, fiber destruction is required so an extremely high shear or 'explosion zone' is set up at the end of the screw.

At elevated extrudate temperatures, foaming at the die can be an issue. Together with optimized screw design, an additional method to reduce extrudate temperature without jeopardizing increased residence time or product quality (especially when processing Reactive Families/Starches) is to adjust the levels of moisture introduction in conjunction with the number of vents and the level of vacuum draw at the vents. When properly adjusted, not only is the extrudate temperature reduced, but the temperature at which foaming occurs increases.

When processing some Bioresin Raw Materials, the powders have a tendency to fluidize in the extruder feed throat which limits extruder throughput. This phenomena can be minimized by optimizing the extruder feed throat design and feeder position.

Biopolymer Development and the Importance of Lab Trials

Now, a word or two about the importance of research and development is in order. It is important to note that virtually all of the above-mentioned processing techniques were learned through development trials at our in-house processing laboratory. We are constantly working with customers and prospective customers to help them test material formulations and improve their processes. Whether its biopolymers or other material compounding applications, we encourage customers to visit, work with us and spend the time necessary to achieve success. It is only through understanding the whole process need, patience and managing the trial criteria that we ultimately learn the best processing techniques.

Summary

In the difficult economy of the past couple of years, the biopolymer market has been one of the few growth areas in our industry. It has provided, and will continue to provide a huge opportunity for companies that have the idea for the 'next big thing' in sustainable, bio-compostable, biodegradable materials. As the current recession begins to turn into recovery (as it already appears to be doing), and investment capital begins flowing, this opportunity will only get larger.

As this paper has shown, much of the groundwork has already been done to develop successful processing techniques for biopolymers. However, this market is still in its infancy, and it is constantly changing. New ideas and new materials are being developed today that will 'push the envelope' of twin-screw extrusion.

To those working to develop new types of biopolymers, perhaps the best advice I can provide is:

- work with an expert in the field who knows the ins and outs of processing, and
- be patient and keep trying – today's challenging lab trial could be tomorrow's 'next big thing' in biopolymers!

ENTEK EXTRUDERS™

ENTEK Manufacturing, Inc.
PO Box 39
200 N. Hansard Avenue, Lebanon, OR 97355
Tel. 541-259-1068
FAX 541-259-8018
www.entekextruders.com