Overview of Key Food Packaging

Steven G. Hentges, PhD

American Chemistry Council

700 2nd Street, NE

Washington, DC 20002

202.249.6624

Conflict of Interest Statement

Dr. Hentges is an employee of the American Chemistry Council (ACC), which represents a diverse set of companies engaged in the business of chemistry (www.americanchemistry.com).

What Is Food Packaging?

- "Food packaging is packaging for food" (Wikipedia)
  - A package provides protection, tampering resistance, and special physical, chemical, or biological needs
- Regulated by FDA as a Food Contact Substance
  - Any substance intended for use as a component of materials used in manufacturing, packing, packaging, transporting, or holding food if such use is not intended to have any technical effect in such food (Section 409(h)(6) of the Federal Food, Drug, and Cosmetic Act)

Food Packaging Materials

- Common materials include:
  - Plastics (e.g., bags, wrappers, trays, rigid containers)
  - Metals (e.g., steel and aluminum cans)
  - Paper/Paperboard (e.g., cartons, boxes)
  - Glass (e.g., bottles, jars)
- Often used in combination, for example:
  - Plastic coated paperboard
  - Multilayer plastic bags, including metalized
- Food packaging is an innovative field

Why Plastics?

- Functionality
  - Versatile for wide variety of foods
  - Helps maintain food freshness; reduce waste
  - Reduce breakage
- Environmental Benefits
  - Reduce material use and weight; reduce transportation costs through light weighting
  - Reduce energy use by extending shelf-life
- Economical

Types of Plastics

- Thermoplastics
  - Polymeric material that becomes pliable or moldable above a specific temperature and solidifies upon cooling
  - Variety of thermoplastics useful for and widely used in food packaging (e.g., containers, closures, films bags)
- Thermoset plastics
  - Solid or viscous liquid prepolymer that changes irreversibly into an infusible, insoluble polymer network by curing
  - Commonly used as protective coating on metal

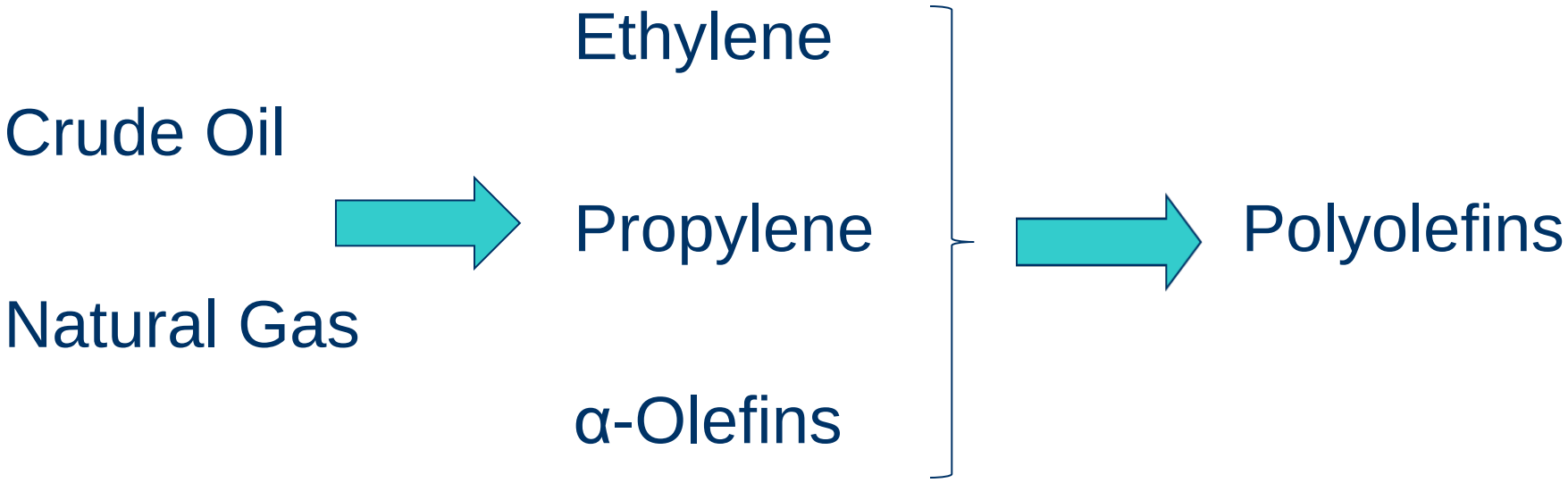
Plastic Food Packaging–Properties

Plastic	Properties
Polyethylene terephthalate (PET) 	Clear, Excellent barrier to oxygen, water, and carbon dioxide, High impact capability and shatter resistance, Excellent resistance to most solvents, Capability for hot-filling
High density polyethylene (HDPE) 	Excellent resistance to most solvents, Higher tensile strength compared to other forms of polyethylene, Relatively stiff material with useful temperature capabilities
Polyvinyl Chloride 	High impact strength, brilliant clarity, excellent processing performance, Resistance to grease, oil and chemicals
Low density polyethylene (LDPE) 	Excellent resistance to acids, bases and vegetable oils, Toughness, flexibility and relative transparency (good combination of properties for packaging applications requiring heat-sealing)
Polypropylene (PP) 	Excellent optical clarity in biaxially oriented films and stretch blow molded containers, Low moisture vapor transmission, Inertness toward acids, alkalis and most solvents
Polystyrene (GPPS, HIPS, EPS) General Purpose & High Impact and Expanded Polystyrene 	Excellent moisture barrier for short shelf life products, Excellent optical clarity in general purpose form, Significant stiffness in both foamed and rigid forms, Low density and high stiffness in foamed applications, Low thermal conductivity and excellent insulation properties in foamed form
OTHER (Including Polycarbonate Polylactic Acid (PLA)) 	Dependent on resin or combination of resins

Plastic Food Packaging–Applications

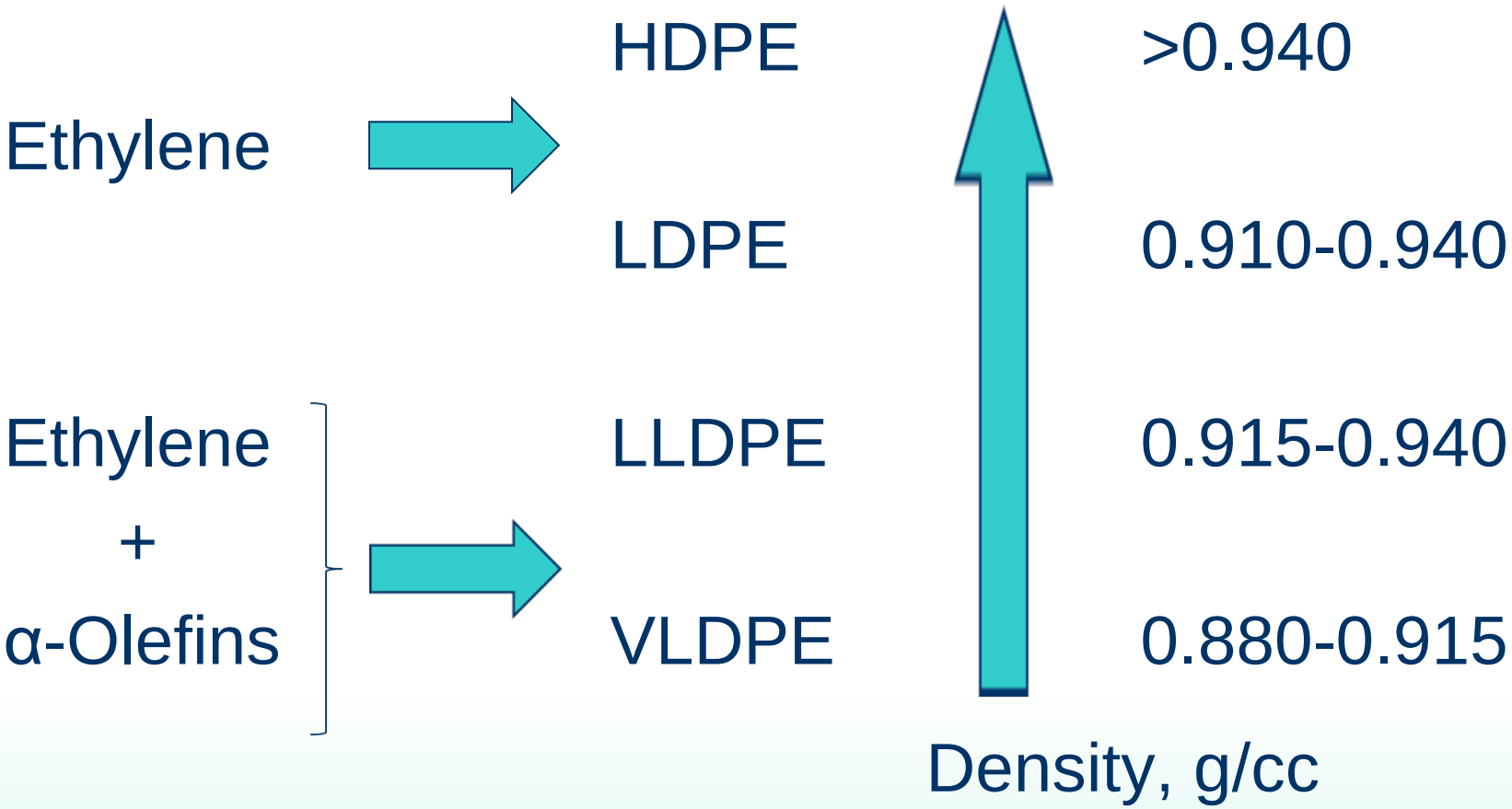
Plastic	Food Packaging Applications
Polyethylene terephthalate (PET) 	Plastic bottles for soft drinks, water, etc. Food jars for peanut butter, jelly, jam and pickles. Microwavable food trays.
High density polyethylene (HDPE) 	Bottles for milk, water, juice, etc. Bags for groceries and retail purchases
Polyvinyl Chloride 	Deli and meat wrap.
Low density polyethylene (LDPE) 	Bags for bread, frozen foods, and fresh produce. Shrink wrap and stretch film. Coatings for paper milk cartons and hot and cold beverage cups. Lids.
Polypropylene (PP) 	Containers for yogurt, margarine, takeout meals, and deli foods. Bags for salty snacks. Bottle caps and closures. Bottles for catsup and syrup
Polystyrene (GPPS, HIPS, EPS) General Purpose & High Impact and Expanded Polystyrene 	Food service items: cups, plates, bowls, cutlery, hinged takeout containers (clamshells), meat and poultry trays, egg cartons.
OTHER (Including Polycarbonate Polylactic Acid (PLA)) 	Dependent on resin or combination of resins

Versatile Polyolefins–From Wellhead to Food Packaging



α-Olefins = 1-butene, 1-hexene, 1-octene

Polyethylene – Primary Classification by Density



Why Is Density Important?

- Polyethylene is a semi-crystalline material
  - Density is a measure of crystallinity
  - Crystallinity controlled by branching
  - Density correlates with structural and performance characteristics
- Crystallinity affects additive migration rates
  - Highest rate of migration with lowest crystallinity
  - LDPE generally considered worst-case for migration from polyolefins

High Density Polyethylene (HDPE)

- Ethylene homopolymer
  - May contain low levels of α-olefin (0-1 mol %)
- Typical food packaging applications–homopolymer
  - Beverage bottles (milk, water, juice)
  - Bag liners (boxed cereal and crackers)
- Typical food packaging applications–copolymer
  - Dairy containers (cottage cheese, sour cream, yogurt)
  - Produce bags
  - Squeezable bottles

Low Density Polyethylene (LDPE)

- Ethylene homopolymer
  - Extensive branching from peroxide catalyzed free radical polymerization
- Typical food packaging applications
  - Bread, product, sandwich bags
  - Condiment packets
  - Container lids
  - Paperboard coatings (milk, juice)

Linear Low Density Polyethylene (LLDPE)

- Ethylene copolymer with α-olefin
  - Branching from 1-3.5 mol % α-olefin lowers density
- Typical food packaging applications
  - Frozen food, ice, and produce bags
  - Container lids
  - Sealant layer
  - Grocery sacks

Very Low Density Polyethylene (VLDPE)

- Ethylene copolymer with α-olefin
  - Branching from > 4 mol % α-olefin gives lowest density
- Typical food packaging applications
  - Fresh cut produce (salads)
  - Fresh red meat packaging
  - Processed meat and poultry packaging

Polypropylene–Primary Classification by Melt Flow Rate

Propylene → Polypropylene homopolymer

Propylene + Ethylene → Polypropylene random copolymer

Propylene + Ethylene → Polypropylene impact copolymer

- Melt flow rate is indirect measure of molecular weight
  - Related to processing and performance characteristics

Polypropylene Homopolymer

- Most common type of polypropylene
- Typical food packaging applications
  - Salty snack food bags (potato chips, pretzels)
  - Bakery and candy wrappers

Polypropylene Random Copolymer

- Random copolymer (RCP) contains up to 6 wt.% ethylene
  - Ethylene reduces crystallinity and improves clarity
- Typical RCP food packaging applications
  - Blow molded bottles (ketchup, syrup, salsa)

Polypropylene Impact Copolymer

- Impact copolymer (ICP) contains higher level of ethylene
  - Essentially a blend of polypropylene homopolymer and ethylene-propylene rubber
  - Up to 40% EP rubber, which contains 30-60% ethylene
- Typical ICP food packaging applications
  - Refrigerated dairy containers (cottage cheese, sour cream, yogurt)
  - Frozen dairy containers

Versatility of Polyolefins Dependant on Additives

- Additives used for various purposes
  - Facilitate conversion of resin to finished article
  - Improved end-use performance
  - Aesthetic properties
- Common additive types for food packaging uses
  - Stabilizers
  - Surface modifiers
  - Antistats
  - Nucleating agents
  - Processing aids