1 Imminent Changes in Packaging Materials

As a professional and decision maker in packaging sustainability, you certainly want to avoid problematic packaging materials that are likely to be banned in the future. More importantly, I bet you are interested to know what the potential alternatives to these problematic materials are. This chapter will address the above two issues and help you make informed decisions. Towards the end of this chapter, I present a **decision-aid table** for problematic materials in packaging.

First, let's consider problematic packaging materials and potential alternatives. **Problematic packaging materials are:**

- harmful to the environment,
- difficult to collect and recycle, and/or
- an impediment to the recycling of other reusable materials in municipal solid waste.

If you are working in the field of packaging, you may be able to identify at least some of those problematic or unnecessary materials. There are lists of questionable materials, such as the one on the U.S. Plastics Pact webpage [2]. Here we will consider all types of problematic materials including paper, glass, metal, and paper, and also present viable options and alternatives.

1.1 Packaging Foams

Introduction and Uses

Foams are plastic materials with cellular structures. These cells are "bubbles" frozen in place. The bubbles can be interconnected in *open-cell foams* and isolated from one another in *closed-cell foams.* Figure 1.1 shows a polystyrene (PS) closed-cell foam cup that is widely used in the packaging sector.

Figure 1.1 A polystyrene foam cup (source: *iStock.com/Michael Burrell*)

Polymers such as PS, polyolefins (polyethylene, polypropylene), and polyurethanes are widely used foam packaging materials. Foams are typically prepared by either extrusion or expansion processes and are accordingly called extruded foams and expanded foams, respectively. Open-cell foams are mainly used to cushion materials during distribution. In contrast, closed-cell foams offer excellent thermal insulation and are used in food packaging such as hot and cold beverage cups. They keep the contents warm or cool and protect a consumer's hands (see Figure 1.1). High-impact-PS foams are also used for packaging such as trays for meat such as beef and pork, fish, and other products such as eggs.

However, these most useful materials present challenges. Because they are about 95% air by volume, foams have very high collection and transportation costs and thus increase the total cost of recycling. In addition, some foams, such as PS foams, are brittle and break down easily during the collection and sorting processes, thus contaminating the whole recycling stream during collection in recycling bins and processing (sorting). Making matters worse, PS foam particles cling to other materials. Thus, foam is not only costly to recycle, it also contaminates other useful recyclable materials.

Legislation Status

Many countries, such as Germany, Italy, the United Kingdom, and others have already banned PS foams. Eight states in the U.S. have already voted to ban PS foam in food service containers. New York City banned expanded polystyrene foams as well as from loosefill insulating materials in packaging and food service containers [3].

Potential Alternatives

There are good alternatives to PS foams including biodegradable/compostable foams made from polylactic acid (PLA), starch, polybutylene adipate terephthalate (PBAT), and other sustainable polymers. However, PLA is only compostable under industrial composting conditions and, upon leakage into the environment, will cause similar consequences as those encountered with PS and polyolefins foams. Nevertheless, owing to its compostable nature, PLA meets regulations demanding compostable packaging. Starch foam is truly biodegradable in soil and marine environments, but it is unsuitable and ineffective for many packaging applications because it becomes soggy at high relative humidity.

■ 1.2 Pigments/Fillers

Introduction and Uses

Often micron size particles called fillers are added to plastics and paper. Some common examples of fillers include calcium carbonate, titanium dioxide, and talc. These materials are added to polymers to provide strength and stiffness and to reduce cost. Carbon black is widely used as a filler to offer protection from UV light, improve abrasion resistance, and impart a black color (as shown in Figure 1.2). Carbon black also increases the performance of the plastic by enhancing its stiffness, tear, and tensile strength. Black plastic packaging is primarily used in food trays and other plastic pots and tubs.

It is worth mentioning that the use of nanocomposites, where nanofillers such as nanoclays, cellulose micro/nanocrystals and cellulose fibrils, and graphene oxides are incorporated into a material, has become a very promising route towards recyclable/biodegradable high-barrier packaging. I don't think these fillers (and their nanocomposites) are problematic materials if they are carefully selected for particular end-of-life options.

Challenges

Today, recycling facilities often use near-infrared light sensors to detect distinct materials. Unfortunately, because carbon black absorbs infrared light, plastics with carbon black pigments are invisible to these sensors and cannot be sorted at most material recovery facilities.

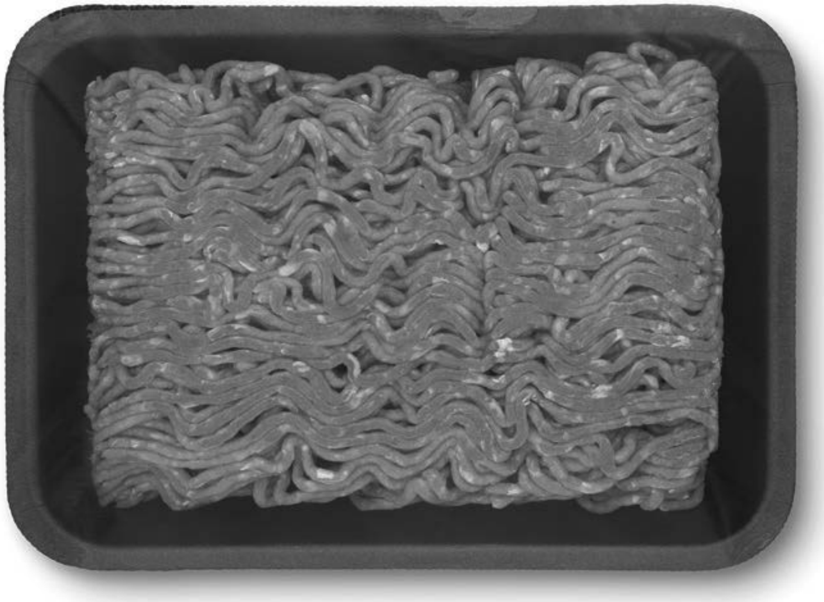

Figure 1.2 An example of carbon black as a filler in plastic foam meat tray (source: *iStock.com/subjug)*

Potential Alternatives

We need dark pigments that reflect infrared waves and can be used as an alternative for carbon black. Fortunately, some companies have already developed alternatives such as Sicopal® Black K 0098 FK, black iron oxide, and nigrosine. These alternatives will offer greater sustainability as they are not likely to interfere with sorting.

1.3 Per- and Polyfluoroalkyl Substances (PFAS)

Introduction and Use

I'll bet you have heard reporters on radio and television talk about "PFAS." What is that? PFAS substances are used to create fluoropolymer coatings and goods to provide barriers against oil, stains, grease, and water. Per- and poly-fluoroalkyl substances, PFAS, for short, are part of a class of compounds that has any molecule with at least one $-CF_3$ or $-CF_2-$ group (as illustrated in Figure 1.3). In 2022, the EPA revised the definition of PFAS to include additional chemicals such as branched PFAS, and PFAS with ether linkers.

Figure 1.3 Image showing a generic chemistry of per-and polyfluoroalkyl substances (PFAS) used in products (source: *iStock.com/Francesco Scatena*)

So, Why Do We Use PFAS?

PFAS substances have low surface energies. In fact, they have the lowest surface energies among all known materials and chemicals. That means that these substances are "non-stick:" they repel water and oil. When forming a packaging shape in a mold using PFAS, it is relatively easy to remove the finished package article from the mold. It doesn't stick!

PFAS serve well as water- and oil-repellent coatings. Consequently, PFAS are widely used to coat paper and cardboard, in molded fiber containers (as shown in Figure 1.4), and in printing (where PFAS is added into ink formulations to prevent the ink from spreading on paper during the printing process).

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