

# Packaging of Biscuits

**Deepanshu Sharma**

Student, Indian Institute Of Packaging

## **ABSTRACT**

Biscuits, a ubiquitous and beloved snack, rely heavily on effective packaging to maintain their freshness, quality, and appeal. This report delves into the world of biscuit packaging, exploring its historical evolution from rudimentary storage methods to the sophisticated solutions employed today. We examine the multifaceted functions of packaging, highlighting its critical role in protecting biscuits from moisture, damage, and contamination, ultimately ensuring consumer safety and extended shelf life.

The primary function of biscuit packaging extends beyond containment; it serves as a vessel for preserving product freshness, enhancing shelf life, and communicating brand identity. However, amidst growing environmental concerns, sustainability has emerged as a pivotal consideration. Manufacturers are increasingly exploring eco-friendly alternatives, such as biodegradable materials and minimalist designs, to reduce waste and mitigate environmental impact.

Innovation lies at the heart of biscuit packaging evolution. From novel materials to advanced sealing technologies, manufacturers are continuously striving to enhance functionality while minimizing resource consumption. Resealable packs, portion-controlled servings, and barrier films are among the innovations aimed at improving convenience and reducing food waste.

Consumer preferences play a significant role in shaping packaging strategies. Increasingly health-conscious consumers are seeking transparency in labelling, prompting manufacturers to provide detailed nutritional information and ingredient sourcing. Moreover, aesthetics and branding play a crucial role in attracting consumers' attention amidst a crowded marketplace.

## **Introduction**

The history of biscuits packaging inter-winded with the development of food preservation techniques and changing consumer needs.

Early days, pre-1800s Biscuits were typically homemade or produced by small bakeries. They were stored in cloth bags, tins or wooden boxes for short periods. Later on, the invention of tinfoil canning in 1810 by Peter Durand offered a significant leap. Tins provided better protection against moisture, pests and damage, allowing for longer shelf life and wider distribution of biscuits. As time passes the evolution comes in the packaging materials of biscuits. In late 1800s, wax paper emerged as a more affordable and flexible option for individual biscuits wrapping. It offered some moisture protection and limited transparency.

In mid-1900s, the development of plastic film revolutionized biscuits packaging. These films provided barriers, increased transparency for product visibility and facilitated more production with heat sealing.



## 2. The Importance of Biscuit Packaging

Biscuit packaging plays a multifaceted role in the modern consumer landscape. Its significance extends beyond mere containment; it serves as a critical interface between the product and the consumer, influencing purchasing decisions, preserving product quality, and communicating brand identity.

### 2.1 Branding and Marketing

Biscuit packaging is a canvas for brand expression and storytelling. Through vibrant designs, captivating imagery, and strategic placement of logos and slogans, brands can create memorable experiences that resonate with consumers. Packaging serves as a silent salesman, attracting attention on crowded shelves and conveying the brand's values, personality, and promise.

### 2.2 Innovation and Sustainability

In an era marked by increasing environmental consciousness, biscuit packaging is undergoing a paradigm shift towards sustainability. Manufacturers are exploring eco-friendly materials, minimalist designs, and innovative packaging formats to reduce waste, minimize carbon footprints, and meet the expectations of environmentally-conscious consumers.

## 3. Biscuits Packaging

Packaging boxes are an important factor affecting the development of the biscuit industry. While the biscuit market is booming, competition in the biscuit packaging industry is fierce. On the one hand, large supermarkets have dozens of biscuits, brands, and packaging boxes that are constantly being renovated; on the other hand, there are dozens of biscuits, brands, and packaging boxes in large supermarkets. All kinds of snack foods and convenience foods provide consumers with different choices. Brand competition is intensifying. More and more world-famous biscuit brands are quickly seizing the market with its high-quality and delicious, exquisite packaging boxes. Therefore, the pace of development of biscuit companies Speeding up has enabled biscuits to reach unprecedented levels in terms of variety, packaging, taste, and functions.

### 3.1 Principle of Biscuit Packaging

Biscuits have very low water content and contain fat. The packaging is mainly for moisture-proof, fat-

oxidation and chipping prevention. Sandwich biscuits and colorful biscuits are commonly decorated with jam, nuts, cream and other decorations. It is also necessary to pay attention to anti-mould and fat oxidation. Choose moisture-proof, light-shielding and oxygen-proof packaging materials, such as tinplate, moisture-proof cellophane, PVDC coated paper, BOPP/PE, aluminium foil; it has good air tightness, extensibility, good surface gloss, and can adapt to automatic packaging machines.

Requirements for mechanical operation. The high-hardness tinplate (tin plated iron) material is used to stamp and form the box to protect the crispy biscuits from crushing. Metal tin box packaging biscuits are generally gift packaging.

### **3.2.Packaging Functions**

- Present the biscuits in an attractive way for the potential consumers
- Display the biscuit type, weight, ingredients and manufacturer
- Maintain biscuit freshness and flavour over a long shelf life
- Provide effective barrier for moisture and foreign odour
- Resist seepage of fats and oils
- Protect against visible light and UV radiation
- Protect the biscuits from damage during transportation
- Stack well on supermarket shelves

### **3.3.The Role of The Biscuit Packaging**

The packaging box is an accessory to the commodity and an important means to realize the value and use value of the commodity. It is to protect the biscuits in circulation, facilitate transportation, promote sales, and use containers, materials and auxiliary materials according to certain technical methods. During the process, certain technical methods and other operational activities are applied.

As a means to realize the value and use value of biscuits, the biscuit packaging box plays an extremely important role in the fields of production, circulation, sales and consumption. As food packaging, it can protect food and extend its shelf life; facilitate circulation; increase convenience food varieties; prevent food contamination; promote the rationality and planning of food circulation; promote food competition and increase food sales. It not only brings much convenience to producers, sellers and consumers, but also promotes the development of the food industry.

The biscuit packaging box is a comprehensive reflection of the biscuit brand concept, biscuit characteristics, and consumer psychology, and it directly affects consumers' desire to buy. The biscuit packaging box is a powerful means to establish the affinity between the product and the consumer. In today's economic globalization, packaging and commodities have been integrated. Packaging boxes are no longer just to protect biscuits, but also to beautify commodities and promote sales.

Nowadays, with the rapid economic development, different products fill the entire market, and the fierce competition has prompted companies to attract consumers' attention through various channels. For example, through TV advertisements, newspaper advertisements, introductions by others, brand reputation, etc., these are not enough to ultimately lead to the occurrence of purchase behaviour. In the retail method of supermarkets, consumers' buying confidence is largely accomplished through comparison. of. The cruel business competition makes designers face unprecedented design opportunities and challenges. Therefore, in the design of customized biscuit packaging boxes, highlighting the concept of individuality and displaying the deep connotation has increasingly become an indispensable core spirit in the design. And food biscuit packaging box as a comprehensive subject  
Increasingly, it has the dual nature of combining commodities and art.

#### 4. Packaging Design and Materials

Materials chosen for the products are very important in the food packaging to keep the quality of the food. To maintain the quality of the food, the good materials are chosen in fabricating the product.

##### 4.1. Packaging Materials

The packaging materials are selected to provide a moisture barrier and to protect the biscuits. The film materials are heat or cold sealable.

Some of the various materials used are the following:

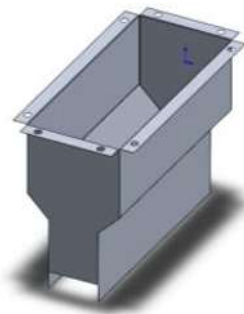
- Polypropylene, metallised orientated polypropylene (OPP) and biaxially oriented polypropylene film (BOPP).
- BOPET, biaxially oriented polyethylene terephthalate (PET), is a poly ester film made from stretched PET.
- Laminates, plastic-coated papers, OPP/paper and metallised polylactic acid/paper.
- For thermoformed trays, PET and recycled PET (PET).
- Aluminium foil.
- Cartons and boxes: paperboard, coated paperboard and paperboard/ polyethylene/aluminium foil.

##### 4.2. Packaging Component Design

The following components were designed for their designated tasks.

###### 1. Cookies Container

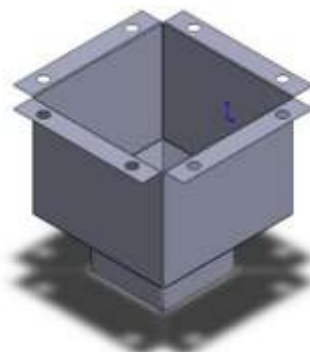
Figure 1 shows the cookies container design. The function of this component is to hold the cookies before they exit into the next stage.



**Figure 1: Cookies Container Design**

###### 2. Dropper

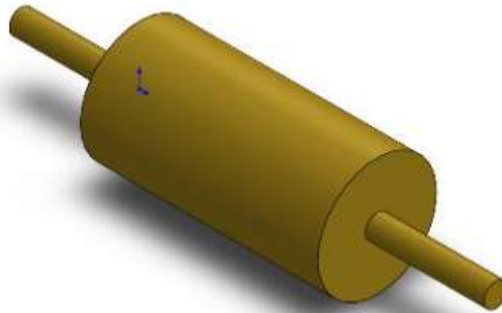
Figure 2 shows that dropper design. The purpose of this component is to guide the cookies down into the package.



**Figure 2: Dropper Design**

### 3. Roller

Figure 3 shows the roller design. The function of this component is to move the belt by using 12V DC motor. This component must rotate to move the cookies to the next stage. The acceleration of this roller must constant to keep the quality of the cookies.



**Figure.3: Roller Design**

### 4. 12V DC Motor

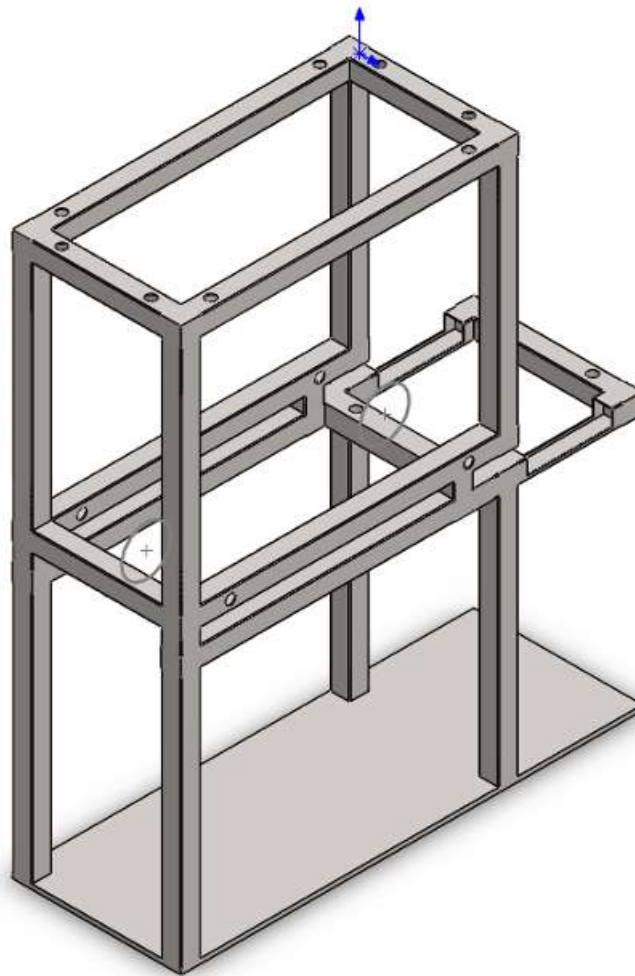
A 12V DC Motor was used to actuate linear motion. A connector is used to connect the linear motor to the roller. Table1 shows the motor specifications for this project.

Specification	Details
Material	Metal
Voltage	12-24 V
Input	12V DC
Weight	115g
Shaft Diameter	5mm
Shaft Length	16mm
Rated Power	130W

**Table 1: Motor Specifications.**

### 4. Support

Figure 4 shows the support structure design for this proposed packaging machine. This component supports the entire system on four legs and on a 465mm x 170mm base. The material of this support is using carbon steels type. The material used for this support is Carbon steels because it is tough and high stiffness. This steel has the ability to become harder and stronger through heat treating; however, it becomes less ductile. Regardless of the heat treatment, a higher carbon content reduces weld ability. In carbon steels, the higher carbon content lowers the melting point.



**Figure 4: Support structure base design**

## **5. Types and Methods of Biscuit Packaging**

### **5.1.Types of Biscuits Packaging**

#### **1. Plastic sealed packing box**

Plastic is a very good moisture-proof packaging material. It is the most widely used in biscuit packaging. There are two main forms: one is in bulk, where the measured biscuits are poured into the bag together, and then sealed with heat; the other is wrapped Packing, that is, a certain amount of biscuits, generally about 50~100g, arranged neatly, and then wrapped and sealed with a film. Film packaging, simple packaging, convenient sales.

Advantages: abundant raw materials, low cost, excellent performance, light weight and beautiful appearance

Disadvantages: There are problems of environmental pollution caused by hygiene and safety and packaging waste recycling.

Sources of safety problems: resin itself has certain toxicity; resin residual harmful monomers, lysates and toxic substances produced by aging; plastic products manufacturing process adding stabilizers, plasticizers, colorants and other additives; toxicity; plastic

Microbes and dust impurities on the surface of packaging materials; large amounts of toxic additives, heavy metals, pigments, viruses, etc. in the illegally used recycled plastics contaminate food. The main

unqualified item of unqualified products is excess benzene residue. The main reason for the excess benzene is the use of benzene-containing solvents in order to dilute the ink in the printing of plastic packaging.

## 2. Paper box

Wax paper packaging box is a simple form of biscuit packaging, as long as the biscuits are arranged neatly after being measured, and wrapped and sealed with wax paper. This method shading, moisture-proof, low cost.

## 3. Carton box

Carton packaging is the main form of biscuit packaging, with square, rectangular, round, special-shaped and other forms. The packaging materials are mostly whiteboard paper and offset paper. When using carton packaging, first wrap the biscuits with film as the inner packaging, and wrap the biscuits with wax paper or film outside the box. This kind of packaging has good packaging strength, a certain degree of compression resistance, beautiful appearance, strong commercial properties, and good moisture resistance and shading properties.

## 4. Metal packing box

Metal packaging is a biscuit packaging box made of color-printed tinplate. There are square, rectangular, cylindrical, oval, and special shapes. The metal biscuit packaging box has a beautiful printing effect, and the biscuit is not easy to be broken. This kind of packaging box has the best airtightness, high packaging strength, bright appearance, generous appearance, excellent shading, and durability, but it requires a lot of space to store empty cans, so cans and boxes are only used for large packaging or expensive varieties and All kinds of gift packaging.

Advantages: high barrier properties, high and low temperature resistance, easy recycling of waste, etc.

Disadvantages: poor chemical stability, not acid and alkali resistance, especially when used in packaging high acid foods, it is easy to be corroded, and metal ions are easy to precipitate, which affects the flavour of food.

## 5. Glass biscuit packaging box

Advantages: beautiful, hygienic, anti-corrosion, low cost, inert material, polluting the environment

Small dyeing; high barrier, bright and transparent, good chemical stability, easy to shape.

Disadvantages: fragile and bulky.

Packaging safety: pay attention to avoid heavy metals such as lead exceeding the standard; for tinted glass, pay attention to the safety of colorants.

## 5.2. Methods of Packaging Biscuits

### 1. MODIFIED ATMOSPHERE PACKAGING

Modified atmosphere packaging (MAP) is the process of removing oxygen from inside the package and replacing it by a gas flushing with a mix of oxygen and inert gases such as nitrogen and carbon dioxide. The process improves the freshness and shelf life of the biscuits.

The effectiveness of the process requires 4 essential elements:

1. a relevant choice of protective atmosphere,
2. a protective packaging material (film, tray), gas barrier,
3. a suitable packaging machine: compensated vacuum or sweeping.
4. correct hygiene and careful preparation.

To ensure the longest possible lifespan, this method of conservation under a modified atmosphere does not allow us to disregard the hygienic conditions ensuring the quality of the product to be packaged. It is important to avoid any risk of poisoning. The starting product must be healthy. Personnel, as well as equipment, must respect health standards throughout the production chain. The cold chain must be respected according to the manufacturer's recommendations.

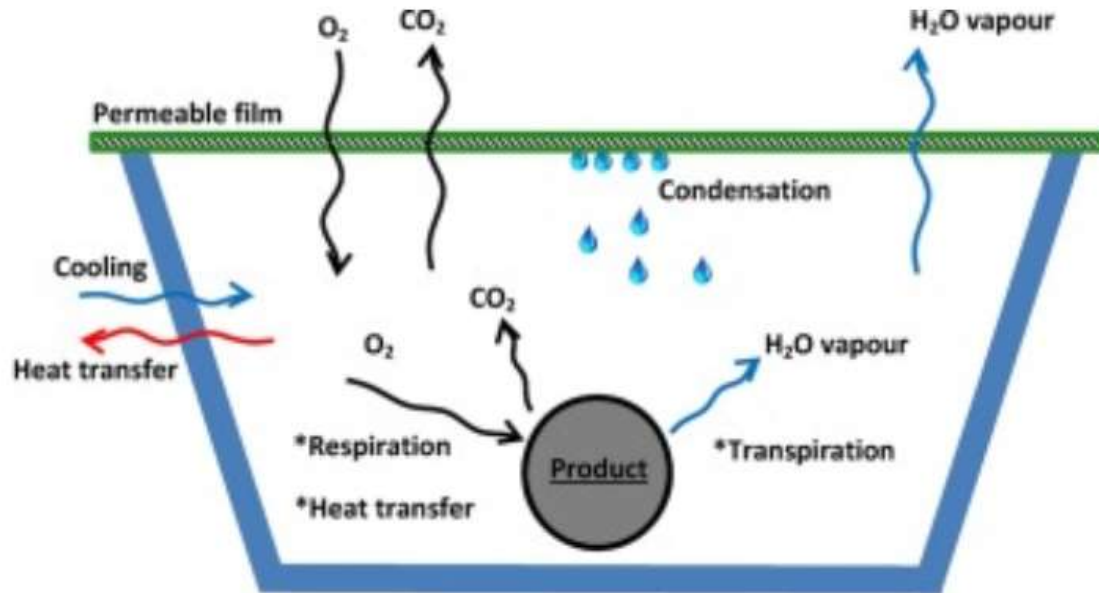


Fig. 5. Overview of continuous phenomenon in MAP packaged products

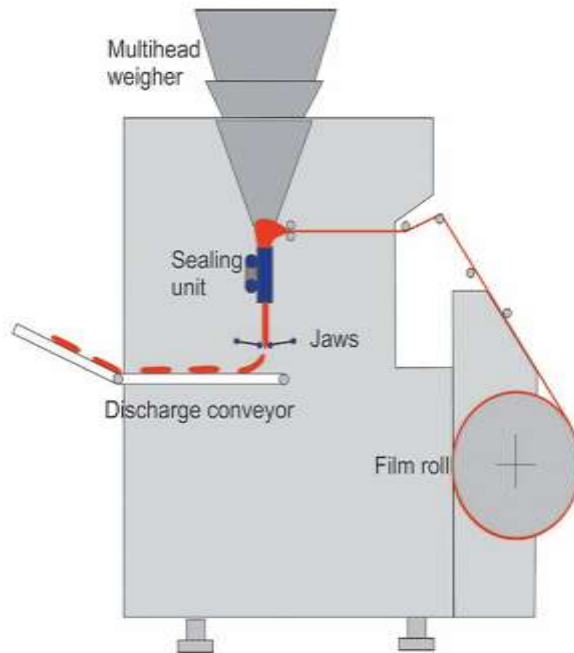
## 2. VERTICAL FORM FILL SEAL PACKAGING

Small snack biscuits are normally packed in vertical form fill seal (VFFS) bags or pillow packs. The biscuits are fed in bulk to a multiheaded weigher, which divides the biscuits into the individual pack weights.

A vertical form fill seal (VFFS) machine creates airtight packaging by forming a bag from a roll of film, filling it with product, and sealing the top.

The process for a VFFS machine is as follows:

- Load the machine with a film roll,
- The film passes through rollers and forms a tube,
- Clamps close the bottom of the tube to create the bottom of the bag,
- The product is dropped into the bag,
- The film pauses so the bag can receive a vertical seal,
- A vertical seal bar moves forward and bonds the film layers together,
- The top of the film is sealed and cut, creating a pillow bag.



**Fig. 6. Schematic drawing of vertical form fill seal system.**

### 3. ON EDGE FLOWPACK

The infeed chain of a horizontal flow pack machine is fed by groups of biscuits. The film is fed from a reel above and folded around the biscuit groups as a tube. The film is heat sealed below as a fin by rotating sealers. The biscuit groups within the film tube then transfer in line to the crimping, sealing and cutting section of the machine.



**Fig. 7. Cavanna Zero 5 NKZ wrapping machine for slug products with automatic feed.**



**Fig. 8 On edge flow pack.**

#### 4. PILE PACKS

Biscuit pile pack packaging machines are flow wrap machines that can package one to four biscuits in a pile. They can produce individual or chain packs, and can be used to package cookies, wafers, and rucks as well.

some features of biscuit pile pack packaging machines:

Continuous loader: Can form biscuits into piles of two and pack one or two piles from a single line

- 1) Twin magazines: Can be adjusted for different biscuit sizes
- 2) Infeed conveyor: Transfers biscuits into wrapping film that has been formed into a tube
- 3) Bottom seal: Made by three sets of rollers
- 4) Cross sealing and cutting knife: Separates the packed biscuits
- 5) Date printing unit: Can be used to print dates on the packs
- 6) Variable speed drive: Can reach speeds of up to 250 PPM

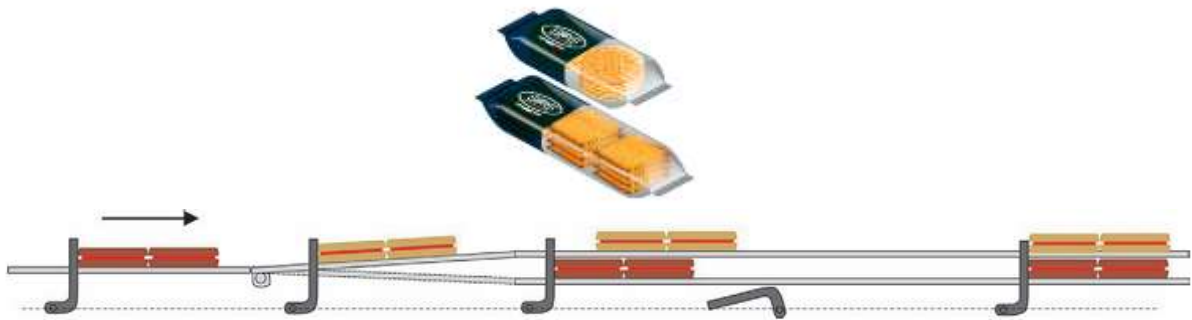


Fig. 9. Pile pack forming system.

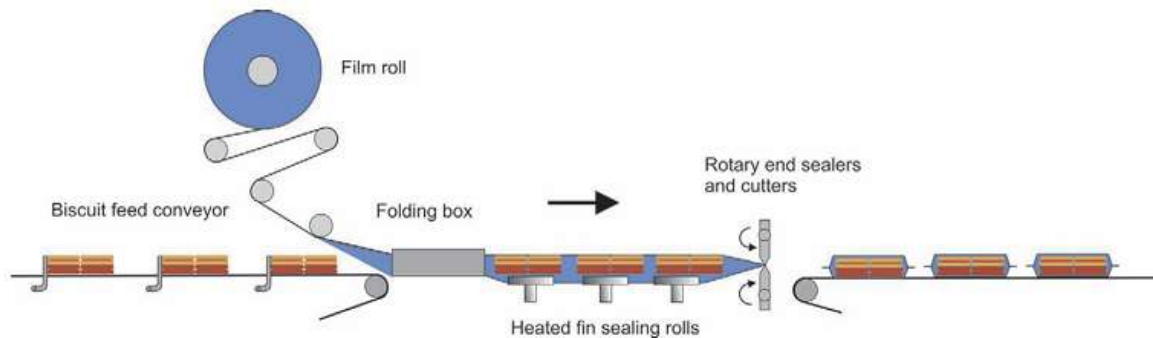


Fig. 10. Flow pack system for pile packs.

#### 6. Packaging Regulations and Standards

##### 6.1. Regulatory requirements for biscuit packaging

Biscuit packaging must meet strict requirements for consumer safety and satisfaction.

- **Some of the requirements for biscuit packaging include:**
- Moisture-proof and mildew-proof
- Shockproof
- Light-proof
- Barrier
- Film smoothness
- Ink standard regulations

- Protective performance test
- Water vapor permeability
- Oxygen exchange
- Aroma impermeability
- Resistance to seepage of fats and oils
- Protection against radiation
- Good printability and appearance
- Physical, mechanical protection
- Compatibility and safety
- **The packaging must also include the following information on the label:**
- Name of the food
- List of ingredients
- Nutritional information
- Declaration regarding veg/non-veg
- Declaration regarding food additives
- Declaration of name and complete address of brand owner, manufacturer, marketer, and packer
- FSSAI logo and license number

## 6.2. Standards

### 1. IS: 1011 : 2002

This standard prescribes the requirements, methods of sampling and test for biscuits baked from dough containing essential ingredients maida or wheat flour, sugar with or without the addition of optional ingredients Cereals and Cereal Products (Whole wheat meal, Wheat ATTA, Semolin, Wheat bran, edible etc), Milk and Milk Products (Casein, edible, Milk powder, Butter milk and its solids, Liquid milk, Condensed milk, Malted milk food)

#### Types of Biscuits

On the basis of sensory attributes, the different varieties can be broadly classified as given below:

Type I Sweet

Type II Semi-sweet

Type III Crackers

Type IV Cookies

Type V Speciality biscuits

#### General Requirements

The biscuits shall be properly baked so that they are crisp and have uniform texture and appearance. The design, if any on the biscuits should be clear. They shall have an agreeable flavour typical of well-baked biscuits of different types and shall be free from any soapy or bitter after-taste. The biscuits shall be free from fungus and insect infestation, rancid taste and odour. The biscuits shall also be free from any harmful or foreign matter.

**NOTE:** The appearance, taste, odour and rancid flavour shall be determined by organoleptic tests.

Biscuits shall be manufactured under hygienic conditions (**IS 5059**).

#### MARKING

The following particulars shall be clearly and indelibly marked on the label of each container/packet:

- Name of the product;
- Trade name, if any;
- Name and address of the manufacturer;
- Batch or code number;
- Net mass in grams or kilograms;
- List of ingredients, in descending order of their composition by mass;
- The statement with respect to addition of permitted colours and flavours;
- Month and year of manufacture;
- The words 'Best before ' (month and year to be indicated); and
- Any other requirements as specified under the Standards of Weights and Measures (Packaged Commodities) Rules, 1977 and the Prevention of Food Adulteration Act, 1954.

### **BIS Certification Marking**

The product may also be marked with the Standard Mark.

The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The details of the conditions under which the licence for the use of Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

### **DETERMINATION OF MOISTURE**

Two methods for the determination of moisture content in biscuits have been given. Method I. namely, the moisture meter method may be used as a routine method after calibrating it with the oven method given under Method II.

#### **METHOD I**

This method involves the use of electrical moisture meters for rapid estimation of moisture in the biscuit samples. Various moisture meters are available. The conversion tables for their use are available with the equipment, but the instruments shall be calibrated under the conditions of actual use in comparison with the oven method given under Method II.

#### **METHOD II**

**Apparatus:-** Moisture Dish, made of procelain, silica, glass or aluminium, Oven, Electric, maintained at  $105 \pm 1^\circ\text{C}$ , Desiccator.

**Procedure:-** Weigh accurately about 5 g of the prepared sample in the moisture dish, previously dried in the oven and weighed. Place the dish in the oven maintained at  $105 \pm 1^\circ\text{C}$  for 4 h. Cool in the desiccator and weigh. Repeat the process of drying, cooling and weighing at 30 min interval until the difference between the two consecutive weighing is less than one milligram. Record the lowest mass.

#### **Calculation:-**

Moisture, percent by mass=  $100(M_1 - M_2)/M_1 - M$

Where,

M= mass, in g, of the empty dish;

M<sub>1</sub> = mass, in g, of the dish with the material before drying; and

M<sub>2</sub> = mass, in g, of the dish with the material after drying to constant mass

## DETERMINATION OF ACID INSOLUBLE ASH

**Apparatus:-** Dish - silica or porcelain, Muffle Furnace - maintained at  $600 \pm 20^\circ\text{C}$ , Water-Bath, Desiccator.

**Reagent:-** Dilute Hydrochloric Acid – approximately 5 N, prepared from concentrated hydrochloric acid.

**Procedure:-** Weigh accurately about 20 g of biscuit powder in the dish and ash in the muffle furnace at  $600 \pm 20^\circ\text{C}$  until light grey ash is obtained. Remove the dish from the furnace and allow it to cool at room temperature. Add 25 ml of the hydrochloric acid to the dish, cover with a watch-glass and heat on the water-bath for 10 min. Mix the contents with the tip of a glass rod and filter through Whatman filter paper No. 42 or its equivalent. Wash the filter paper with water until the washings are free from acid when tested with a blue litmus paper. Return the washed filter paper to the dish for a shing in the muffle furnace as above. Cool the dish in a desiccator and weigh. Again ignite the dish for half an hour in the furnace, cool and weigh. Repeat this operation until the difference between successive weighing is less than 1 mg. Filter 25 ml of the hydrochloric acid through a blank filter paper, wash, ash and weigh it as in the case of acid insoluble ash. Subtract its mass from the mass of insoluble ash of the sample.

## CALCULATION

Acid insoluble ash,

percent by mass =  $100(M1-M)/M2$

where

M= mass, in g, of the empty dish in which the sample is taken for a shing;

M1 = mass, in g, of the dish containing acid insoluble ash and

M2 mass, in g, of the sample.

OR

Acid insoluble ash,

percent by mass ( on dry basis) =  $A \times 100 / 100M$

where,

A= acid insoluble ash, percent by mass and

M= percentage of moisture in the biscuit.

## 7. Case Studies On Packaging of Biscuits

The sustainability aspects are assessed for the life cycle phases through which a plastic packaging film cycles: sourcing of the material, production and filling of the packaging, use of the packaging to preserve the biscuits and consumption of the biscuits, and end-of-use at which the plastic film is discarded and processed. At each phase in the life cycle, different considerations regarding sustainability come into play, while decisions in one phase might also affect the impact at other phases. From a designer's perspective, this journey starts with the use phase. The purpose of the product and the context in which it will be used, determine the basic set of technical requirements and constraints for a shortlist of possible materials. Therefore, this case study will consider the use phase first, after which the sourcing of the feedstock, the production of the packaging and its end-of-use are discussed. This approach is not to be confused with a Life Cycle Assessment (LCA), a method to determine the environmental impact of a specific packaging (or product) throughout its life cycle, while the current study aims to identify and address environment and health considerations in each phase of the life cycle.

### 7.1. Overview of the Packaging Film for Biscuits

This section provides a general overview of the life cycle of packaging film for biscuits. The different stakeholders in the life cycle are visualised in Figure 11, with an indication of their primary activity and end product. Subsequently Table 1.1 provides an overview of the important factors influencing the sustainability of the biscuit wrapper for each life cycle phase.

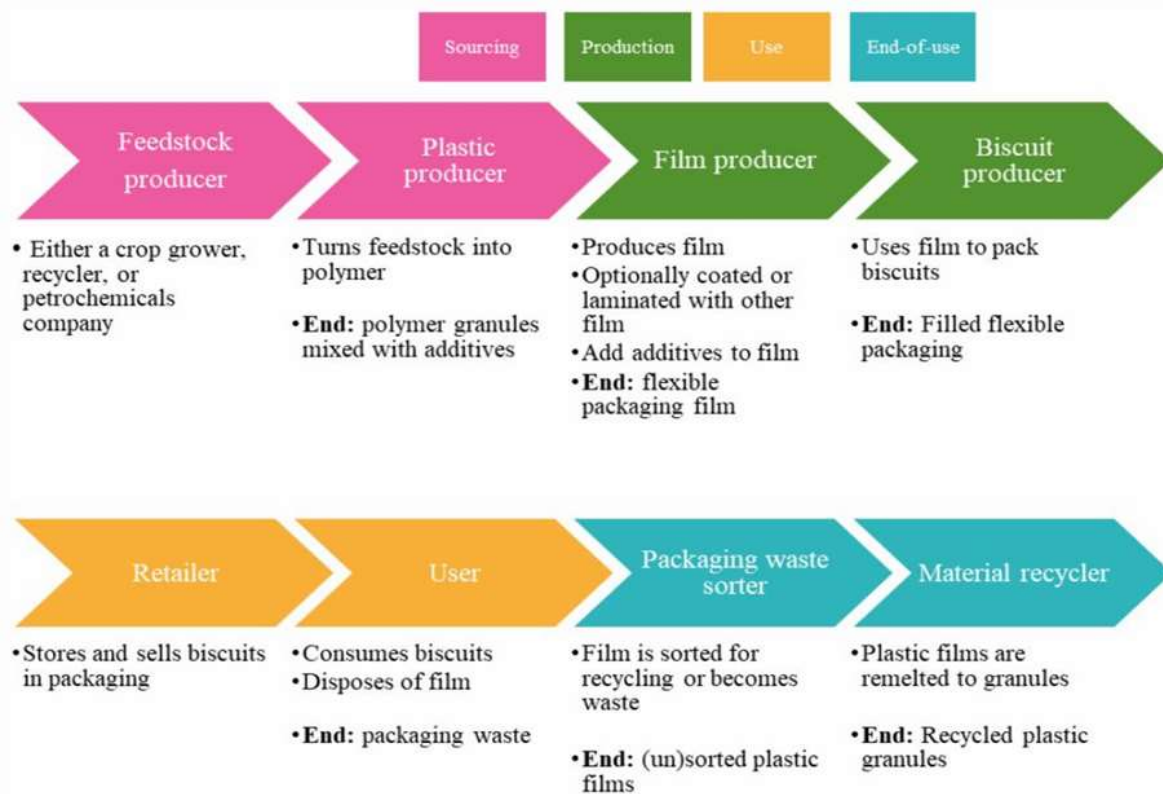


Figure 11. Visual representation of the life cycle of a biscuit packaging film

### 7.2. Methodology

#### 7.2.1. Sustainable Design Goals

To guide the material and chemical selection, over-arching sustainability goals need to be set. Using secondary feedstock for the production of the film reduces dependency on fossil resources, but might lead to incorporation of hazardous substances in the film. A chemical additive might increase efficiency in the production of the packaging and thus reduce the overall CO<sub>2</sub> emissions in the process, but it could hinder the recycling of the material at the end-of-use. Establishing over-arching sustainability goals from the outset will enable the designer to ensure these kinds of benefits and drawbacks are taken into account when examining material alternatives. Furthermore, the goals will guide the designer in the selection of materials when trade-offs need to be made. The following five sustainable design goals are chosen for the case study of a plastic biscuit packaging. Examples of other goals are given at the end of the section.

#### 1. Prevent product spoilage:-

The packaging serves to protect the product. Usually the (environmental) impact of the production of the product is far higher than that of the packaging's total life cycle. Preventing the waste of the product before it reaches its intended goal is an important goal in the sustainable design of the packaging.

## 2. Reduce material use:-

Packaging is a short-lived product but amounts to 40% of the world's total use of plastic (PlasticsEurope, 2019). Designers should strive to reduce the amount of used plastic to the absolute minimum to meet the packaging requirements.

## 3. Close material loops:-

Due to the short-lived use of packaging, the used material should make multiple life cycles. The plastic should either be made from secondary feedstock or be able to be used a second time in another product. In an ideal situation, a combination of both is made.

## 4. Preserve natural capital:-

Humans depend on natural capital for a wide range of ecosystem services. Poorly managed natural capital can destroy productivity and resilience, making it difficult for humans and other species to sustain themselves. Destruction of natural capital throughout the packaging life cycle can occur in the form of land use for mining and crop growing, biodiversity loss due to toxic emissions, exhaustion of feedstock, and climate impact through greenhouse gas emissions.

## 5. Safeguard the health of participants in life cycle:-

From feedstock extraction, through packaging manufacturing and product use, to the eventual end-of-use scenario, the packaging and its subcomponents will interact with humans. The direct negative effects of the packaging and its subcomponents on the health of these people needs to be minimised. The focus with regard to health in this case study will be in three phases of the life cycle:

- The first is residential human health exposure: hazards for consumers in the use phase through migration of substances into the food or through skin contact with the packaging.
- The second is occupational human health exposure during waste management at end-of-use: the hazards for recycling facility employees who come into contact with the chemicals during treatment of the packaging waste.
- The third are hazards for the general population when substances spread into the environment due to emissions from production and waste treatment.

This focus is applied because it is assumed that the health risks at the plastic producing plants, film manufacturers, and product packaging facilities are known and adequate precautions can be taken. This is not the case for individual consumers, waste management employees, and the general public.

### 7.2.2. Chemical Selection Process

During the design process, the listed five sustainable design goals must be considered to select the most sustainable plastic(s) to be used in the packaging. During the analysis of the life cycle, it will become apparent that trade-offs must be made. The selection of one material based on one sustainable design goal in one phase of the life cycle can counteract the realisation of another goal in another part of the life cycle. In addition to the selection of the most sustainable polymer for the packaging, the use of chemicals in the production of the polymer and the packaging and their consequences in later phases of the life cycle must be considered. This is especially important since the packaging is used for foodstuff and migration of known or potential hazardous substances to the biscuits must be taken into account.

To select a polymer or a combination of polymers from a list of options, the most important considerations and trade-offs need to be identified. It is not practicable to consider all possible chemical substances and their potential hazards for all the polymers simultaneously. The following selection process is therefore used in this case study and is proposed as a method for safe chemical selection.

1. Based on the over-arching sustainable design goals, identify the sustainability considerations for the packaging throughout the life cycle.
2. List and weigh the sustainability considerations; some will be regarded as key considerations while others have a minor impact on the overall sustainability of the packaging.
3. Collect data on the optional polymers for the plastic film.
4. Compare the polymers based on the identified key considerations.
5. Select the polymer that is identified as the best fit (i.e. having minimal or no impact on human health while maintaining the highest level of environmental sustainability) for the biscuit packaging.

Subsequently, for the selected polymer only, the relevant chemical considerations should be taken into account. Additives, residual production chemicals and potential non-intentionally added substances (NIAS) must be investigated on their consequences for environmental sustainability and human health.

6. Demand from all your suppliers that they comply with all applicable regulations on food contact materials.
7. Select a list of hazardous substances or substances of concern to review your packaging. The selection of the list can depend on the product, previous experience within the design team, or be mandated by company standards. The sources for this list will be discussed in the next section.
8. Check, in collaboration with your material supplier if necessary, whether they found chemical considerations involve any of the substances on the selected list with hazardous substances.
9. If substances on the list are part of a chemical consideration, reconsider the need for using this substance and try to find an alternative substance for the intended goal. Some lists provide overviews of alternative substances. Safe alternatives can be found with the help of ‘positive lists’ such as the Safer Chemical Ingredients List (US EPA, 2020). For guidance on the selection of alternatives, please refer to OECD (2021).
10. If step 8 cannot be passed, revisit step 5 and select another polymer or polymer combination.
11. If no polymer can be selected without the incorporation of hazardous chemicals, as identified on the list of hazardous substances: Innovate.
  - Re-evaluate the functional requirements of the packaging (discussed in this case study in Section 3.1): do these enforce unsustainable decisions?
  - Re-evaluate the shortlist of polymers: is innovation on a material level required?
  - Re-evaluate the product-packaging combination, can another form of packaging be chosen? This might lead to reusable packaging, packaging-free concepts or non-plastic materials.

#### 7.2.2.1. Lists to Support The Chemical Selection Process

Hazardous substances or substances of concern can be identified with the aid of lists of substances. Examples of these lists are the ‘Proposition 65 list’ from the State of California (OEHHA, 2021), the Substitute It Now (SIN) list developed by non-profit organisation ChemSec (ChemSec, 2021) and the Restricted Substances List (RSL) of the Cradle-to-Cradle Products Innovation Institute (Cradle-to-Cradle Products Innovation Institute, 2021).

The Californian list contains substances with known reproductive toxicity or carcinogenic properties. The SIN list consists of chemicals that have been identified by the NGO ChemSec as being Substances of Very High Concern. The SIN list provides information on REACH status, use and function, concerns, production and available alternatives for each chemical. The Restricted Substances List (RSL) is a checklist for materials that are not allowed to be used in Cradle-to-Cradle certified products. This is a certification for sustainable products and certifies them as safe, responsible, and fit for a circular economy.

These lists differ in hazards that are included, how restrictive they are and whether alternatives are suggested. Besides these three examples, other lists can be used. More lists with hazardous substances are discussed in the publication *Guidance on Key Considerations for the Identification and Selection of Safer Chemical Alternatives* (OECD, 2021), in the ECHA (2019) publication ‘Substances of concern: Why and how to substitute?’, and in the OECD Substitution and Alternatives Assessment Toolbox (OECD, 2020).

### 7.3. Use Phase

In the use phase, the packaging is used for its intended goal: transporting the biscuits from the producer to the consumer safely, providing information and attracting attention in the store. The main functional requirements to the plastic film in the use phase are discussed. A shortlist of possible polymers is introduced and compared based on these requirements. Inks and the associated sustainability considerations are discussed. Inks are discussed in this phase because they are added to the packaging to fulfil a function in the use phase.

The use phase touches upon three of the over-arching sustainable design goals: (1) preserving the biscuits, (2) while using as little material as possible, and (3) without exposing humans to hazardous chemicals in the packaging.

#### 7.3.1 Functional Requirements to Packaging Film

The functions of the plastic biscuit packaging are collating the individual biscuits, labelling and advertising, and mechanical protection (i.e. to prevent breaking). However, these functions can also be performed by packaging made from other materials. The plastic packaging is usually chosen because it serves to protect the biscuits from spoilage. The quality of the biscuits can be spoiled by moisture. Moisture uptake will make the biscuits lose their crunch, this is the main requirement mentioned by industry experts and is taken into account in this case study. Oxidation of fats in the biscuit will change the taste and uptake of odours from the environment will change the taste and aroma of the biscuits. The oxygen barrier is listed in Table 3.1, but not regarded as one of the main requirements by industry experts. The three main requirements for biscuit film packaging are:

- **Water Vapour barrier** of the plastic to prevent moisture uptake. Biscuits are expected to be crisp and the loss of crunchiness poses the highest risk for deterioration in the journey between production and the consumer.
- **Toughness** of the film is an important factor since the barriers will only be effective as long as the packaging is intact. A thin plastic film minimises the amount of material used in the packaging. The more the thickness of the film is reduced, the greater the chance of damage to the packaging. A thin film with good barrier properties but low tensile strength may not survive the logistics channel of the biscuits from producer to consumer.
- **Heat-sealing** of the film on a fast filling line. On the fast paced, high volume packaging lines either a plastic film is wrapped around the biscuits, or the biscuits are placed in an opened bag. In both cases, the packaging needs to be closed which is commonly done through heat sealing.

#### 7.3.1.2 Commonly Used Polymers And Barrier Layers

Table 2. shows a shortlist of common polymers and plastic coatings for packaging and indicates how each performs as a film on the main three required properties, plus the oxygen barrier. This can be used to make a first selection of materials to consider in the biscuit packaging.

	Water vapour barrier	Oxygen barrier	Toughness	Heat sealing
LLDPE / LDPE	Yellow	Red	Light Green	Dark Green
HDPE	Light Green	Red	Light Green	Light Green
PP	Yellow	Red	Light Green	Light Green
BOPP	Light Green	Red	Dark Green	Red
PET	Yellow	Yellow	Dark Green	Red
BOPET	Yellow	Light Green	Dark Green	Red
PA	Red	Light Green	Dark Green	Red
PLA	Red	Red	Red	Yellow
Regenerated cellulose	Red	Light Green	Light Green	Red
Coatings and barrier layers				
Acrylics	Red	Red	Red	Light Green
PVdC	Dark Green	Dark Green	Red	Light Green
EVOH	Red	Dark Green	Red	Yellow
EVA	Red	Red	Light Green	Dark Green

**Table 2. Commonly used polymers and their properties. Ranking order: inadequate: red - excellent: dark green.**

### 7.3.1.3. Multilayer films

As can be concluded from Table 2, not one material scores perfect on all required properties. To improve the properties of the packaging film, multiple layers of polymers can be combined. A thin layer of a polymer with a good oxygen barrier can be combined with a thin layer of a polymer with a good vapour barrier. This can drastically reduce the amount of (mono-)material required to perform both functions. However, these multilayers do have consequences in other phases of the packaging’s life cycle.

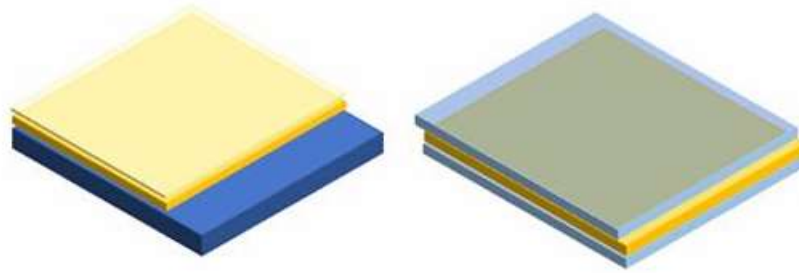
### 7.3.2. Printing and Inks

Biscuits are sold in attractive packaging to attract consumers with images and colours printed on transparent or evenly white coloured films. Food producers are required to print information about ingredients and nutritional value on the packaging. The inks that are used and their chemical constituents can have great impact on the overall sustainability. Potential hazardous substances from the ink can contaminate the consumers’ hands and be absorbed through the skin or contaminate the biscuits with the consequence of being ingested by the consumer posing a potential threat to their health. Inks can also have negative effects when leached into the environment in a landfill, decrease the quality of the secondary material after recycling, and bring about both environmental and health risks when incinerated or heated during recycling.

#### 7.3.2.1. Printing Techniques

There are multiple methods to apply ink on a surface: flexographic printing, gravure printing, inkjet printing, and more. There are differences with respect to sustainability between these methods, but in the chemical selection for a flexible food packaging two other aspects are of much greater importance: the surface on which the ink is printed and the curing of the inks on the printed surface. Choices made in these aspects have impacts on the safety for human health.

Plastic films can either be surface printed, on the outside of the plastic film, or reverse printed, on the inside of one layer that is then laminated on a second layer of film.



**Figure 12. A depiction of a surface printed plastic film with overcoating (L) and laminated film with reverse printing in between (R). The yellow layer represents the ink.**

- **Surface printed inks** have the downside that they can be rubbed off and contaminate the consumer's fingers. Chemicals can be absorbed through the skin or form miniscule airborne particles that enter the respiratory system. In the production process, films are stacked as sheets or rolled as one piece on a reel. Surface printed inks on the outside can transfer off to the food contact layer on the other side. To prevent this, overprint coatings can be applied. This extra layer is applied over the surface-printed inks to protect the ink from rubbing off. Surface printed inks may come with health risks regarding contamination and spreading of the inks; this method should only be chosen if all constituents of the ink are deemed safe or when an overprint coating can be applied that is proven to be safe and not to negatively affect the recyclability of the film.
- **Reverse printed inks** are usually applied to the outermost plastic layer when multilayer films are used. They protect the inks from rubbing of and prevent direct migration to the food or skin. However, they require the lamination or coating of multiple plastic layers in the film, with the corresponding issues in recycling and health risks of migrating adhesives.

#### 7.3.2.2. Ink types

- **Solvent-based inks** are cured by drying to the air. The solvent evaporates and leaves the pigments and binders on the film. The binders make up the largest part of the ink and can be biobased resins such as nitrocellulose or rosin resin, or synthetic resins such as PVB, PA, or PU. For food-grade applications, bio-based resins are preferred due to the lower odour and migration risk (ILSI Europe, 2011). The evaporation of the solvents creates high risks for the release of volatile organic compounds (VOCs), which can be toxic and carcinogenic. The use of mineral oils in solvents for food-grade applications has been minimised (EuPIA, 2013), but contamination can happen. The migration of Mineral Oil Saturated Hydrocarbon (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH) therefore need to be monitored when a solvent based ink is chosen. MOSH can bioaccumulate and have long-term toxicological effects. MOAH can be mutagenic and carcinogenic.
- **Water-borne inks** are not 'water-based' inks. The pigments and binders are still dissolved in a solvent (commonly an alcohol), but this is diluted with water. This decreases the amount of solvent that evaporates and reduces the emitted VOCs. Drawbacks of waterborne inks are that the ink cures more slowly on non-absorbent surfaces such as plastic film or that heat sources are used to decrease curing time. This might result in higher energy demand in production. Furthermore, it is important to control the evaporation process because retained solvent in the dried ink can act as a plasticiser, which increases the risk of migration of the ink to food and increases setoff in surface prints (ILSI Europe, 2011).

- **UV curing inks** do not use solvents, but rather a liquid binder of photo-initiators, monomers and oligomers mixed with the pigments (see Section 4.3 for an explanation of monomers and oligomers). In liquid form, they can be applied to a surface. When treated with UV light, the photo initiators start the polymerisation of the monomers and oligomers, binding the pigments to the plastic film. For food-safe applications, it is essential that highly reactive oligomers and monomers be chosen so that all these are polymerised and migration of unreacted oligomers and monomers is minimised. Using highly reactive substances does add to the health risks in production and they could be more hazardous when incorporated in the packaging while unreacted. This is a trade-off that needs to be made between the additional hazard when the substance remains unreacted and decreasing the chance of having unreacted substances. For both UV and EB curing, it applies that curing time must be tightly controlled to make sure that no unreacted oligomers and monomers are present in partly cured inks. Photo-initiators that are demonstrated to be safe and having low migrating potential should be chosen, as they will remain fixed in the cured ink (ILSI Europe, 2011).
- **Electron beam (EB) curing inks** work in a similar way as UV curing inks, but do not require photo initiators. Because the electron beams penetrate all the way into the inks, the reaction of monomers and oligomers is better controlled than that of UV curing inks. The binders and additives (with the exception of photo-initiators) are comparable to those used in UV-curing inks.

#### 7.3.2.3. Biodegradation And Recycling of Inks

- **Biodegradability of inks** and varnishes is usually limited. Some bio-based pigments and binders exist, so that only natural occurring substances remain after composting. However, with current industrially used inks and their required application and curing speeds, minor traces of non-biodegradable additives will always remain even if the binders and pigments biodegraded. If biodegradability is intended, print should be done on as little surface as possible.
- Plastic recycling is intended to reclaim the polymers in the packaging. The addition of inks and varnishes will in any case contaminate the recycling products and should be used as little as possible. Surface printing of small surfaces with a thin overcoating are preferred since reverse printed inks will require an extra lamination layer, adding to the contamination. Light colours, irrespective of curing method are preferred. The pigment TiO<sub>x</sub> (white) is a known disturbance in the colouring of recycle, while Carbon Black (black) is incompatible with near-infrared automatic sorting technology.

#### 7.3.2.4. Pigments

Pigments colour the ink colour and are the most important ingredients. Pigments are insoluble coloured chemical compounds with the ability to give colour to another material. “Pigments keep their original shape (as small crystals) over the complete life cycle, a consideration that must be taken into account during the material health assessment process” (Cradle to Cradle Products Innovation Institute, 2019).

“Several toxicity studies have been performed on pigments for select hazard endpoints including acute toxicity, mutagenicity and irritation potential. The results showed that very few pigments are hazardous. The main reason for this is that most pigments are poorly water soluble and predominantly chemically inert, and as a consequence are not bioavailable” (Cradle to Cradle Products Innovation Institute, 2019). However, some pigments, for instance those based on heavy metals, pose known hazards and should be excluded. The European Printing Ink Association (EuPIA) (2018) lists pigments with antimony, arsenic, cadmium, chromium (VI), lead, mercury and selenium as pigments to be excluded for use, together with the dye colourants, Auramine, Chrysoidine, Fuchsine, Induline, Cresylene Brown. For more information,

please refer to the overview by the Verband der Mineralfarbenindustrie (2019) on national and international regulations regarding pigments and fillers in food contact materials.

### 7.3.2.5. Inks and Safe chemical Selection

Besides the previously discussed substances in inks, a wide range of additives can be used depending on the producer, the printing and curing techniques that are used, the solvents and the pigments. The International Life Sciences Institute (ILSI) lists antifoam agents, jellifying agents, adhesion promoters and twenty other possible types of additives in inks for food packaging (ILSI Europe, 2011). Regardless of the choices made about the polymer and other required chemicals, inks should always be subjected to a critical review during the design of the packaging. Involvement of the ink producer in this process is crucial. The European Printing Ink Association has published a list of excluded substances in inks (EuPIA, 2018) and Guidelines for Good Manufacturing Practices including risk assessment and management (EuPIA, 2016). These documents can be adhered to in the chemical selection process, in addition to local chemical safety regulations, food contact regulations and screening with a list of hazardous substances.

## CONCLUSION

The realm of biscuit packaging encapsulates a multifaceted landscape, where functionality, sustainability, and consumer appeal intertwine to shape the very essence of consumer experience and industry practices. Throughout this exploration, it becomes abundantly clear that biscuit packaging serves as much more than a mere vessel for transportation and preservation—it is a reflection of evolving consumer values, technological advancements, and environmental imperatives.

At the forefront of the discussion lies sustainability—a cornerstone of modern packaging practices. As consumers become increasingly conscientious about the environmental footprint of their purchases, the demand for sustainable packaging solutions has surged. Manufacturers are responding by embracing eco-friendly materials, innovative designs, and streamlined production processes to minimize waste and resource consumption. However, this transition towards sustainability is not without its challenges. Balancing environmental considerations with cost-effectiveness, regulatory compliance, and supply chain dynamics remains a delicate equilibrium that requires ongoing collaboration and innovation.

Innovation emerges as a driving force propelling the evolution of biscuit packaging. From advanced barrier technologies to user-friendly designs, manufacturers are continuously pushing the boundaries of what is possible, striving to enhance functionality and improve consumer convenience. Resealable packs, portion-controlled servings, and interactive packaging formats represent just a glimpse into the myriad innovations shaping the future of biscuit packaging. By embracing a culture of innovation and fostering collaboration across the industry, stakeholders can unlock new opportunities to elevate consumer experiences while minimizing environmental impact.

Crucially, consumer preferences serve as a guiding compass in navigating the complexities of biscuit packaging. In an era marked by information abundance and heightened awareness, consumers are demanding greater transparency, authenticity, and ethical responsibility from brands. Packaging serves as a tangible manifestation of these values, providing a platform for brands to communicate their commitments to quality, sustainability, and social responsibility. As such, effective packaging design and branding are essential not only for capturing consumer attention but also for fostering long-term trust and loyalty.

Looking ahead, the trajectory of biscuit packaging is marked by both uncertainty and opportunity. Rapid advancements in technology, shifting consumer behaviors, and evolving regulatory landscapes will

continue to reshape the industry in profound ways. However, amidst this uncertainty lies a world of possibilities—a chance to redefine the role of packaging in promoting sustainability, innovation, and consumer well-being.

In conclusion, the packaging of biscuits represents a dynamic nexus of sustainability, innovation, and consumer trust. By embracing these principles and working collaboratively towards shared goals, stakeholders can forge a path towards a future where biscuit packaging not only preserves and protects but also inspires and empowers, enriching the lives of consumers and safeguarding the planet for generations to come.

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