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APPLIED PACKAGING

NOOR HAZNIDA BAKAR & NGAI CHOOI HOONG

APPLIED PACKAGING

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There are a limited number of books on Applied Packaging; therefore, this book has been designed to simplify the knowledge of shelf life, active and intelligent packaging. This book also covers the areas of sustainability packaging. We are thankful to our contributors for their cooperation and support of this book project. We also thank the families for their support and encouragement throughout this e-book project.

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TOPIC 1
PACKAGED PRODUCT QUALITY AND SHELF LIFE

Synopsis

This topic explains that the shelf life of food products is an important feature for both manufacturers and consumers. It is important to understand the mode of food deterioration in order to establish any particular product's shelf life. Product formulation, process conditions and storage conditions are important considerations for product shelf life

PACKAGED PRODUCT QUALITY

What is quality packaging?

- Packaging acts as a barrier to limit potentially harmful amounts of oxygen, water, and light.
- Preventing a variety of external hazards from contaminating and spoiling raw or processed food.
- It makes things easier to use and provides enough storage.
- Communicating information regarding ingredients, nutrition facts, manufacturer name and address, weight, bar code information, and packaging labeling.

Product quality must meet or exceed consumer expectations for repeat purchases.

When packaging anything, quality is one of the most crucial factors to take into account.
Quality packaging is the best way to protect the goods you are delivering, and it also prolongs the life of products for safer use.

SHELF LIFE

Introduction to Shelf Life

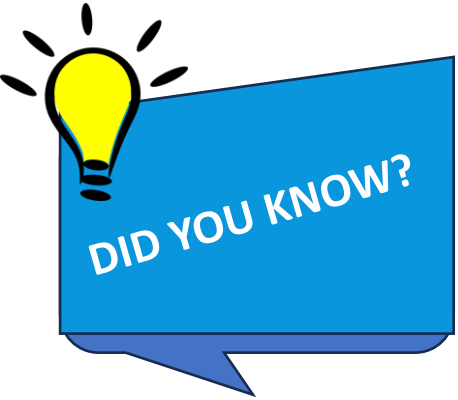
The time a food is safe and appropriate for eating, assuming it has been stored according to specified storage conditions, is known as shelf life. This means the food did not have deteriorated in quality or have lost significant amounts of any nutrients. Shelf life make sure the product remains safe to consume. This is meaning it shouldn't cause food poisoning due to the growth of pathogenic bacteria or the production of toxins (bacterial and fungal) in the food during storage.

DEFINITION SHELF LIFE

Shelf life is the length of time (period) that products can be stored, during which the defined quality of a specified proportion of the goods remains acceptable under expected conditions of distribution, storage and display.

SHELF LIFE - PACKAGE PROPERTIES

- ✓ **PROTECTION -**Protect against spoilage or deterioration.
- ✓ **COMMUNICATION -** Instructions or information.
- ✓ **CONVENIENCE -** Ease of access, handling and disposal, product visibility, resealability.
- ✓ **CONTAINMENT-** Hold the contents and keep them secure until they are used.
- ✓ **TRACEABILITY -** Ability to track any food.
- ✓ **TAMPER INDICATION -** Detect tampering.
- ✓ **PACKAGING AS A MARKETING TOOL -**Interests of consumers.



Legal requirements for shelf life - If a food is toxic or inappropriate for human consumption, it cannot be put on the market. The shelf-life of a food, expressed as a use-by or best-before date, must be determined and verified by the maker.

SHELF-LIFE DISTRIBUTION ENVIRONMENT

Planning how to distribute a product across a supply chain is known as shelf-life distribution. The shelf life of a product can influence the design of a production and distribution network. This procedure is important to minimizing waste, optimizing inventory, and ensuring your products are fresh and safe.

How long will your product last?

Will your product deliver the same nutritional integrity, flavor and appearance.

Distribution becomes essential when it is sent across the country. The stability of your product is important in a worldwide market.

Shipper storage time at warehouse

Transit time service distance

Customer

FACTORS AFFECTING *food* SHELF LIFE

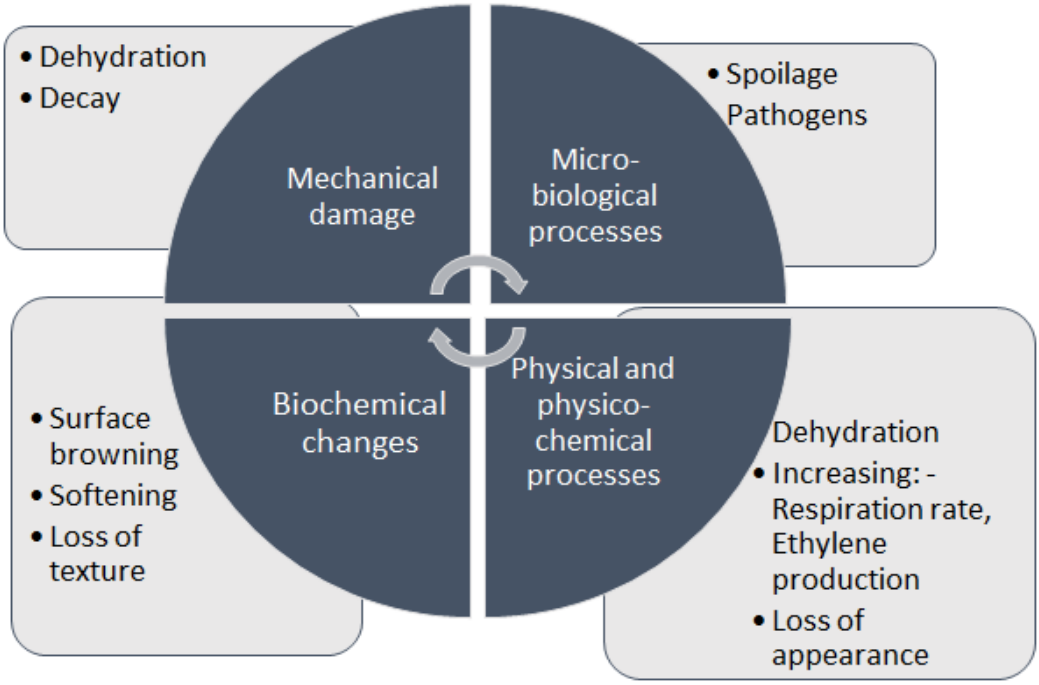
1.Characteristics of food itself (intrinsic factors)
- **The nature and quality of the raw materials.**
- **Product formulation**
- **Product structure**
- **Oxygen availability and redox potential within the food**

2. External factors (extrinsic factors)
- **Processes applied to the food**
- **Cooling methods**
- **Type of packaging**
- **Storage temperature**
- **Conditions during distribution, storage, retail display and storage by consumer**

3.Combination of intrinsic and extrinsic factors
- **hurdle effect - Microbial growth**

Short SHELF LIFE

Deterioration and spoilage.



CHEMICAL/BIOCHEMICAL PROCESSESS

Deteriorative changes can occur from reactions within the food or with its components.

Chemical reactions

Oxidation

Number of chemical components of food react with oxygen affecting the colour, flavour, nutritional status and occasionally the physical characteristics of foods.

Foods containing a high percentage of fats, particularly unsaturated fats, are susceptible to oxidative rancidity and changes in flavour.

The most significant chemical change is linked to oxidative reactions and enzymatic action, specifically lipid oxidation, which modifies food flavor, and non-enzymatic browning, which results in aesthetic alterations.

Biochemical reactions

Enzyme activity

Fruits and vegetables are living commodities and their rate of respiration affects shelf life – generally, the greater the rate of respiration, the shorter the shelf life.

Figure 1.1 Rotten fruits

MICROBIOLOGICAL PROCESSES

During growth in foods, microorganisms will consume nutrients from the food and produce metabolic by-products, such as gases or acids. They may release extracellular enzymes (e.g. amylases, lipases, proteases) that affect the texture, flavour, odour and appearance of the product.

Some of these enzymes will persist after the death of the microorganisms that produced them, continuing to cause product spoilage.

(a)

(b)

Figure 1.2(a),(b) Fungal growth

EXAMPLES OF FOODS SHELF LIFE

Product & Approximate Shelf Life	Mode of Failure
Frozen Baked Good 3-6 months	Loss of baked volume, surface drying, freeser burn, dough color change
Baverages 3 days – 12 months	Color less, browning, loss of flavor, vitamin degradation
Cookies, crackers, cereals 6-12 months	Loss of flavor, loss of crispiness, texture changes, color changes
Sauces 9-18 month	Color changes, browning, loss in flavor, separation
Jams/jellies 6-24 months	Color changes, loss in flavor, separation
Refrigerated Product 1 week – 4 months	Off falvor development, viscosity change, color change, microbial spoilage
Ice cream & Frozen Desserts 6-12 months	Ice crystal growth, freezer burn, loss of flavor, color change, darkening, gritty and gainy texture.

EXTENDING SHELF LIFE

- ✓ Modify the product ingredients and its inherent properties. Use natural preservatives such as salt, vinegar, and citric acid.
- ✓ Introduce changes to the manufacturing process. Use packaging techniques such as vacuum sealing and modified atmosphere packaging to prevent spoilage.
- ✓ Choose another type of packaging. Using airtight containers to prevent moisture and air from entering.
- ✓ Change the environmental factors. Temperature control or freezing is an excellent choice for perishable items such as meat and produce, while canning is the perfect method for preserving fruits and vegetables.
- ✓ Proper storage and handling practices. Handling raw meat and poultry requires regular cleaning and disinfecting of surface.

DID YOU KNOW?

There is a need for technologies such as active and intelligent packaging that reduce the rate of food deterioration and provide information about the quality of foods.

FOOD CONTACT MATERIAL MIGRATION

What is migration?

May impact food in two ways:

- ✓ Food safety (migration of harmful substances)
- ✓ Food quality (migration of substances which impart taint or odour)

Migration occurs from:

- ✓ Food packaging
- ✓ Materials and articles used in food manufacture, transport and storage
- ✓ Materials and articles used in food preparation and consumption

Factors affecting migration

Migration is a diffusion and partitioning process that is dependent on:

- ✓ The nature of the food contact material (FCM)
- ✓ The nature and concentration of the migrating substance
- ✓ The nature of the foodstuff
- ✓ The nature, the extent and the type of contact between the food contact.
- ✓ Material/article and the foodstuff

DEFINITION
FOOD MIGRATION

Food migration occurs when chemical compounds from food packaging materials are transferred into the food itself. This can happen during various stages of the food supply chain, such as production, processing, storage, cooking, and eating.

EXERCISE

Question 1

Define the packaging product shelf life

Answer

Shelf life is the duration of that period between the packing of a product and the end of consumer quality as determined by the percentage of consumers who are displeased by the product.

Question 2

Discuss the THREE (3) factors that affect the shelf life of the product.

Answer

1.Product characteristics, including formulation and processing parameters (intrinsic factors)

- include pH, water activity, enzymes, microorganisms, and concentration of reactive compounds. Many of these factors can be controlled through the selection of raw materials and ingredients, as well as the choice of processing parameters.

2.Environment to which the product is exposed during distribution and storage (extrinsic factors)

- include temperature, RH, light, total and partial pressures of different gases, and mechanical stresses, including consumer handling. Many of these factors can affect the rates of deteriorative reactions that occur during the shelf life of a product.

3.Properties of the package

The properties of the package can have a significant effect on many of the extrinsic factors and thus indirectly on the rates of the deteriorative reactions. Thus, the shelf life of a food can be altered by changing its composition and formulation, processing parameters, packaging system, or the environment to which it is exposed.

TOPIC 2
ACTIVE PACKAGING

Synopsis

This topic explains that active packaging is an innovative approach in the packaging industry designed to interact with the contents and environment to enhance product shelf life, safety, and quality. It also explores the different types of active packaging systems and their applications.

ACTIVE PACKAGING

Active packaging can be described as packaging intended to extend the shelf life or maintain or improve the condition of packaged foods. It represents a revolution in the food industry. It is designed to intentionally release or absorb substances into or from the food or its surroundings.

How does active packaging preserve food?

Active packaging interacts directly with a packaged product. The typical systems include oxygen and carbon dioxide scavengers or emitters, moisture absorbers, ethylene scavengers, flavor and odor absorbers, and ethanol emitters. It was developed as a response to the demands of modern consumers.

TYPES OF ACTIVE PACKAGING

Two types of active packaging

i. Sachets and pads are placed inside packages and active ingredients are incorporated.

ii. Ingredients that are integrated directly into the packaging materials. For example, it can be incorporated into thin film composites for multilayer packaging.

Figure 2.1 Different Types of Active Packaging, adapted from Deshmukh 2023

ACTIVE PACKAGING SYSTEMS

What do you know about active packaging systems?

Active packaging has been used with many food and beverage products. Table 2.1 details some of the different types of active packaging systems and their potential application.

Table 2.1 Active packaging systems and applications, adapted from Richard 2011

Active Packaging System	Food & Beverage Application
Oxygen scavengers	▪ Bakery goods (bread, cakes) ▪ Prepared foods (sandwiches, pizza, ready meals, cured meats & fish, dried foods & beverages)
Carbon dioxide scavengers	Coffee, yeast-based goods
Carbon dioxide emitters	Bakery goods, prepared foods
Ethylene scavengers	Fruit, vegetables
Ethanol emitters	Bakery goods (cakes, bread)
Moisture absorbers	Meat, poultry, fish, fresh fruit & vegetables
Flavor/odor absorbers	Fruit juices, meat, poultry, fish

Oxygen Scavengers

Food spoilage can occur due to oxygen in the packed food or the oxygen generated by metabolic reactions in fresh produce. An oxygen (O_2) scavenger, sometimes called an O_2 absorber, is one of the active systems used to remove or decrease the amount of O_2 inside a package.

The oxygen scavengers prevent the adverse effect that O_2 causes through several reactions that affect food like oxidation and rancidity of fats and oils, ripening and senescence of fresh produce, staling of bakery products, and encouraging aerobic bacteria that can spoil food (Scott, 2022).

The most well-known O_2 scavengers are in small sachets containing various iron-based powders combined with a suitable catalyst. The chemical systems react with water from the food to produce a reactive hydrated metallic reducing agent that scavenges O_2 within the food package and irreversibly converts it to a stable oxide.

Carbon Dioxide Scavengers

Carbon dioxide (CO_2) level optimization in the food package helps extend the shelf life of various foods in active packaging. Removal of carbon dioxide is sometimes necessary when the products are CO_2-sensitive. It is also required to remove the CO_2 produced so the package does not burst. CO_2 scavengers are often used in food packaging for coffee, cheese, and fresh produce.

Figure 2.2 CO_2 Scavengers

CO_2 scavengers include:

i. Chemicals like calcium hydroxide, sodium hydroxide, silica gel, potassium hydroxide, and calcium oxide.

ii. Biofilms that can absorb the gas. These are sometimes used as labels for fresh produce and mushrooms.

Carbon Dioxide Emitters

In fresh meat, fish, fresh produce, dried fruits, nuts, snacks, and baked goods, CO_2 levels are kept high. Normally, concentrations up to 99% are used in the headspace, as the gas has antimicrobial effects.

Active CO_2 emitters produce and release the gas in the non-respiring food packaging. This helps to control microbes, which cause spoilage and extend shelf life. In some fish and shellfish packages, the CO_2 levels can be filled to 10% - 80%. High CO_2 levels also decrease fruit softening rates and pigment retention.

CO_2 emitters are chemicals, such as ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate. They are present as pads and box systems.

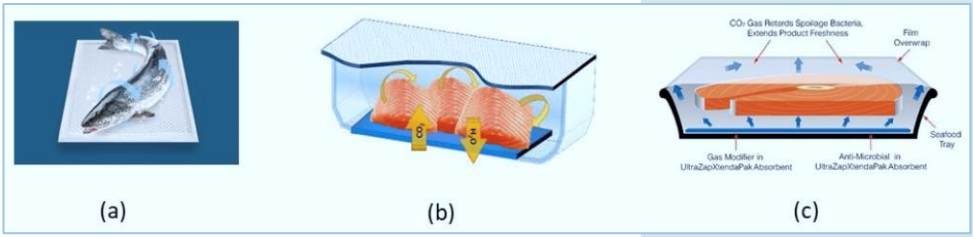


Figure 2.3 (a) CO_2 Emitter Pad, (b) CO_2 Emitter and Moisture Absorber Pad, (c) CO_2 Emitter and Antimicrobial Pad, adapted from ResearchGate 2021

Ethylene Scavengers

Many fruits and vegetables are sensitive to ethylene, which upon prolonged exposure induces the deterioration of food quality, such as a change in taste, odor, and color or microbial growth. (KK Gaikwad, 2020).

Ethylene scavengers most commonly come in sachet form containing Potassium permanganate. They are non-toxic and chemically inert, posing no harm to the products or consumers. When placed inside the package or incorporated into packaging material, these sachets remove ethylene gas to extend a product's shelf life. This active system can also absorb ethylene produced by the natural ripening process, causing damage to fresh produce.

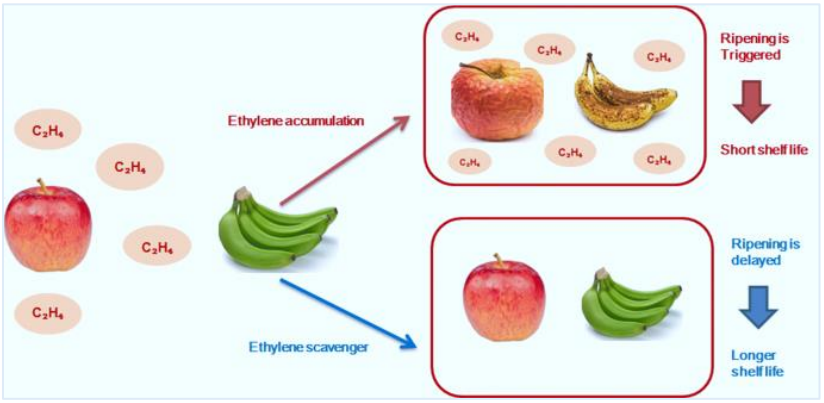


Figure 2.4 Ethylene Scavengers, adapted from SpringLink 2019

Ethanol Emitters

Ethanol emitters can be used in active packaging for food products, which can release the ethanol into the headspace of the closed system during storage. The presence of ethanol inhibits the growth of microorganisms by acting on the cell wall, and cell membrane, or disrupting protein configurations. This can increase the shelf-life of bakery products by several weeks, preserving the sensory quality and safety.

Ethanol emitters exist as inedible films or sachets that can be contained within the packaging. Ethanol is adsorbed or encapsulated onto a carrier such as silicon dioxide. The sachet must be durable to prevent the carrier from leaking, but simultaneously permeable to ethanol vapors.

Ethanol is a preferable preservative in breads and bakery products because it can inhibit the growth of spoilage yeasts and molds that may cause staling in the products.

Moisture Absorbers

High humidity causes food spoilage via mold and bacteria growth. Moisture control is necessary to lower water activity (a_w), and protect packaged foods from moisture accumulation, which may result in deterioration, such as ready-to-eat meals.

Moisture absorbers often come in sachet form and prove useful in high-water activity food packaging. The proper amount used for moisture absorption is to prevent excessive moisture, which can impact product quality and shelf life. Silica gel is the most commonly used moisture scavenger since it is non-toxic and non-corrosive.

Figure 2.5 Moisture absorbers in Food Packaging

Flavor/Odor Absorbers

Flavor/odor absorbers are substances added to the packaging material to remove unpleasant flavors, aromas, and odors produced during the breakdown of food, such as fish, dairy products, fruit, and poultry. The formation of undesired flavors/odors in food products mainly from the oxidation of fats and oils, and the breakdown of proteins in fish muscle.

Activated carbon or charcoal-based odor removal is popular because of its high efficiency, low cost of production, and moisture absorption properties. A sachet may be necessary to contain odor absorbers to prevent them from mixing with the product.

Figure 2.6 Activated Charcoal Odor Absorbers

Conclusion

Active packaging technologies offer new opportunities for the food industry in the preservation of foods. The objectives of this technology are to improve food safety and significantly extend food product storage life while at the same time maintaining food quality.

Active packaging is a great method to achieve the objectives by manipulating the headspace atmosphere inside the package through active agents or systems (for example, oxygen scavengers, ethylene scavengers, moisture absorbers, flavor/odor absorbers, etc.).

However, the development of active packaging will also depend on the consumers' acceptance and cost-effectiveness in food industries. Besides, one of the primary challenges is the creation of functional materials capable of retaining their original properties during the distribution and storage processes.

1. In Active packaging, the atmosphere inside the package remains constant. (True/False)

2. Active packaging can extend shelf life but not improve food quality. (True/False)

3. Active packaging systems can also help to reduce food waste. (True/False)

4. Iron acts as _____ scavenger system.

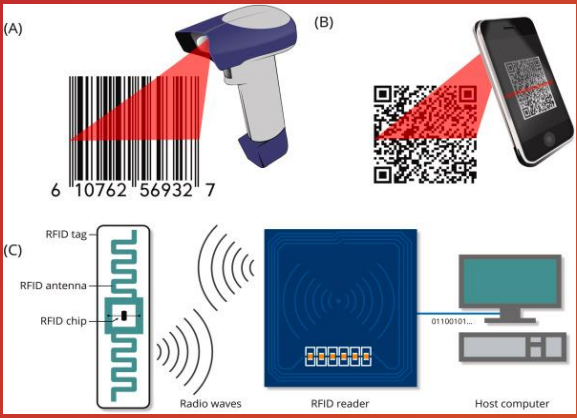
5. $Ca(OH)_2$ and NaOH acts as _____ scavenging system.

6. Potassium permanganate acts as _____ scavenging system.

7. _____ is used as a preservative in active packaging.

8. Polyacrylates (sheets), propylene glycol (film), and silica gel (sachet) act as _____ scavenging system.

9. _____ is a common example of an odor absorber.



TOPIC 3
INTELLIGENT PACKAGING

Synopsis

This topic explains that intelligent packaging is a smart technology in the packaging industry designed to improve communication of changes in food inside the package and to display various alerts of potential problems in the package that display food quality. It also explores the different types of intelligent packaging and their applications.

INTELLIGENT PACKAGING

What is intelligent packaging?

Intelligent packaging is one of the technologies within the food packaging field. Even though this technology is still growing, it has enormous potential to improve the safety and traceability of food products. Intelligent food packaging is usually designed to monitor the interactions between the food itself and the environment around it, providing customers with information on food quality and safety through some signals.

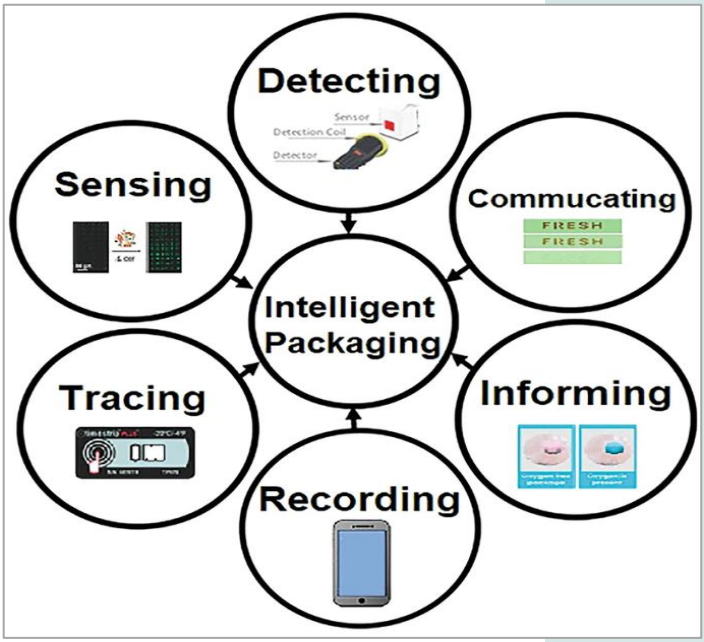


Figure 3.1 Intelligent Packaging, adapted from Kuswandi 2022

APPLICATIONS OF INTELLIGENT PACKAGING

How does intelligent packaging works?

Intelligent food package devices are small, inexpensive labels or tags that are used to facilitate communication throughout the supply chain by being attached to:

i. Primary packaging systems such as pouches, trays, and bottles.

ii. Secondary packaging systems which are shipping containers.

The function of communication can help to facilitate decision-making to achieve the benefits of enhanced food quality and safety. Intelligent systems can also improve traceability, reduce costs, and increase efficiency in food applications. Therefore, intelligent packaging offers a range of benefits to both product distribution and manufacturing processes.

INTELLIGENT PACKAGING SYSTEMS

What do you know about intelligent packaging systems?

In general, there are three main technologies used for intelligent packaging systems:

i. Indicators. Informed customers by direct visual changes about specific properties related to food quality.

ii. Sensors. Detect a specified analyte by using receptors, transducers, and signal-processing electronics.

iii. Data carriers. They are not typically used for information on food quality, but rather to track the food along the supply chain.

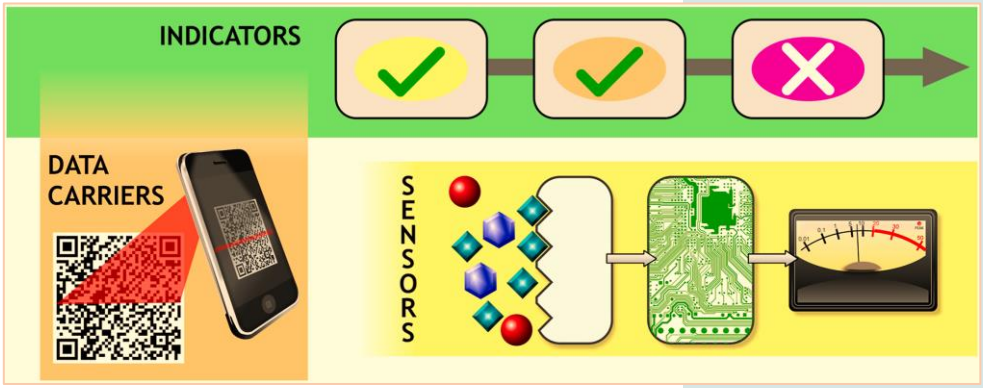


Figure 3.2 Intelligent Packaging Systems, adapted from Azeredo 2021

TYPES OF INTELLIGENT PACKAGING

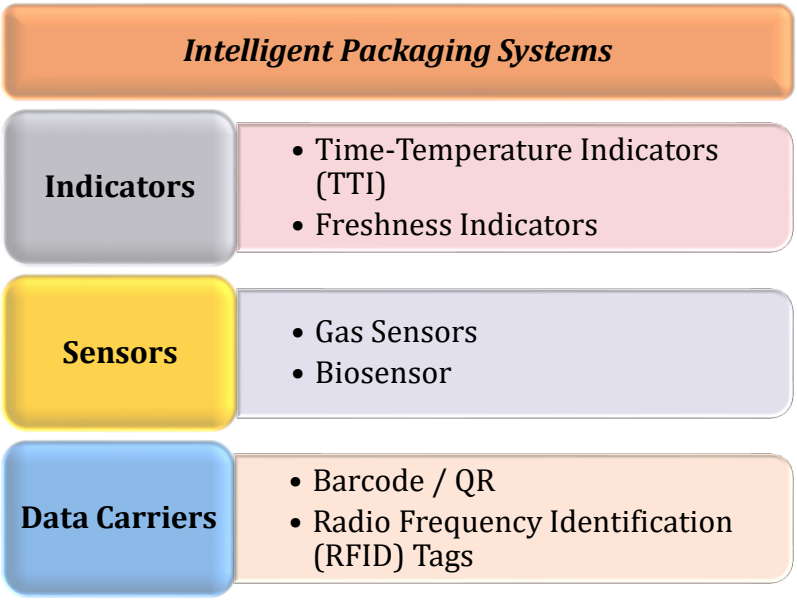


Figure 3.3 Types of Intelligent Packaging

Indicators

Indicators determine the presence or absence of a substance, the extent of a reaction between different substances, or the concentration of a particular substance. This information is visualized by changing colors. It also depends on the indicator placed inside or outside of the package. In this way, they provide the consumer with qualitative or semi-quantitative information regarding the quality and freshness of the food products.

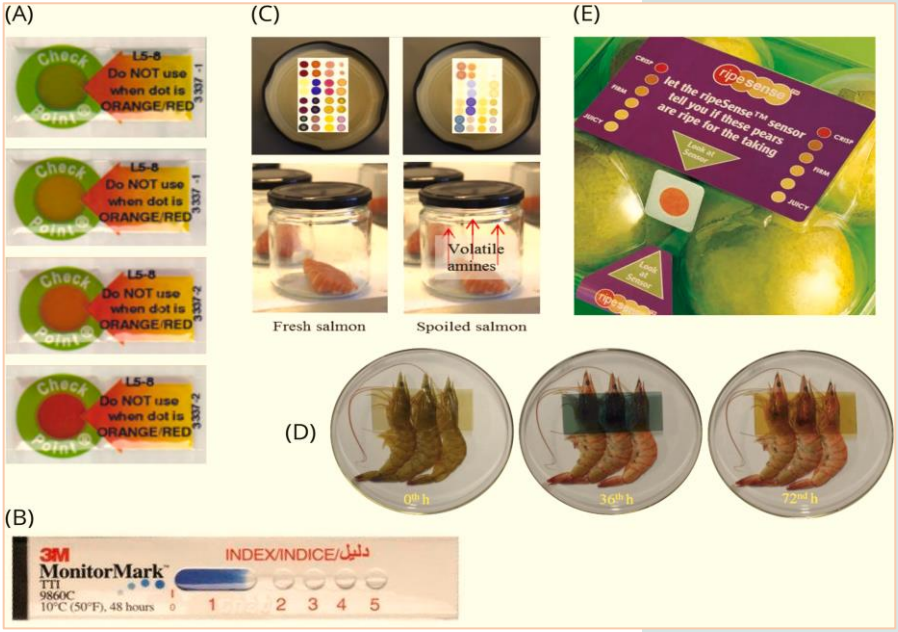


Figure 3.4 (A) TTI Seafood Label, (B) TTI Monitor Mark™, (C) Freshness Indicator, (D) pH indicator, (E) Fruit Ripeness Indicator, adapted from Azeredo 2021

Time-Temperature Indicators

Temperature is an important factor in determining food product shelf life. Time-temperature indicators (TTIs) provide information on the full temperature history of the food product along the food supply chain.

The devices are simple, in the form of stickers/labels attached to the outside of collective or individual packaging, recording even short-term thermal changes in the environment (an increase or a decrease in temperature beyond the limit acceptable for a given product) during the storage, transport, and distribution.

The functional principle of TTIs is based on the detection of time and temperature-dependent mechanical, chemical, enzymatic, or microbiological changes in a food product. The measured values are usually expressed as a visible response, like color changes or mechanical deformations.

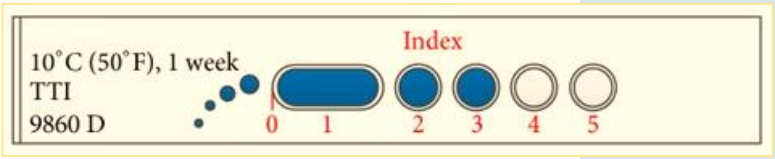


Figure 3.5 TTI Indicator

Freshness Indicators

Freshness indicators supervise the quality of food products during storage and transportation. Reasons for the loss of freshness can be disadvantageous conditions or exceeded durability. Therefore, they submit information about microbiological growth and chemical changes in the products.

Besides, the devices indicate freshness by showing different colors or color changes. They provide direct information on product quality resulting from microbial growth or chemical changes in the food product.

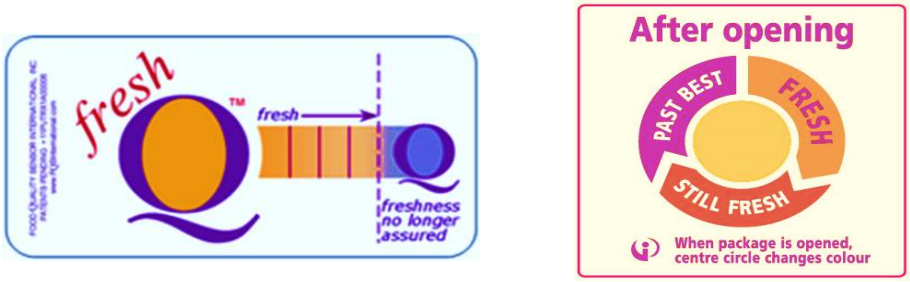


Figure 3.6 Freshness Indicators

Sensors

A sensor is an instrument that detects, locates, or determines events or changes in the surrounding environment. It responds by giving a continuous output signal that can be interpreted to measure the physical or chemical parameters.

Generally, sensors are composed of two basic components:

i. A receptor - is to transform physical or chemical information into a form of energy.

ii. A transducer - converts the energy into an analytical chemical, optical, electrical, or thermal signal.

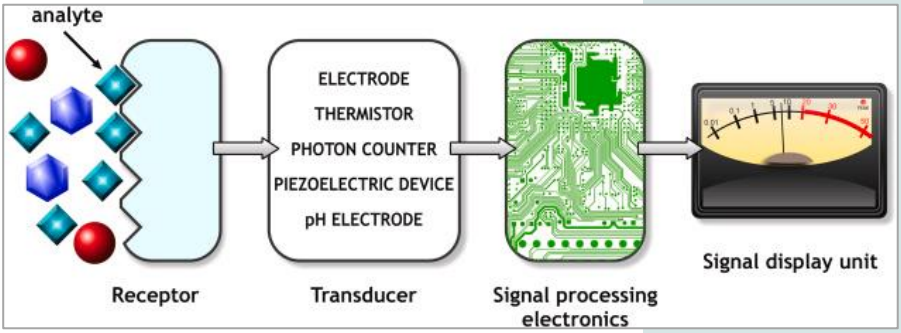
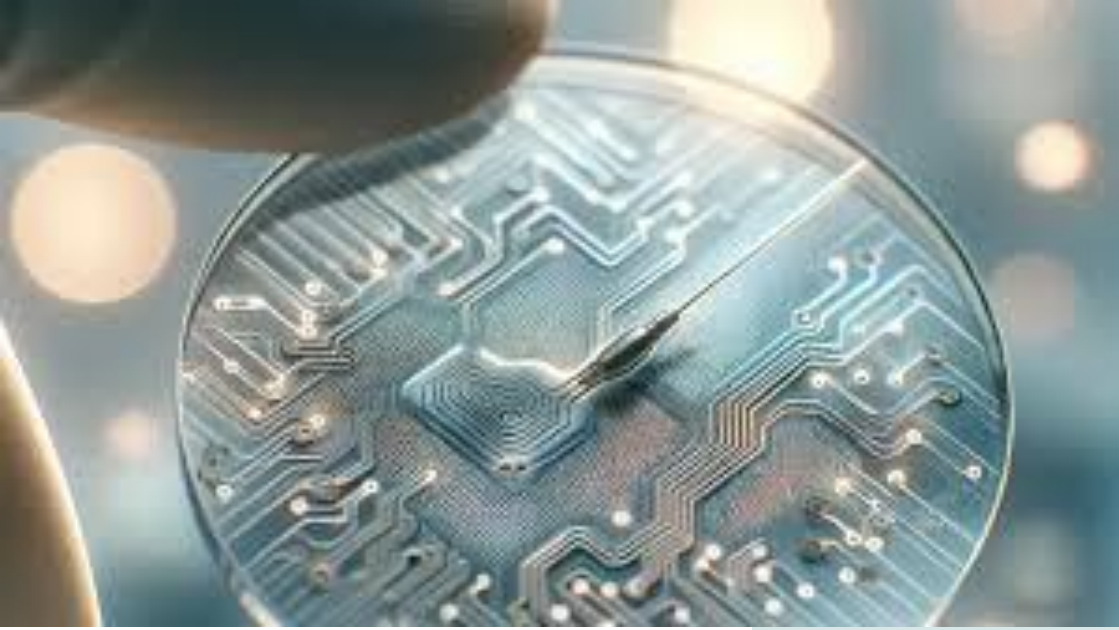


Figure 3.7 Components of a Sensor, adapted from Ghaani 2016



Biosensors

A biosensor is a chemical sensing device in which a biologically derived recognition is coupled to a transducer, to allow the quantitative development of some complex biochemical parameter.

Biosensors apply the working principle of monitoring and detecting potential changes in controlled products and then convey information relevant to biological systems. The main components of biosensors are:

i. Bioreceptor - which is responsible for controlling microbiological changes in food products. It is capable of recognizing enzyme activity, antigens, hormones, or microorganisms.

ii. Transducer - which converts biological signals into electrical ones. The transducer used can be optical, acoustic, or electrochemical in nature.

Gas Sensors

Gas sensors are devices monitoring changes in the composition of gases inside the package that can be used to detect gaseous analytes like oxygen, water vapor, carbon dioxide, ethylene, etc. Other than the gas oxygen, gas carbon dioxide, and water vapor sensors, the most commonly used gas sensors are ethanol sensors.

Additionally, gas sensors detect gases generated from enzymatic reactions, chemical reactions, and microbial metabolism within the food, and also the gases entering the package from the external environment, and provide this information to the user.

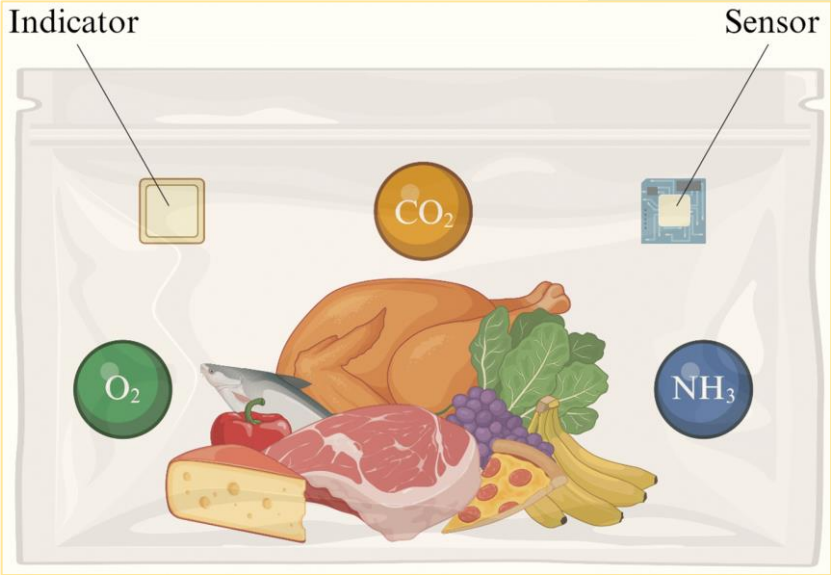


Figure 3.8 Gas Sensor and Indicator in Food Packaging, adapted from Wonyoung H. 2024

Data Carriers

Data carriers, including barcodes and radiofrequency identification tags (RFID), are specifically intended to help detect the movement of food products along the food supply chain, being generally not used to collect information on food quality status, but rather to enable automatization, traceability, theft prevention, and counterfeit protection (Ghaani, 2016).

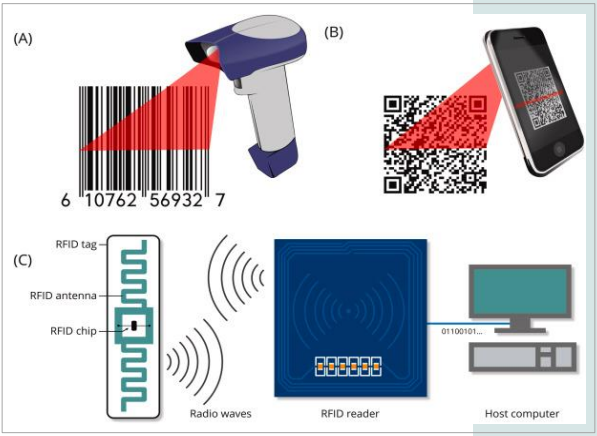


Figure 3.9 (A) Barcode, (B) QR, (C) RFID, adapted from Azeredo 2021

Barcode Labels

Barcode labels are the data carrier in food packaging. A barcode is a machine-readable pattern of parallel bars and spaces or an array of dots and spaces (QR) arranged to represent hidden encoded data, the information being decoded by an optical scanner that conveys it to a system where it is stored and processed.

Barcodes are commonly associated with retail packaging. Comprised of numbers and parallel lines of varying widths, they have traditionally been used for stock control and point-of-sale functionality.

QR codes on packaging revolutionize consumer interaction and significantly improve the customer experience. QR codes allow manufacturers to collect real-time feedback once customers receive their purchases.

Radio Frequency Identification (RFID) Tags

An RFID system, more advanced and convenient, is based on wireless communication between a tag attached to the product and an interrogator. The main components of an RFID system are an RFID antenna for communication linked to a chip for unique identification and data storage, a reader for wave emission and reception upon backscattering from the tag, and a host computer/cell phone for data saving and processing (Bibi, 2017).

This system can be placed on any packaging material and it can have any shape. RFID tags are the most advanced data carrier systems attached to packages to track and identify objects using radiofrequency electromagnetic fields. Tags and readers are designed to communicate with each other.

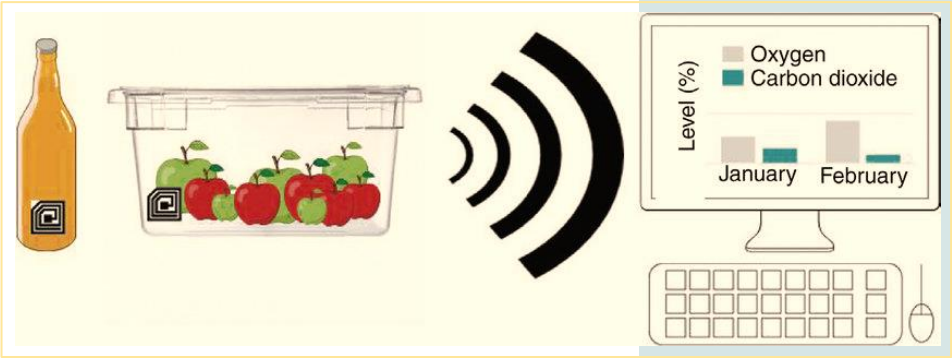


Figure 3.11 RFID for Food Quality Control

Conclusion

Intelligent packaging is a rapidly growing industry that combines traditional packaging with advanced technologies to create interactive and functional packaging. It holds various benefits, including improved traceability, enhanced product quality, and increased efficiency in the supply chain.

The packaging utilizes advanced technologies such as sensors and RFID tags to interact with the environment and offer additional features to customers. It can monitor the product's condition, track it through the supply network, and provide relevant information to customers.

Furthermore, there is a great deal of scope for intelligent indicator-based packaging technology in the food sector. Indicators provide visualizations of food freshness and continuous monitoring of the food and can be effectively used to improve food safety and reduce food waste.

1. Intelligent packaging provides information and communication in the entire supply chain. (True/False)

2. Biosensors used to reduce temperature, humidity, and gas composition in intelligent packaging. (True/False)

3. Intelligent packing can also serve as a freshness indicator. (True/False)

4. Time-temperature indicator (TTI) covers the _____ function of food packaging.

5. The 2 basic components of the sensor are _____ and _____.

6. _____ serve as a valuable medium for sharing all kinds of information with consumers.

7. _____ is used for intelligent packaging in storage and distribution.

8. What is the main difference between active packaging and intelligent packaging?

TOPIC 4
PACKAGING SUSTAINABILITY

Synopsis

This topic explains the role of packaging in sustainable development. There is a growing need to facilitate and communicate an understanding of the relative sustainability of packaging and that need is growing. Delivering packaging which is more sustainable will include cost reductions, reduced environmental impact, enhanced consumer perception, improved decision making and ultimately extended influence within the packaging value chain and the broader corporate world.

What is Sustainable Packaging?

SUSTAINABLE PACKAGING is integrating environmental criteria in the design process of a product- packaging combination. This can result in improving the current packaging system, but also in developing a complete new product- packaging system for the circular economy or even packaging solutions with a positive impact.

- Is beneficial, safe & healthy for individuals and communities throughout its life cycle;
- Meets market criteria for both performance and cost;
- Is sourced, manufactured, transported, and recycled using renewable energy;
- Is manufactured using clean production technologies and best practices;
- Is made from materials healthy in all probable end of life scenarios;
- Is physically designed to optimize arterials and energy;
- Is effectively recovered and utilized in biological and/or industrial closed loop cycles.

Four main attributes of sustainable packaging:

effective, efficient, safe and cycle

Effective: the packaging system adds real value to society by effectively containing and protecting product

Efficient: the packaging system is designed to use materials and energy as efficiently asa possible throughout the product life cycle.

Cycle: Packaging materials used in the system are cycled continuously, minimizing material degradation.

Safe: packaging components used in the system do not pose any risks to humans or ecosystems.

Pillars of sustainability of sustainable packaging

The four pillars of sustainability packaging is environmental, economic, social, and human sustainability .

1. ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability refers to preserving natural resources. This is often referred to as natural capital. This is a way to improve human welfare for future generations and is often executed through environment sustainability initiatives, like:

- Businesses charging for plastic bags
- Planting trees with every purchase
- Creating recyclable products or creating products from recycled materials

2. ECONOMIC SUSTAINABILITY

Economic sustainability aims to preserve financial capital. Businesses, governments, and all kinds of organizations must focus on this to see social and economic improvement in their area. This directly links to environmental sustainability because many initiatives focus on reducing pollution and increasing recycling. When there is less waste, your processes are more efficient and your product is more valuable, encouraging economic growth.

3. SOCIAL SUSTAINABILITY

Social sustainability focuses on the broader framework of our society. This means the development of programs, initiatives, and organizations that are set out to structure the world and foster growth. Without this pillar, business, health and education systems, and governments wouldn't be able to function.

4. HUMAN SUSTAINABILITY

Human sustainability prioritises fostering connection and community. It goes hand in hand with cultural sustainability and is essential for a functioning, healthy, and fair society.

Reduce, Reuse, Recycle

Reduce

Reducing means going after the source of waste production, rather than managing the consequences of this production. Example: Choosing a box in which muffins are not individually wrapped.

We can also reduce our consumption, our production of waste and our impact on the environment by practicing responsible consumption.

What can you reduce?

1. Reduce waste production at the source. This means reducing the quantity of waste during production, distribution, purchasing, use and elimination.
2. Replace your consumption of disposable objects and products by reusable ones.
3. Buy products that contain recycled materials.
4. Buy products that aren't over-packaged.
5. Buy recyclable products.
6. Avoid plastic bags. Instead, get a reusable shopping bag.
7. Use washable containers for your lunches, breaks and snacks instead of wrapping things in plastic wrap or using Ziploc bags.

Reuse

Reusable packaging is a waste-free, environmentally friendly packaging choice that can be used repeatedly. It can be made to be used for a different product or to be refilled with the same one.

Reuse helps reduce not only the content of your garbage cans but also that of your recycling bin. All you need is to extend the life of a product by using it more than once or to be creative by giving it a second life.

What can you reuse?

1. Reuse your family-pack containers to buy in bulk: it's economical (buying in bulk costs less) and environmental for all of us (by reusing the same containers, you reduce the water, energy and raw-material consumption needed for the production of new containers, and you reduce your contribution to pollution and waste accumulation).
2. Use a reusable plastic or cotton bag for your purchases. If the volume of your purchases exceeds the volume of your bags, take the plastic bag provided by the store and reuse it at least once in your kitchen garbage can. This action remains "the most beneficial for the environmental , after the reusable bag".
3. Wrap your gifts with used bags, ribbons and tissue paper or create ecological and original
4. Wrappings with magazines, comics cut out of newspapers, boxes and fabric scraps.

Recycle

Recycling means bringing an object back to a state of raw material: paper goes back to pulp, plastics are melted and moulded into new products, etc. What was once considered waste becomes a resource, thus breaking with the linear extraction-production-consumption-destruction logic.

Why recycle?

1. Preserves our more and more of our precious natural resources by minimizing forest and mining activities;
2. Preserves huge amounts of water;
3. Reduces energy demands during manufacturing;
4. Bypasses air, water and soil contamination during mining and disposal (dumps, incinerators);
5. Favors the conservation and protection of the environment and ecosystems;
6. Reduces pollution.

LIFE CYCLE ASSESSEMENT (LCA)

DID YOU KNOW?

How to measure "Sustainability".

- LCA stands for life cycle assessment, which is a popular approach to understanding the environmental profiles of products and services.
- LCA considers the entire life cycle of a product or service, from its procurement to conversion, manufacture, distribution, and end of life.

LCA study quantifies the impact of all relevant emissions and raw materials and consumables used at every stage of a product, the problem is avoided whereby solving one environmental problem leads to another or whereby a positive effect during a particular part of the cycle has a negative effect somewhere else. LCA thus contributes to a higher level of value chain and material cycle sustainability, from a global perspective.

- If one wanted to perform a LCA of a product or service, one would need at least three different LCI data sets, which stands for life cycle inventory data. These data sets would be averaged to determine the metrics used for the product or service LCA.
- LCI data is primary data that is collected for a specific product or service.

LIFE CYCLE ASSESSEMENT (LCA)

LCA main stages:

- Goal definition and scope. Identify a product / process / technology; establish context and system boundaries.
- Inventory analysis. Identify and quantify energy, water, and materials as inputs as well as environmental releases as outputs.
- Impact assessment. Assess the potential human and ecological effects, quantify metrics.
- Data interpretation. Compare data from Inventory Analysis and Impact Assessment stages to select or recommend a preferred product, process, or technology.

LCA Limitations:

✓ LCA thoroughness and accuracy will depend on the availability of data; gathering of data can be problematic; hence a clear understanding of the uncertainty and assumptions is important.

✓ Classic LCA will not determine which product, process, or technology is the most cost effective or top-performing; therefore LCA needs to be combined with cost analysis, technical evaluation, and social metrics for comprehensive sustainability analysis.

✓ Unlike traditional risk assessment, LCA does not necessarily attempt to quantify any specific actual impacts. While seeking to establish a linkage between a system and potential impacts, LCA models are suitable for relative comparisons, but may be not sufficient for absolute predictions of risks.

Application of *Sustainability Packaging framework*

The different levels of packaging in supply chains is purchasing sustainable raw materials (such as biomaterials or recycled materials), optimizing the use of packaging materials, using clean production methods, using energy efficiently and renewable energy in all stages, and creating closed loops through waste management, reprocessing, and reuse.

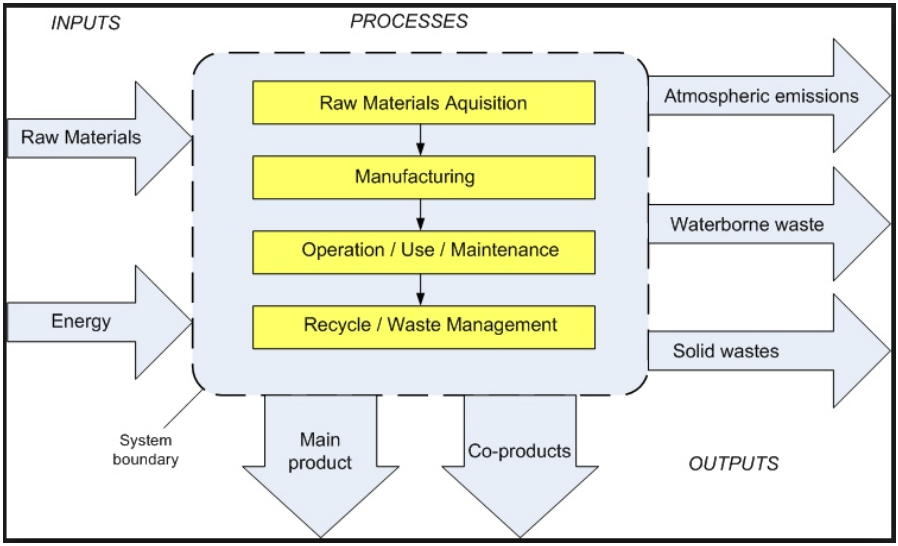


Figure 5.1 Schematic diagram of Life Cycle Assessment adopt from Samuel, 2022

EXERCISE

Question

What is the best option for dealing with waste more responsibly and discuss the advantages of Reduce, Reuse and Recycle.

Answer

The best option dealing with waste are:

1. Reduce Your Trashcans - It may seem counter-intuitive in some ways, but by eliminating wastepaper baskets from around your home, you are much more likely to reconsider things that you originally relegated to the trash.
2. Know Your Waste Management - you should get information about where you can take your recyclable products yourself.
3. Consume Mindfully - Adjusting your spending habits to start in-taking less, buy more in bulk, and buy mostly — if not all — recyclable products.

Advantages of Reduce, Reuse and Recycle (3R).

1. Reduce energy consumption - Recycling plays its part in the green energy debate by reducing the amount of energy required to manufacture certain products. This reduces greenhouse gas emissions generated by the manufacturing process and lowers global energy consumption.
2. Decreased pollution – 3R drastically reduce the amount of industrial waste. The less waste we throw onto the planet, the cleaner and safer it will be for future generations to come.
3. Considered very environmentally friendly - Recycled paper products mean less trees that need to be cut down and processed.
4. Flights global warming –By reducing the amount of waste that's burned when it's time to clear some space.

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