A Journey Toward Packaging Sustainability

Donna L Visioli, E I DuPont de Nemours, Wilmington, DE, USA
Karlheinz Hausmann and Sarah Perreard, DuPont de Nemours International, Geneva, Switzerland

Abstract

Packaging sustainability has many contributing factors including: renewable materials; reduced package weight; recyclable materials; reduced food waste (for food packaging); and reduced packaging waste. These factors and interactions among them are described, along with examples of implementation.

Introduction

Packaging sustainability has many contributing factors including: renewable materials; reduced package weight; recyclable materials; reduced food waste (for food packaging); and reduced packaging waste. Concurrently, packaging cost must be kept constant or reduced.

An approach based on the factors of reduce/recycle/rethink/renew can provide a useful framework going forward. These factors are linked in the circular economy model, which is an alternative to a traditional linear economy (make, use, dispose) in which resources are used for as long as possible, the maximum value is extracted from them while in use, then recovery and regeneration products and materials occurs at the end of service life (1). Below we describe these factors and how they interact, along with examples of implementation.

Reducing waste

Excess packaging is linked to broad market issues. Excess packaging has affected margins for shippers like UPS and FedEx, reducing the amount of value-add space available in their trucks and planes. As a result, shippers moved away from an old weight-based charge scheme to a volumetric charge scheme called dimensional weight pricing in which shipping charges are higher for low weight, high packaging volume item. This resulted in a market incentive, in the form of higher shipping fees, for companies reduce packaging. Additionally, if packages were right-sized to fit a given product, shippers could fit 30% more packages per truck, since the limiting factor for packages in a truck is usually the volume of packages rather than their weight (2).

In the case of food packaging, reducing waste includes reducing both the packaging waste and the food waste due to improper or sub-optimized packaging.

Reduction of packaging waste can be accomplished by light weighting. Much of this can be accomplished by the transition from rigid to flexible packaging which has been ongoing for a number of years (3). The impact of switching to flexible packaging incudes not only reduced weight, which impacts shipping cost, but also reduced package production cost. The production process for flexible packaging, in some cases, requires 85% less energy than rigid packaging production (4).

Reducing flexible packaging weight while maintaining integrity, enhancing durability, and maintaining the stiffness required for filling and shelf presentation at lower thickens requires a well-engineered approach to package design. A computer-based stiffness model has been developed to re-engineer packaging structures and produce up to 30% lighter packaging with improved overall performance and cost (5). The model predicts bending stiffness of multilayer packaging structure. For a multicomponent structure, stiffness in bending mode depends on the position of the layers. If put on the outside, stiffer materials have the strongest influence on overall film structure, enabling a decrease in the overall thickness of the inner layers. An example using stiffer ethylene copolymers Nucrel® and Surlyn® (supplied by DuPont™) is below:

Case studies based on this model for food packaging have shown packaging weight reduction of 20% – 30% while maintaining the integrity and barrier properties required by the package contents.

Developments in film converting equipment can contribute to light weighting. Coex bi-orientation technologies (Triple Bubble®) can be used in production of 7 to 13 layer structures. These structures are produced by blown film coextrusion of multiple layers (7-13 layers) of film in one step followed by water quenching to produce an amorphous (disordered) film which is subsequently reheated and oriented in the machine and transverse directions simultaneously (6). The film is then annealed to relax the polymer chains and stabilize the...
These structures, which can be used in place of conventional laminated structures, are up to 67% lighter than traditional structures while maintaining the required mechanical and barrier properties (7).

**Food waste reduction**

Packaging contributes to food waste reduction by increasing the shelf life. The shelf life of foods can be extended by changing the package type (8). A study of Austrian retailers shows that waste of packaged food can be reduced significantly when the package type is optimized: for example, cheese waste can be reduced from 5% to 0.14%, and bakery waste can be reduced from 11% to 0.8% (9). In the case of beef steak, increasing the shelf life of sirloin steak from 6 days to 16 days has been shown to reduce food waste by 50%.

<table>
<thead>
<tr>
<th>Packaging type</th>
<th>Shelf-Life (d)</th>
<th>Whole Muscle</th>
<th>Display-Life (d)</th>
<th>Shelf-Life (d)</th>
<th>Display-Life (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-Permeable Overwrap</td>
<td>Red</td>
<td>5 - 7</td>
<td>3 - 7</td>
<td>2 - 3</td>
<td></td>
</tr>
<tr>
<td>Master Pack Low Oxygen</td>
<td>Purple</td>
<td>28 - 35</td>
<td>2 - 7</td>
<td>25 - 30</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Masterpack High Oxygen</td>
<td>Red</td>
<td>10 - 14</td>
<td>2 - 7</td>
<td>10 - 20</td>
<td>2 - 7</td>
</tr>
<tr>
<td>High Oxygen</td>
<td>Red</td>
<td>12 - 16</td>
<td>3 - 4</td>
<td>10 - 12</td>
<td>3 - 4</td>
</tr>
<tr>
<td>Low Oxygen</td>
<td>Purple</td>
<td>25 - 30</td>
<td>2 - 7</td>
<td>25 - 30</td>
<td>2 - 7</td>
</tr>
<tr>
<td>Peelable Low Oxygen</td>
<td>Red</td>
<td>15 - 22</td>
<td>3 - 7</td>
<td>15 - 22</td>
<td>3 - 7</td>
</tr>
<tr>
<td>Low Oxygen w/ CO</td>
<td>Red</td>
<td>35</td>
<td>35</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

In the study above, a distinction has been made between case life, which is the time during which color is not significantly changed, and shelf life, which is the amount of time passing before the meat is unfit to eat, as seen below (10).

Changing the package type also leads to reduced package weight. Changing from the traditional tray and cling wrap for packaging meat to vacuum skin packaging results in a 3X lighter package with 3X longer shelf life (9).

**Recycle**

Despite ongoing efforts to facilitate recycling of plastics, only a small fraction of plastic waste is recycled. In 2008, only 13.3% of plastic packaging was recycled in the US (11). Plastic (PET) soft drink bottles and PE milk jugs have a high value in recycling, since they are single material, but in the US, only 27% of these are recycled (11).

Successful plastic recycling depends on both the disposal and collection of the plastic waste, and on the chemistry and consistency of the mixed polymer steam chemistry. These factors interact, and success may depend on integrating them. This can involve collaboration between different players in the value chain.

Improvement in performance for PE-contaminated PET is exemplified below (13). This example involved production of textile fibers from PE-contaminated PET; because developing a stable fiber spinning process is inherently sensitive to contaminants, this result so an especially good demonstration of the property improvement due to compatibilizers.
A good example of how compatibilizers contribute to collaboration across the value chain is the collaboration between DuPont and Cimflex to enable used multilayer agrochemicals bottles in Brazil to diverted from landfills and turned into high-value recycled content for higher value products. Adding 5% compatibilizer improves toughness, elongation and processibility sufficiently to allow manufacture of products such as pipes, hoses, and motor oil containers (14). Another good example is using store drop-off recycling programs for LDPE grocery bags enables the recycling of polyethylene-based multilayer barrier packaging as part of Dow’s Recycle-Ready® technology. A compatibilizer is also included in this technology package (15).

Most post-consumer plastic waste is used for applications other than food packaging due to concerns about contamination of food by components of the recycled plastic. The FDA has developed a process for the manufacturer who wishes to use recycled plastic for a food-contact application (16).

**Rethink**

Rethinking, or designing to recycle, has been encouraged by the Institute of Scrap Recycling Industries, (ISRI) for more than 25 years (17). This Design for Recycling® initiative encourages manufacturers to think about the ultimate destiny of their products during the design-stage of a product’s development. In the case of flexible packaging, design to recycle can include use of monolayer films such as using structural and sealant layers with similar chemistry so that they can use a recycle code of 1 (PETE), 2 (HDPE), or 4 (LDPE) rather than 7 (other). However, this approach requires use of thicker films and is only suitable for applications requiring low to moderate oxygen barrier unless reduced shelf life is acceptable. An alternative approach to designing to recycle is use of simplified multilayer films (eliminating paper, metallization, solution-based adhesives, carbon black); this approach enables lightweighting while allowing for excellent barrier. Optimally, the multilayer films can contain integrated compatibilizers to facilitate recycling.

**Renew**

Renewable raw materials can be suitable for use in flexible packaging. A thorough life cycle analysis is necessary to quantify the environmental impact of such materials. Early efforts to develop bio-based plastics have caused controversy over using food ingredients such as corn for making plastics has been extensively discussed (18). Presently there are only a few biobased resins widely used: PTT (poly (trimethylene terephthalate); polymers based on FDCA (Furan-2,5-dicarboxylic acid); and polysaccharide based polymers and blends made with them.

The diol used to prepare PTT, 1,3-propanediol, is renewably sourced via DuPont’s fermentation process. Based on the weight of the diol in the polymer, PTT polymer commercialized by DuPont™ as Sorona® is 37% renewably sourced. It is used primarily in fiber applications (carpet fibers, apparel, etc.) because of its durability and stain resistance as well as for molding applications because its good chemical resistance, and scratch resistance an eliminate the need for lacquer topcoat (19).

FDCA (2,5-Furandicarboxylic acid) has been included by the US Department of Energy as one of 12 priority chemicals for establishing the “green” chemistry industry of the future (20). It can be prepared by dehydration of sugars using hexamethyl furfural as an intermediate which then can be enzymatically converted to FDCA. Furan-2,5-dicarboxylic acid (FDCA) has been suggested as an important renewable building block because it can substitute for terephthalic acid (TPA) in the production of polyesters and other current polymers containing an aromatic moiety. DuPont has announced the production of FDCA for use in PTF (21). FDCA-based polyesters such as PTF (poly(trimethylene furandicarboxylate) are of interest for packaging applications because they offer better CO2 barrier than PET. Polysaccharide based polymers such as cellulose, chitin and chitosan can be compounded with natural and synthetic polymers (22) for a wide variety of applications. A recent example of this is the polyethylene/starch-based film produced by BiologiQ under the name TaterMade™ which contain 25% renewable content (23). Compounding of the potato starch with DuPont’s ethylene copolymer compatibilizer enables production of TaterMade™ film having higher tensile strength than LDPE (24).
Conclusions

Although sustainability of packaging has been a concern for many years, more work is needed. Despite near-universal efforts to promote recycling, only 14% of plastic packaging is collected today. The results have had enormous environmental consequences. An estimated 150 million tons of plastics are in our ocean today. Under business as usual projections, this figure is expected to grow until it exceeds the aggregate weight of fish in the ocean by 2050 (25). Challenges lie ahead in collecting and sorting of films and trays, consolidating streams to reach critical volumes of consistent quality, and application development for recycled or renewable materials. The EU target is 75% of packaging recycled by 2030 (26). Recycling policy in the US is less uniform, but some states have set forth goals similar to the European goals (27). Cost effective solutions will continue to be required to meet these demands.

Combining ongoing efforts around recycling with other factors contributing to sustainability use of (renewable materials, reduced package weight, recyclable materials, and waste reduction) will be necessary to develop solutions to sustainability which will achieve the target recycling rates.

References

3. E Fish, Flexible Packaging, June 1, 2015
7. www.kuhne-group.com
17. http://www.isri.org/about-isri/awards/design-for-recycling#.WHAVimorLIU