Plastic packaging material identification & property testing

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Introduction

Plastic is widely used as a food packaging material due to its versatility, durability, and cost-effectiveness. It offers several advantages that make it a popular choice for packaging various food products.

- Protection: Plastic packaging provides a barrier against moisture, oxygen, and other contaminants, helping to maintain the quality and freshness of the food. It safeguards against spoilage, extends shelf life, and reduces the risk of foodborne illnesses.
- Convenience: Plastic packaging is lightweight and easily portable, making it convenient for consumers to carry and store food items. It is also available in various shapes and sizes, allowing for easy portioning and portion control.
- Visibility: Plastic packaging can be transparent or translucent, enabling consumers to see the contents of the package. This helps in making informed purchasing decisions and assessing the quality of the food product.
- Safety: Food-grade plastics are specifically designed to be safe for contact with food. They undergo rigorous testing to ensure they do not release harmful substances into the food. Plastic packaging also reduces the risk of contamination during transportation and handling.
- Versatility: Plastic packaging can be moulded into different shapes and sizes, offering flexibility in design. It can be customized with features such as resealable closures, easy-open mechanisms, and portion compartments, enhancing the convenience and usability of the packaging.

Commonly used plastic materials for food packaging

Several types of plastic are commonly used for food packaging.

- ***Polyethylene*** (PE): PE is a widely used plastic for food packaging. It is flexible, lightweight, and resistant to moisture and chemicals. It is commonly used for plastic bags, plastic films, and squeeze bottles. PE is available in various forms, including low-density polyethylene (LDPE) and high-density polyethylene (HDPE).
- ***Polyethylene Terephthalate*** (PET or PETE): PET is a transparent and lightweight plastic that is commonly used for beverage bottles, salad dressing containers, and food trays. It is also recyclable.
- ***Polypropylene*** (PP): PP is a versatile plastic that can withstand high temperatures. It is commonly used for microwaveable containers, yogurt cups, and food storage containers.
- ***Polystyrene*** (PS): PS is a rigid plastic that is commonly used for foam food trays, disposable cutlery, and cups. It provides insulation and keeps food warm.
- ***Polyvinyl Chloride*** (PVC): PVC is used in food packaging applications that require excellent clarity, such as cling films and shrink wraps. It is also used for making food trays, and bottles. PVC offers good barrier properties against moisture and oxygen.

While PVC is widely used, there are growing concerns about its environmental impact and potential health risks associated with certain additives used in its production.

- **Nylon**/Poly amide: Nylon is a strong and versatile plastic material that finds applications in food packaging, particularly in vacuum-sealed bags and films. It provides excellent puncture resistance and helps extend the shelf life of perishable products. However, nylon is not commonly used for direct food contact packaging.

Food packaging symbols

Food packaging symbols play a crucial role in providing essential information to consumers about the contents, handling, and safety of the packaged food products. These symbols are visual representations that convey important messages regarding ingredients, nutritional value, allergens, storage conditions, recycling, and more. By incorporating these symbols, food packaging aims to enhance transparency, ensure consumer safety, promote sustainable practices, and assist individuals in making informed decisions about the products they purchase and consume.

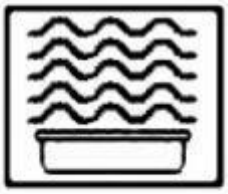
1. **Food Contact Symbol**: This symbol resembles a glass and fork, signifying that the packaging material is suitable for food contact and is deemed food-safe.

2. **Recycling Symbol**: This symbol is usually a triangle made of arrows, indicating that the packaging material is recyclable. The number inside the triangle indicates the specific type of plastic used.

3. **Vegetarian/Vegan Symbol**: These symbols, often represented by a leaf or a variation of a plant-based image, certify that the food product is suitable for vegetarian or vegan diets, respectively. They help individuals easily identify products that align with their dietary preferences.

4. **Allergen Symbols**: These symbols, typically found on food packaging, highlight the presence of common allergens such as peanuts, tree nuts, wheat, soy, dairy, eggs, fish, and shellfish. They help individuals with allergies or dietary restrictions easily identify potential allergens in the product.

5. **Microwave-Safe Symbol**: This symbol depicts a microwave oven and indicates that the packaging can be safely used in the microwave.



6. **Freezer-Safe Symbol**: This symbol typically shows a snowflake or a snowflake within a square, indicating that the packaging can be safely used for freezing food.

7. **Tidy Man**: The "Tidy Man" symbol is commonly used on packaged items as a reminder to customers to dispose of the packaging in an appropriate manner. It serves as a visual cue to promote responsible waste management. The symbol typically features a simple depiction of a person engaged in tidying up, holding a trash bag or broom.

It's important to note that the symbols may vary depending on the region and the specific regulations in place.

Resin identification code/Plastic identification number

The ASTM International (formerly known as the American Society for Testing and Materials) Resin Identification Coding System, commonly referred to as RIC, is a series of symbols found on plastic products. These symbols serve the purpose of identifying the specific plastic resin used to manufacture the product. The system was initially created in 1988 by the Society of the Plastics Industry, which is now known as the Plastics Industry Association, in the United States. However, since 2008, the administration of the coding system has been taken over by ASTM International.

The plastic identification numbers are usually represented by a triangular symbol with the number inside it. These identification numbers and symbols are often found on the bottom

of plastic containers and products, within the recycling symbol. They help with the sorting and recycling process by allowing consumers and recycling facilities to easily identify the type of plastic used.

Table 1: Identification codes for plastics

Resin identification code	Plastic Type	Description
1	PETE (Polyethylene Terephthalate)	Clear, rigid bottles; commonly used for soda, water, and food containers.
2	HDPE (High-Density Polyethylene)	Translucent or coloured, rigid bottles; commonly used for milk jugs, detergent bottles, and some food containers.
3	PVC (Polyvinyl Chloride)	Rigid or flexible; commonly used for pipes, window frames, flooring, and certain types of packaging.
4	LDPE (Low-Density Polyethylene)	Flexible and stretchable; commonly used for plastic bags, cling wrap, and some squeezable bottles.
5	PP (Polypropylene)	Translucent or coloured, rigid containers; commonly used for yogurt cups, margarine tubs, and medicine bottles.
6	PS (Polystyrene)	Rigid or foam; commonly used for disposable cups, food packaging, and insulation materials.
7	Other Plastics and Composites	Miscellaneous plastics not covered by the other numbers; can include polycarbonate (PC), nylon, acrylic, and others.

Identification of plastic packaging materials by conventional methods

Different plastics exhibit unique characteristics that can help in identifying plastic packaging materials. Some key characteristics and their relevance in plastic identification are as follows:

- **Density**: The density of a plastic material, expressed in grams per cubic centimetre (gm/cc), can provide a clue about its type. Different plastics have distinct density ranges, allowing for differentiation between them.

Table 1: Density of different polymers

Polymer	**Density range (g cm^{-3})**
PP, polypropylene	0.89-0.91
LDPE, low-density polyethylene	0.91-0.93
HDPE, high-density polyethylene	0.94-0.96
PS, polystyrene	1.04-1.11
PVC, polyvinyl chloride (PVC)	1.20-1.55
PET, polyethylene terephthalate	1.38-1.40
EPS, expanded polystyrene	0.02-0.06
PVDC, Polyvinylidene Chloride	1.63-1.72
PVA, Polyvinyl Alcohol	1.21 - 1.33
PC, Polycarbonate	1.20–1.22
Nylon/Poly amide	1.06 - 1.14
Cellophane	1.42 – 1.48

Sinking/floating test

The floating or sinking behaviour of an object in a liquid can be used as a general guideline to identify certain types of plastics. The principle is based on the relative densities of the plastic and the liquid. If a plastic object floats in a liquid, it suggests that the plastic has a lower density than the liquid. If a plastic object sinks in a liquid, it indicates that the plastic has a higher density than the liquid. The water test/sinking/floating allows us to categorize polymeric materials into two groups.

1. Polymers that float in water (PE & PP)
2. Polymers that sink in water (all other Polymers)

Table 2: Sinking/floating pattern of plastic in water

Plastic Polymer	**Sinking/floating in water**
LDPE (Low-Density Polyethylene)	Typically floats
HDPE (High-Density Polyethylene)	Typically floats
PP (Polypropylene)	Typically floats
PET (Polyethylene Terephthalate)	Typically sinks or remains submerged
PS (Polystyrene)	Typically sinks or remains submerged

- **Flammability**: The flammability behaviour of plastics is an important characteristic for identification. Some plastics are self-extinguishing and do not sustain combustion, while others burn readily. This behaviour can be observed during a flame test.

  Colour: The colour of a plastic material can provide an initial visual clue for identification. Different plastics often have distinct natural colours or pigmentation.

  Odour: The smell emitted by a burning plastic material can be indicative of its type. Different plastics produce varying odours when subjected to heat or combustion.

Here are some key characteristics of commonly used plastics and their corresponding identification features:

1. **Polyethylene** (PE)
   - Flammability: Does not self-extinguish
   - Colour: Top yellow, bottom blue
   - Behaviour: Melts and drips like burnt wax
   - Odour: Produces white smoke
2. **Polypropylene** (PP)
   - Flammability: Does not self-extinguish
   - Colour: Top yellow, bottom blue
   - Behaviour: Melts and drips like burnt wax, acrid odour
   - Odour: Produces white smoke
3. **Polyvinyl Chloride** (PVC)
   - Flammability: Self-extinguishes
   - Colour: Yellow orange with a green edge
   - Behaviour: Darkens, softens, and decomposes
   - Odour: Smells like chlorine
4. **Polyvinylidene Chloride** (PVDC)
   - Flammability: Self-extinguishes
   - Colour: Similar to PVC with green spurts
   - Behaviour: Leaves a black, hard residue
   - Odour: Smells like chlorine
5. **Polyvinyl Alcohol** (PVA)
   - Flammability: Self-extinguishes but slowly
   - Colour: Yellow with grey smoke
   - Behaviour: Swells, softens, and turns brown
   - Odour: Pungent scent
6. **Polycarbonate** (PC)
   - Flammability: Self-extinguishes
   - Colour: Yellow orange with black smoke
   - Behaviour: Does not drip, decomposes
   - Odour: Pleasant smell
7. **Polyester/Polyethylene Terephthalate** (PET)
   - Flammability: Does not self-extinguish
   - Colour: Yellow with black smoke

- Behaviour: Does not drip, softens, and burns steadily
- Odour: Pleasant smell

8. **Polystyrene** (PS)
    - Flammability: Does not self-extinguish
    - Colour: Yellow orange, black shoots
    - Behaviour: Does not drip, softens
    - Odour: Floral (sweet) scent
9. **Nylon**/Poly amide
    - Flammability: Self-extinguishes
    - Colour: Blue, yellow top
    - Behaviour: Melts, drips, and froths; rigid drips when burnt
    - Odour: Smells like burnt hair
10. **Cellophane**
    - Flammability: Does not self-extinguish
    - Colour: Yellow, orange, grey, and smoke
    - Behaviour: Burns fast and completely, leaving a brittle burnt area
    - Odour: Smells like burnt paper

Table 3: Flammability/Burning test of polymers

Behaviour	**PES**	**PE**	**PP**
In flame	Melts, burns with light flame, sooty black smoke, melting drops fall down.	Shrinks, curls, melts and burns with light flame, drops of melting fall down.	Shrinks, melts and burns with light flame, melting drops fall down.
After leaving the flame	Stops burning, melting bead may be stretched into fine thread.	Continues to burn rapidly, hot melting substance cannot be stretched.	Continues to burn slowly, hot melting substance can be stretched.

Solubility test

The solubility of plastic polymers refers to their ability to dissolve or disperse in different solvents. The solubility behaviour of plastic polymers can vary depending on factors such as their chemical composition, molecular weight, crystallinity, and the nature of the solvent. In general, polar polymers tend to dissolve in polar solvents, while nonpolar polymers dissolve in nonpolar solvents. This principle is known as "like dissolves like." For example, polar polymers like poly (vinyl alcohol) are soluble in polar solvents such as water, while nonpolar polymers like polystyrene are soluble in nonpolar solvents such as toluene.

However, solubility is not solely determined by polarity. Other factors, such as molecular weight, crystallinity, and crosslinking, also influence solubility. Higher molecular weight polymers generally have lower solubility. Crystalline polymers, which have ordered and tightly packed structures, often have lower solubility compared to amorphous polymers. Crosslinked polymers, which have interconnected networks, are typically insoluble. It's important to note that solubility is also influenced by temperature, solvent concentration, and the specific polymer-solvent system. Experimental testing is typically required to determine the solubility of a specific polymer in a particular solvent under given conditions. Understanding the solubility of plastic polymers is important for various applications, including polymer processing, recycling, and material characterization.

Among the various solvents used for plastics, toluene, tetrahydrofuran, dimethylformamide, diethyl ether, acetone, and formic acid are widely utilized. Additionally, in specific cases, chloroethylene, ethyl acetate, ethanol, and water can also be useful. It is important to be aware that many solvents used in this context can be flammable and toxic, requiring careful handling. It is recommended to minimize the use of benzene due to its potential hazards.

Table 4: Solubility of plastic polymers

Plastic Polymer	Solvent Solubility
Polyethylene (PE)	Insoluble in most solvents (Polyethylene (other than cross-linked polyethylene) usually can be dissolved at elevated temperatures in aromatic hydrocarbons such as toluene or xylene, or in chlorinated solvents such as trichloroethane or trichlorobenzene.)
Polypropylene (PP)	Insoluble in most solvents (At elevated temperature, PP can be dissolved in nonpolar solvents such as xylene, tetralin and decalin.)
Polyvinyl Chloride (PVC)	It is insoluble in water and alcohol but slightly soluble in Tetrahydrofuran (THF).
Polyethylene Terephthalate (PET)	PET is *insoluble in water, diethyl ether*, and many common organic solvents. However, it is soluble in DMSO, nitrobenzene, phenol, and o-chlorophenol.
Polystyrene (PS)	Soluble in Aromatic solvents (e.g., Toluene, Xylene)
Polycarbonate (PC)	Soluble in Aromatic solvents (e.g., Chloroform, Dichloromethane)
Polyamide (PA or Nylon)	Soluble in Formic Acid, Sulfuric Acid, and some strong alkaline solutions
Polyethylene Glycol (PEG)	Soluble in Water and some polar solvents

The above-mentioned characteristics can aid in the identification of plastic packaging materials. However, it's important to note that accurate identification may require additional tests.

Advanced methods for plastic identification

In cases where precise identification is necessary, techniques such as Fourier Transform Infrared (FTIR) spectroscopy or Differential Scanning Calorimetry (DSC) can be employed to determine the specific polymer composition of the plastic material.

Differential Scanning Calorimetry (DSC)

DSC is a valuable technique used to identify plastic materials based on their thermal properties. This technique involves measuring the heat flow in or out of a sample while it undergoes controlled heating or cooling. Plastic materials exhibit distinct thermal behaviours due to their unique compositions, including properties such as melting points, glass transition temperatures, and crystallization characteristics. By examining the thermal properties of a plastic sample and comparing them with known data for various polymers, it becomes possible to determine the specific polymer present. However, it is crucial to note that relying solely on DSC results may not always lead to definitive identification, particularly when multiple polymers share similar thermal properties. In such situations, supplementary techniques like FTIR spectroscopy or other advanced analytical methods may be necessary to ensure more accurate identification.

Table 5: Melting point of plastic polymers in DSC

Polymer	**Melting Point (°C)**
LDPE (Low-Density Polyethylene)	105 - 115
HDPE (High-Density Polyethylene)	120 - 130
PP (Polypropylene)	160 - 170
PS (Polystyrene)	70 - 115
PET (Polyethylene Terephthalate)	245 - 255
PVC (Polyvinyl Chloride)	100 - 260

Fourier Transform Infrared (FTIR) spectroscopy

FTIR spectroscopy involves the measurement of infrared light absorbed by the plastic sample. This method analyses the infrared light absorption patterns of material. Each type of polymer has a unique infrared spectrum, allowing for the identification of specific functional groups present in the material. The specific polymer composition can be determined by comparing the infrared spectrum of an unknown plastic sample with a library of known spectra.

FTIR allows for the identification and analysis of major functional groups present in polymers. Here are some common functional groups and their corresponding infrared (IR) absorptions in various types of polymers.

- **Carbonyl stretches** (polyesters): Polyesters contain ester functional groups (-CO-O-) in their polymer chains. The carbonyl stretch typically appears as a strong absorption peak in the range of 1700-1750 cm^{-1}.
- **N-H stretches** (polyamides): Polyamides, such as nylon, contain amide functional groups (-CONH-) in their polymer chains. The N-H stretch usually appears as a broad and strong peak in the range of 3200-3500 cm^{-1}.
- **Aromatic bends** (polystyrene): Polystyrene is an aromatic polymer with a phenyl ring structure. The aromatic bends typically exhibit absorptions in the range of 700-900 cm^{-1}, resulting in a series of peaks known as the "fingerprint region" for aromatic compounds.

- **O-H stretches** (poly (vinyl alcohol)): Poly (vinyl alcohol) (PVA) contains hydroxyl groups (-OH) in its polymer chains. The O-H stretch appears as a broad and strong peak in the range of 3200-3600 cm^{-1}.
- **C≡N stretches** (polyacrylonitrile): Polyacrylonitrile (PAN) contains nitrile groups (-C≡N) in its polymer chains. The C≡N stretch is typically observed in the range of 2210-2240 cm^{-1}.
- **C-H stretches** (polyethylene): Polyethylene is a hydrocarbon polymer composed of repeating ethylene units. The C-H stretches typically appear as a series of peaks in the range of 2800-3000 cm^{-1}.

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