Plastic Mulch Use and Management

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Summary:

Soil-biodegradable mulches (BDMs) are increasingly used in agriculture to replace conventional plastic mulch and reduce waste and disposal challenges. BDMs are designed to be tilled into the soil after use at the end of growing season. Growers and agricultural professionals have questions regarding the formulation of BDMs. This is an introduction to what BDMs are made from.

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USDA United States Department of Agriculture National Institute of Food and Agriculture

What is a Soil-Biodegradable Plastic mulch Composed Of?

Soil-biodegradable plastic mulches (BDMs) are an alternative mulch technology designed to biodegrade in soil upon tillage through the activity of native soil microorganisms. They were created in the early 1990s as an alternative to non-degradable plastic polymers, primarily polyethylene (PE), that reduce plastic waste generation in agriculture. Functionally, BDMs should be 100% biodegradable and provide the same horticultural benefits as non-degradable mulches including weed suppression, soil temperature moderation, soil moisture retention, and overall increased yields and crop quality. BDMs should biodegrade in field soil or a composting environment and form no environmentally harmful residues.

Figure 1. *Strawberry grown with soil biodegradable plastic mulch. Photo by L.W. DeVetter.*

But what is a BDM composed of and what provides the various properties in this alternative mulch? This factsheet and Table 1 provides a general list of ingredients that may be found in commercial BDMs and lists their various functions. In general, 75-95% by mass of BDM films are composed of

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polymeric feedstocks with the remainder being additives/minor components. Feedstocks are the primary raw material used to make a BDM and are biobased, derived from fossil fuels, or a blend of the two. Commercially available BDMs are a blend of both biobased and fossil fuel feedstocks with biobased content ranging from 10-50%. **Biobased content does not correlate with biodegradability**. One example of BDM created for an experiment contained 78.7% polymers, 13.3% binder (calcium carbonate), 4.4% plasticizer and processing aid, 2.0% carbon black, and 1.6% slip agent (Hayes et al., 2017). Individual mulch manufacturer formulations will vary, however, as they are proprietary and are unique to the company.

Note that a glossary of terms associated with soil-biodegradable mulches for specialty crops can also be found online at https://smallfruits.wsu.edu/plastic-mulches/.

Table 1. List of primary ingredients that may be found in a soil-biodegradable plastic mulch.

Category	Ingredient	Description
Polymeric Feedstock	*Biobased* - starch	Extracted from natural materials and includes thermoplastic starch (TPS) and cellulose. TPS is made from high-amylose starch derived from a number of sources, such as potato, corn, sugar beets, etc. The high-amylose starch is processed at high temperatures with water and alcohols to make TPS. TPS is one of the most common biobased feedstock due to its cheap cost.
	Biobased [1] - polylactic acid (PLA)	Lactic acid units are chemically linked together to form long chains known as polylactic acid (PLA). Lactic acid is made industrially using genetically modified bacteria that ferment carbohydrates into lactic acid. PLA is used in other applications, such as 3-D printing to make models and prototypes, including objects used in the medical field. PLA is a thermoplastic polyester.
	Biobased - polyhydroxyalkanoates (PHA)	A biodegradable polyester and fatty acid biopolymers produced from genetically modified microorganisms (e.g., bacteria and yeasts). Includes poly(hydroxybutyrate) (PHB) and poly(hydroxyvalerate) (PHV).
	Fossil fuel - polybutyleneadipate-co-terephthalate (PBAT) [2,3]	A biodegradable co-polymer or co-polyester made from organic materials including adipic acid, 1,4-butanediol, and terephthalic acid (DMT). Description of organic materials provided below. Properties are similar to PE.
	Fossil fuel - polycaprolactone (PCL)	Biodegradable polyester.
	Fossil fuel - polybutylene succinate (PBS) and polybutylene succinate Adipate (PBSA) [2,3]	Biodegradable polyester with properties similar to non-degradable polyethylene.

Category	Ingredient	Description
Additives	Plasticizers	Added to improve flexibility and processing properties of brittle polymers. Glycerol, sorbitol, and triethyl citrate are examples of plasticizers that may be used to make BDMs. Phthalate-based plasticizers were once used, but no longer due to human-health concerns.
	Lubricants	Modifies material viscosity and improves processing properties (e.g., vegetable oils such as canola or castor oil) (Mitrovich et al. 2012).
	Fillers	Includes wood, silica, clay, or other polymers. Added to improve mulch properties and reduce costs. Also added to improve processing and in-field performance.
	Nucleating or clarifying agents	Increases crystallization of polymeric ingredients, which in turn can increase physical mulch properties like stiffness and tensile strength (e.g., thermopalstic starch) (Kang et al., 2008).
	Antioxidants	Prevent loss of strength, flexibility, thermal stability, and/or color to mulch film from oxidation during mulch manufacturing and after in-field application (e.g., flavenoids) (Arrigo and Dintcheva, 2017).
	UV Stabilizers	Prevents polymer break down by UV-light. Example is carbon black, which is a pigment and also a UV-stabilizer.
	Antibacterial additives	Added to prevent bacterial growth on mulch (e.g., zinc pyrithione, silver nanoparticles).
	Colorant	Synthetic organic material used to provide color to a material. Can also function as a stabilizer.
	Pigment	Inorganic material used to provide color to a material. Example is carbon black, which is commonly and may or may not be naturally derived. Titanium dioxide (TiO_2) may be used for white mulch, but has human and environmental health concerns and may be replaced by talc or calcium carbonate ($CaCO_3$). Pigments can also function as a stabilizer.

[1] Although the monomer, lactic acid, is biobased, PLA is a "synthetic" because the polymerization is performed chemically using a catalyst; [2] Feedstocks prepared by some manufacturers are partially biobased; for instance, the monomers 1,4-butanediol and succinic acid; [3] Low molecular weight oligomers and monomers (e.g., 1,4-butanediol and adipic acid) may be present at trace levels (< 1%).

References

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