

SECTION I

c0001

Overview of Polyolefins and Additives.

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c0001 Introduction

p0010 This brief introduction will cover broader issues with polyolefins (PO) that justify this book's central focus on PO additives. As with forthcoming chapters, this chapter begins by listing some general guiding questions (and the sections in which they are discussed):

- u0010 ■ (1.1) Why are POs important enough to focus on as a distinct segment of the plastics industry?
- u0020 ■ (1.2) Why are additives critical for the overall success of POs?
- u0030 ■ (1.3) What are some recent issues in PO use and production that have been influencing the use of additives?

s0010 **1.1 IMPORTANCE OF POs**

p0050 Plastics would not be so common in daily life if not for the technologies behind one general family of polymers—POs. Since World War II, daily life in both industrialized and developing societies has become radically changed by these carefully formulated organic materials, which are based on deceptively simple molecular structures built only from carbon and hydrogen. With polyethylene (PE) and polypropylene (PP), products once made from other materials became cheaper and often more durable. Innovative products that never existed before became possible (and affordable) and other products became lighter, brighter, and more user-friendly. And food and water could be packaged and transported in new, flexible ways (with even the modest PO water bucket contributing much to a community that otherwise could afford few other industrial products).

p0060 The sheer total volume of POs that are used reflects their importance. PE and PP make up over half of the +150 million metric tons of thermoplastics demanded worldwide (with PE accounting for nearly two-thirds of all POs). This consumption is equivalent to roughly 15 kg of PO product per year for

each person on earth. So, given this demand for POs and the range of product types available with these versatile materials, it is likely that most people in the world now come into contact with an article made from PE or PP at least once each day [1-1, 1-2].

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The production and use of POs in the world continues to grow, though at changing growth rates over time. PP, fueled by its particular versatility and improved properties, continues to grow ahead of other resins. PP has maintained an annual average growth rate of 6%–7% since 1980. Annual growth has since fallen off to under 3% in the 2000s, although some experts have now predicted a return to continued growth at 7% to over 8%. PP production capacity is expected to lead this growth by doubling during the period from 2008 to 2013 due to plant expansions in the Middle East. PE's growth rate, likewise, has been over 6% in the late 1990s/early 2000s. This growth has fallen below 1% since, though it may rise back to 6% by 2010, following the trends of a recovering global economy, new production capacity, and new food packaging and other applications. Meanwhile, both PE's and PP's growth will be supported by more efficient processing aids, stabilizers, and other additives that are being introduced into the market [1-3, 1-13, 1-14, 1-15].

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1.2 IMPORTANCE OF PO ADDITIVES

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Given their low cost, PE and PP have traditionally been categorized as "commodity plastics." But this is misleading; in fact, POs have been used for some engineering applications for years. Their properties continue to be expanded by the use of material additives whose contributions for improving properties are often under-reported and poorly understood. (In this book, "additive" will be used generally to refer to any material intentionally added to the base PO resin to influence the resulting compound's properties.)

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Although the molecular weight and polymer structure of POs can be carefully controlled by advances in polymerization techniques, these advancements account for only part of the property improvements in commercial PE and PP grades. Reaction catalyst technologies are critical for providing many desired physical properties and processing characteristics, but they cannot address all the issues POs face during processing and service. And they cannot enhance many of the properties that make PO materials serious candidates for applications once controlled by more expensive engineering plastics. Additive reinforcements such as glass fibers, for example, will likely continue to be the main way PP is strengthened for its most extreme engineering applications.

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Meanwhile, markets are driving improvements in low-cost, nonengineering applications of POs, such as packaging. But now, just efficiently enclosing a food item or other product is no longer enough; the packaging itself must communicate a

product brand's unique qualities. Better reactor technologies have been heralded as providing high-clarity resins allowing new packaging uses, but new additives are at least as important for creating clarity or subtle effects in color or design that sells the packaged product. As these demands increase, traditional additives will continue to be challenged by alternative additive technologies.

s0030 **1.3 RECENT ISSUES IN USING ADDITIVES**

p0110 Even though they have been used commercially since only the mid-twentieth century, POs, and thermoplastic materials in general, have reached a certain maturity. Processors and designers are no longer excited by their basic capabilities; instead they ask, "How can I make more effective use of these materials?"

p0120 Consequently, the plastics industry has seen the wall thickness of plastic articles become thinner, though still stiff. The industry has seen greater demands for tougher materials with greater resistance to environmental factors. And it has faced the need for "leaner," more flexible processing, adding additives nearer the point of final molding or extrusion to tailor compound properties. Meanwhile, the industry has also seen more complex additives become available whose purpose and cost-effective use are not always adequately explained or demystified by suppliers.

p0130 Below, five key current issues are identified and discussed that relate to the choice and use of PO additives. These are the underlying themes of this book.

s0040 **1.3.1 Matching property requirements with additive type and amount**

p0140 Complicated and changeable relationships exist between resin supplier, compounder, processor, and end user. But operations of all sizes benefit from using materials at effective economies of scale, which depend on market volume, plant size, processing rates, and many other factors. For example, high-volume operations for diverse markets may tend to purchase standard additive formulations that cover a wide range of properties. Companies in smaller volume or specialized markets may rely more on compounders to provide custom formulations or masterbatches. And, in the interest of increased processing flexibility, all processors may seek options for adding additives to resin in-line or nearer the process that forms the final product [1-4].

p0150 For efficiency and flexibility, operations also benefit from purchasing only the additives required for the properties they actually need. Additive type or amount can be adjusted to provide no more than the required property that is demanded over the actual expected lifetime of the product (e.g., adding only just enough stabilizers to protect the product's appearance throughout its limited shelf-life). But this efficiency requires a good understanding of additive capabilities [1-5].

p0160 Achieving this flexibility also often requires blurring the lines between compounder and converter. A processor might start adding more different kinds of additive concentrates from masterbatch suppliers, rather than buying a fully compounded resin grade from a compounder. Or a processor might even bring its own compounding line in-house, if costs favor the expansion [1-6].

s0050 **1.3.2 Doing more with less material**

p0170 Over the last decade especially, calamities of weather and war have pressured petroleum and natural gas prices upward, and this has periodically shifted the cost of PO feedstocks in radical ways. Minimizing the amount of PO in a product is one way to soften the blow of major raw material cost changes [1-2].

p0180 Overall, higher energy prices (and environmental concerns) have created more calls for the “lightweighting” of products, especially in the transportation industries. For users of metal components, one satisfactory solution has been to switch to lightweight plastics when possible. But now the burden rests on all industries, including plastics, since an energy factor is attached to the production and transportation of all products, and all stand to benefit from energy savings and reduced emissions.

p0190 Thus, plastics manufacturers and end users need to use additives creatively to extend resin properties. In durable applications, longer-lasting, low-density PO products support the goals of material and energy efficiency. These materials require better fillers and reinforcements for increased mechanical properties and additives that protect the base polymer from degradation through longer product lifetimes. Unfortunately, a company’s material-selection process does not always fully take into account all the properties required over the complete lifetime of a plastic product. Here, long-term testing and design-of-experiment (DoE) methodology are used to help identify the property contributions of each ingredient in a formulation. For example, DoE can be used to optimize a formulation by showing how much different levels of impact modifier, filler, or other additives, along with various processing conditions, affect the performance of a thermoplastic olefin (or thermoplastic polyolefin, TPO) in a rigorous automotive application [1-7, 1-8].

p0200 Other issues relevant to energy and the environment can influence additive selection. For instance, interest is growing in the use of alternative—plant-based fiber reinforcements and fillers. These agricultural products (produced mostly by solar energy) reduce the energy or “carbon footprint” of plastics production. And they reduce material densities and handling hazards, as found with glass-filled POs, for example. This interest has also led to more extreme ideas for using waste organic materials, such as scrap leather, as PO fillers. Moreover, interest in improved PO recyclability will continue and perhaps increase. Greater recycling will require better methods for compatibilizing

resins of different morphology or rheology to create useful products that are equivalent in properties to virgin materials. Still the costs of these approaches have to be weighed against their overall benefits, and often the “greenest” and cheapest approach of all may be simply to reduce the amount of plastic in each packaged product [1-11, 1-12].

s0060 **1.3.3 New properties for new markets**

p0210 POs are still young enough materials that new markets remain to be conquered by them. New reactor technologies and additives are allowing them to penetrate markets currently dominated by other plastics. For example, transparent PP with improved clarifying additives can now compete with PET bottles in certain packaging applications. And improved PP-based TPOs in the automotive industry are becoming the norm for exterior and interior plastics on vehicles, replacing metals or other plastics.

p0220 However, new successful applications for POs tend to increase consumer expectations. For outdoor applications, this means POs will require better ultraviolet light-resistance (e.g., for large playground equipment or storage) made possible with light stabilizers. And indoors, expectations continue to increase for durability and appearance. Here, additives supply new aesthetic features to POs, increasing the market appeal of plastics. These include pigments that bring bright hues to colored products to attract the eye and even fragrances to attract the nose. Thus the phrase “it’s just cheap plastic” is not being overheard now nearly as often as it was in the 1970s. (No longer can plastics afford to be seen as “cheap.”)

s0070 **1.3.4 Unintended additive interactions**

p0230 To enhance polymer properties, additives must interact with the polymer matrix and the mechanisms that tend to stress or degrade it. Unfortunately, they may also interact with other additives or the external environment in unexpected ways. One additive might improve property X while hurting property Y (or while diminishing a different additive’s effect on improving property Y).

p0240 These complex interactions create challenges for the compounder, processor, and end user, and also help reinforce the mysterious and sometimes controversial public image of plastics in general. Accordingly, some additives’ and polymers’ interactions with consumers’ health and the environment are often questioned by skeptical environmental organizations. This makes an understanding of these materials’ health and safety effects essential for the industry, so that industry experts can communicate authoritatively with these organizations and government regulators. In the interest of protecting consumers, regulators are sensitive to the sometimes hazardous nature of some additives (even though the hazard may exist only when the additive is in pure bulk form, for example).

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Perhaps inevitably, regulators and other external forces influence plastic industry trends in additive selection. In Europe, REACH registration is requiring manufacturers to document the properties of materials they plan on using. Restriction of Hazardous Substances (RoHS) directives in the European Union (EU) and China are targeted at restricting the use of heavy-metal and halogenated ingredients in electrical and other applications. Legislation in the EU, California, and elsewhere is already tending to discourage or stop the production and overall use of brominated fire retardants, for instance. The registration of the toxicological effects of more popular additives, such as antimicrobial agents, has also been targeted. And overall, there currently seems to be a trend toward industry limiting the use of an additive or material even before scientific studies about its health effects are completed [1-3, 1-9, 1-10].

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So for better or worse, regulations play a role in dictating additive choice. They can create major obstacles (or at least extra paperwork) for suppliers, even when they have a new material that the industry and consumers want. But there may be opportunities lying behind these obstacles. And to some extent, additive makers and users are victims of their own success by being able to adapt so many substances for plastics use, and thus creating so many new applications visible to public speculation.

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1.3.5 Faster processing

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The last but not the least-important issue concerns speed. POs, which are so often used in high-volume commodity applications, are being processed with faster, computer-controlled equipment and tooling. Competition is driving this need for speed. A simple example is a molder who requires a PP margarine tub to be molded at a certain cycle time on a high-speed injection molding press; if it is not, the molder cannot be competitive and profitable at the same time, and the job cannot be considered a "winner." With processing machines getting faster all the time, PO formulations include additives that help processors reach their productivity goals using processing aids, nucleating agents, and other additives.

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Productivity is a final overarching theme of this book. Here, additive selection can play a multi-faceted role for success. But among all the decisions made in a manufacturing operation, decisions about materials are often the hardest to make, especially by those who are closest to the process. Engineers or technicians who are comfortable with how a certain material runs or performs may feel that adjustments to the material's formulation are unreasonably risky. However, such changes do not have to be stressful and much can be gained at the bottom line.

Author Query

{AUQ1} Please confirm whether the edits made to the sentence “In this book...compound’s properties” retain the intended sense.