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LEARNING SCENARIO
MODULE 6

BIO-PACKAGING
TECHNICAL CHARACTERISTICS OF BIO-PACKAGING

COLOPHON

Authors

This module is part of the Learning Scenario *Bio-packaging*. It is developed by partners in the European Erasmus + project "BioComp".
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PREFACE

The Learning scenario *Bio-packaging* has been developed as part of the Erasmus + project BioComp. In that project, the most relevant competences for professions in the sector "Bio-packaging" are analysed, described, and ranked. Based on these competences, this Learning Scenario has been developed for EQF-level 3-4. The focus is on technical competences. Please see https://navigator.biocompetences.eu/ for further information.

The *Bio-packaging* learning scenario addresses the topic of food for packaging (in a biobased economy (BBE) context) as presented and analysed in IO1 and the final competence ranking list which gives the following results:

Cultivation of Tomatoes *(in a BBE context)*

Nr	Competences	Ranking points
T1	Working in a greenhouse – identifying the instructions of climate control (light, heat, humidity)	Biomass production in BBE context (2)
T2	Cultivation of tomatoes – Identifying and monitoring the growing process and maintaining quality control	Biomass production in BBE context (2)
T3	Working in a greenhouse – identification and preparation of the soil and nutrition/water system and planting	Biomass production in BBE context (2)
T4	Working in a greenhouse – identification and management of biological pest control	Biomass production in BBE context (2)
T5	Harvesting tomatoes – Identification and management of harvesting of tomatoes and post harvesting activities	Biomass production in BBE context (2)
T6	Harvesting tomatoes – Identification of the plant and implementation of harvesting of the tomato plant	Biomass production in BBE context (2)

Cereal production *(in a BBE context)*

This is finalized as "cereal production" which is more general

Nr	Competences	Ranking points
C1	Harvesting rice/cereals – identification and management of harvest methods; estimation of by-products and biomass potential	Biomass production in BBE context (2)
C2	Energy uses – Identification of by-products for non-energy and energy uses	Biomass production in BBE context (2)
C3	Biomass evaluation – Identification of biomass as a by-product of the food production process that can be re-used	Biomass production in BBE context (2)
C4	Biomass production and management – identification of plan, organization and performance of farming operation to grow	Biomass production in BBE context (2)

Packaging process

Nr	Competences	Ranking points
P1	Control of process – Identification and monitoring of manufacturing quality standards	Control of process (4)
P2	Ecological benefits – Identifying the benefits of **bio packaging**	Ecological benefits of bio-packaging (1)
P3	Production of **bio-packaging material** – identifying technological and chemistry responses: to know the process of fermentation and processing methods/types	Production of bio-based (or bio-packaging) material (3)

P4	**Biobased material** – Identifying physical and mechanical features/characteristic of biobased material	Production of bio-based (or bio-packaging) material (3)
P5	Production of **bio-packaging material** – identifying new packaging concepts	Production of bio-based (or bio-packaging) material (3)
P6	Quality control – identifying the testing procedures	Control of process (4)
P7	Control of process – Identifying the Standard Operating Procedures (SOP)	8,04
P8	Quality control – Identifying the test procedures and the ICT systems	7,99
P9	Production of bio-packing material – Identifying the technical features, benefits, and limits of bio packaging	Control of process (4)
P10	Logistics – Identification of potential manufacturing deadline pressure	7,81

The Bio-packaging learning scenario includes the production and supply of the initial biomass (cases: tomato and cereals), the production of the material suitable for packaging, and the technical characteristics of the bio-packaging products. The 20 identified competences derived from IO1 were evaluated according to the average values and its coefficient of variation and were grouped according to similar content wherever possible.

This Learning Scenario is based on these competences and has been developed for EQF-level 3-4. It has the following 6 modules:

1. Circular economy
2. Introduction
3. Ecological benefits of bio-packaging
4. Biomass production in BBE context
5. Production of bio-based material
6. **Technical characteristics of bio-packaging**

Module 6 provides an introduction to the technical characteristics of bio-packaging material which makes them suitable for food packaging. The aim of this module is to provide a basic overview of bio-packaging which is suitable for food packaging.

Apart from these 6 text documents, the scenario also has a trailer and a WIKI with background information. To support the teacher, didactic guidance is available. It can be used for all scenarios and also includes suggestions for learning activities to develop personal and transversal competences. For this guidance, see the *Pedagogical Guidelines* in the Navigator.

This project is focused on food. The central objective of this work is food packaging.

CONTENT

Module 6 contains the following topics:

1. General Regulations in Europe for Food Packaging materials
2. Identify Product Quality Standards and Uses
3. Identifying the Testing Procedure (an example)
4. Labelling
5. Quiz
6. Sources

MODULE 6 TECHNICAL CHARACTERISTICS OF BIO-PACKAGING

1. GENERAL REGULATIONS IN EUROPE FOR FOOD PACKAGING MATERIALS

This section provides the general outlines for the basic characteristics which food packaging materials should meet according to European rules. It also refers to the specific labelling and technical rules that are currently used for the description of biobased materials suitable for food packaging.

Food packaging materials are those which are suitable for food applications and include materials like plastic, glass, metal, and paper. There is a wide area of scientific research and application studies within the food industry that deals with the different chemical structures and the diverse corresponding properties of these materials that are beyond the scope of this learning scenario. Instead, the basic outlines and related information concerning important technical characteristics of bio-packaging materials are provided here.

Bio-packaging materials should meet some key characteristics that make them suitable as food packaging materials. These identities are connected with the general function of food packaging materials as materials and articles intended for food contact (food contact materials, FCM), which have been studied in great detail for conventional food packaging. All FCM applied in **Europe must be in alignment with European regulations** describing the **features of packaging materials** (EC, No 1935/2004). In addition, **for plastic materials,** there are specific rules set in Regulation (EC) No 10/2011 (with amendments).

Biobased plastic materials must meet the above regulations and amendments as well as Regulation EC no 2019/1338 on plastic materials and articles intended to come into contact with food (Nilsen-Nygaard *et al,* 2020; Briassoulis and Giannoulis, 2018).

In summary, the general legislation of **all food contact materials** is ensured by the regulation provided in Table 1.

Table 1. Basic legislations that regulate the characteristics of materials which are brought into contact with food

Regulation (EC) No 1935/2004	This regulation is applied to materials and articles that: a) are intended to be brought into contact with food; b) are already in contact with food and were intended for that purpose; or c) can reasonably be expected to be brought into contact with food or to transfer their ingredients to food aims at securing a high level of protection of human health.
Regulation (EC) No 10/2011	This regulation sets out safety requirements for plastic materials and articles intended to come into contact with food. This regulation is a specific measure for plastic food contact materials as mentioned in the European Framework Regulation (EU) 1935/2004.
Regulation (EC) No 2019/1338	Regulation (EU) 10/2011 **sets out safety requirements for plastic materials and articles intended to come into contact with food**. This regulation is a specific measure for plastic food contact materials as mentioned in the European Framework Regulation (EU) 1935/2004.

A recent development regarding the use of biobased materials that are biodegradable, as mentioned above (Table 1), is that the EU recognized the need to set rules for a **biodegradable substance** called poly((R)-3-hydroxybutyrate-co-(R)-3-hydroxyhexanoate) (FCM substance No 1059, CAS number 147398-31-0). The European Food Safety Authority (EFSA) has adopted this new favourable scientific opinion which defines this substance as a biodegradable copolymer that is produced by fermentation of palm oil using a genetically modified microorganism.

(Source:https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1338&from=EN)

Apart from food safety, the main functions that traditional food packaging must comply with are (Salgado et al 2021):

-To contain foods

To hold the contents and keep them clean and secure without leakage or breakage until their use by the consumer.

-**To protect food against a wide variety of hazards**

During the distribution and storage of the food products, several hazards may occur like dirt, micro-organisms, or other contaminants which may damage the food product and put into risk the health of the consumer. Other problems may be caused by insects, birds and rodents, or abiotic factors such as heat, oxidation, moisture pick up or loss. Food packaging needs to protect the food product from all of the above dangers.

-**To provide convenient handling during the food production process**

The food production chain includes the production, storage, and distribution system up to consumption. This includes easy opening, dispensing and re-sealing, easy disposal, recycling, or re-use as well as facilitating the transport and distribution of the product

-To provide information to the consumer about the product

It provides information about the identity of the food, its ingredients, details about their production process, and instructions for the proper storage and use of the product.

-**To provide marketing elements**

It provides elements and information which present and identify the product to the consumer in order to facilitate its purchase.

Figure 1. Main functions of traditional food packaging
Source: adapted from Salgado et al, 2021, https://doi.org/10.3389/fsufs.2021.630393

In addition to the above-mentioned regulations and legislation, some additional criteria which need to be made concerning product description and measurement of biodegradability or renewability of a given material, have been agreed to in principle. This standardization aims to define generally accepted criteria within the industry for the description of the different biobased product materials.

2. IDENTIFY PRODUCT QUALITY STANDARDS AND USES

There is a great variety of packaging materials that come in contact with food and it is important to know some basic technical characteristics that describe their properties and quality parameters. The different types of material (paper, plastic, packaging films) show diverse technical characteristics and different flexibility. These characteristics are also connected with the final use of the product, e.g., if the water permeability of a material is low, it can be used for liquid containers. All of the above issues have been studied analytically and in great detail within the specific scientific disciplines of the Food Science and engineering sector. The scope of this section is to present students with only some important key representative mechanical and physical functionalities.

1. Thickness

Thickness (T) is defined as the width of an object, mainly when it is significantly smaller than the other dimensions. Measuring thickness needs a tool with great precision such as callipers. In the case of very thin packaging materials like polythene, the use of a micrometre is ideal. This measurement is necessary to define the dimension of the product. It should also be mentioned that in the case of flexible materials (e.g., plastic films) dimension testing also involves testing the weight of the film (the grammage of the film) used to manufacture the packaging. This is measured as grams per square meter - a higher measurement implies a denser and heavier film (Fig. 2).

Figure 2. An example of equipment suitable to measure the thickness of the material

Source: https://chem.libretexts.org/Courses/

Mechanical properties

1. **Tensile strength** is defined as the force required to break flexible packaging and how much it can be elongated before it breaks.

Tensile strength test is a mechanical test performed on packaging materials to determine the maximum load force that can be applied to a material before it ruptures or tears. In essence, it is a "pulling" test used to measure the strength of paper, cardboard, and plastics (Fig. 3).

Figure 3. Schematic representation of tensile strength

2. **Tear resistance (or tear strength)**

This parameter is defined as how well a material can withstand the effects of tearing. It is a useful engineering measurement for a wide variety of materials by many different test methods.

Tearing is the act of breaking apart a material by force, without using a cutting tool. A tear resistance test in a piece of paper and film materials or other similar objects may be the result of the force perpendicular to the plane of the sheet required to tear single or multiple plies through a specified distance after tear initiation (Fig. 4).

Figure 4. Schematic representation of the forces involved during tear resistance force.

Sources: https://en.wikipedia.org/wiki/Tear_resistance
https://www.campdenbri.co.uk/services/packaging-plastics-testing.php

3. Penetration or puncture resistance

This parameter measures the maximum force or energy required to penetrate a material. Loss of package integrity may result in gases, odours, or contaminates affecting the food package headspace. There are several methods for the measurement of this parameter, the basic principle is a dowel vertically penetrating the material under examination (Fig. 5).

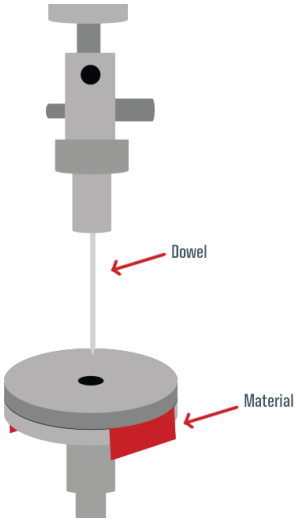

Figure 5. Schematic procedure of a test to examine penetration resistance of a material.

Source: https://www.212performance.com/blog/post/puncture-resistance

4. **Seal strength**

This parameter shows how secure the seal is of flexible packaging and how well it keeps the packaging enclosed over time.

Seal strength is connected to the pack opening energy and a measure of the consistency of the packaging process. This parameter is a quantitative measure for use in process validation, process control, and capability. Seal strength is not only relevant to opening force and package integrity, but to measuring the packaging processes' ability to produce consistent seals. Seal strength at some minimum level is a necessary package requirement, and at times it is desirable to limit the strength of the seal to facilitate opening.

This test method covers the measurement of the strength of seals in flexible barrier materials.

The test may be conducted on seals between a flexible material and a rigid material.

Physical properties

In contrast to glass or metal packaging materials, packages made with plastic show a different degree of permeability to small molecules like gases, water vapour, and organic vapour as well as to other low molecular weight compounds such as aromas, flavour, and additives present in food. As a consequence of the barrier properties of the material, the transfer of these molecules ranges from high to low and their study is very important (Siracusa 2012).

1. **Gas transport properties – Water vapour**

The check of the permeability of a material to water vapor at a selected temperature, pressure, and humidity is important for the different packaging materials and defines the range of their uses. The transmission rate is measured as how much water vapor is transmitted through the packaging film per unit area per unit time.

2. **Gas transport properties – CO_2 and O_2 permeability**

The concept of permeability is normally associated with the quantitative evaluation of the barrier properties of a plastic material. Several factors can influence the barrier properties of a packaging material, like food contact and environmental conditions such as temperature and relative humidity (Siracusa 2012).

3. **Barrier to moisture**

Films with suitable moisture barrier properties are required for a great number of applications. Indeed, control of the moisture content and activity of heterogeneous food components or of the elements of a mixture influences the microbiological, physico-chemical and organoleptic characteristics of the food.

4. Barrier to air/odour

Materials with suitable oxygen barrier properties are required to protect oxidizable foods (to reduce rancidity and vitamin loss), but some permeability to oxygen, and especially to CO_2, is essential for fresh fruit and vegetable coatings.

Chemical properties

1. Migration test

Food packaging may contain chemical substances which may be toxic when used for the improvement of their barrier properties or the strength of the packaging film. There is a risk of these substances contaminating foods if the toxic substances migrate from the packaging material to the food. Materials, like **paper or plastics**, can be a direct source of migrants. A migration test evaluates the toxicological risks associated with the packaging. Global migration checks how inert the materials are and if it can contaminate the food.

Table 1. Properties of selected packaging materials

Film	Coating	Barrier to		Strength	Clarity	Thickness (µm)
		Moisture	Air/odours			
Cellulose	PvDC	*	***	*	***	21-40
	Aluminium	***	***	*	***	19-42
	Nitro-cellulose	***	***	*	-	21-42
LDPE	-	**	*	**	*	25-200
HDPE	-	***	**	***	*	350-1000
Polypropylene	-	***	***	***	***	20-40
	PvDC	***	***	***	***	18-34
	Aluminium	***	***	***	-	20-30
Polyester	-	**	**	***	**	12-23
	-	***	***	***	-	20-30

Source: https://www.bizongo.com/blog/flexible-packaging-testing-methods

3. IDENTIFY THE TESTING PROCEDURE (EXAMPLES)

An important part of the quality control for any type of packaging is testing. This provides manufacturers with informationregarding the shelf-life of the product or its strength during shipping. The testing of packaging type and flexibility is an investment that can save a lot of money in the production process.

Examples for measuring different characteristics

Measuring the flexibility of a material

Another parameter related to the technical characteristics of a material is the flexibility of the material. The skills obtained for the learner is that he/she will be able to test the flexibility of a material.

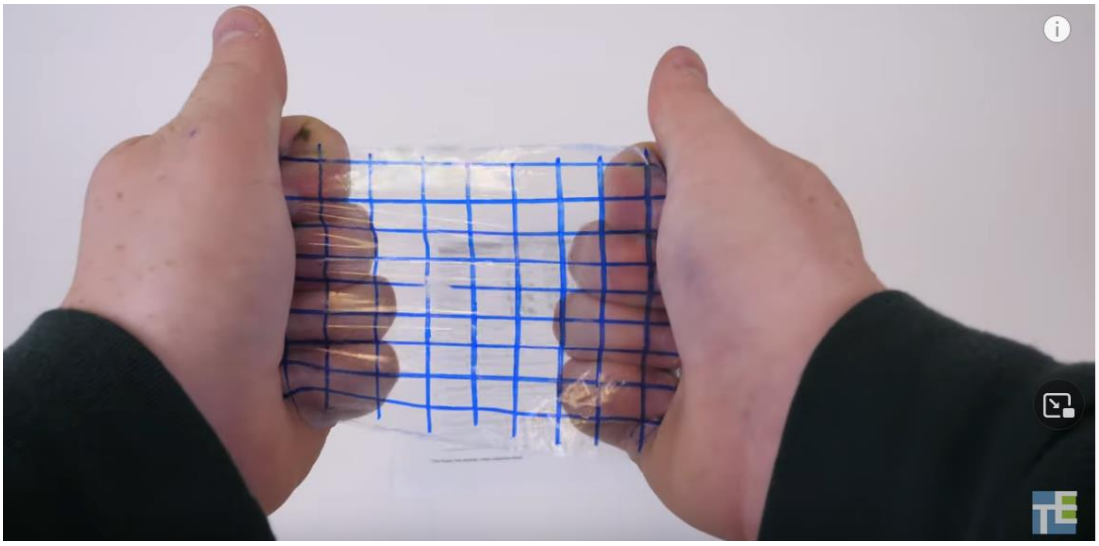

Figure 6. Examples of how to measure the flexibility of a material

Video: https://www.youtube.com/watch?v=Pmyu_8jiUZs&list=RDCMUCpRCG3gGtWqieJe-LGmi93w

Measuring thickness

Another parameter related to the technical characteristics of a material is thickness. The skills obtained for the learner is that he/she can test the thickness of a material and use Vernier Callipers to estimate the thickness of a material.

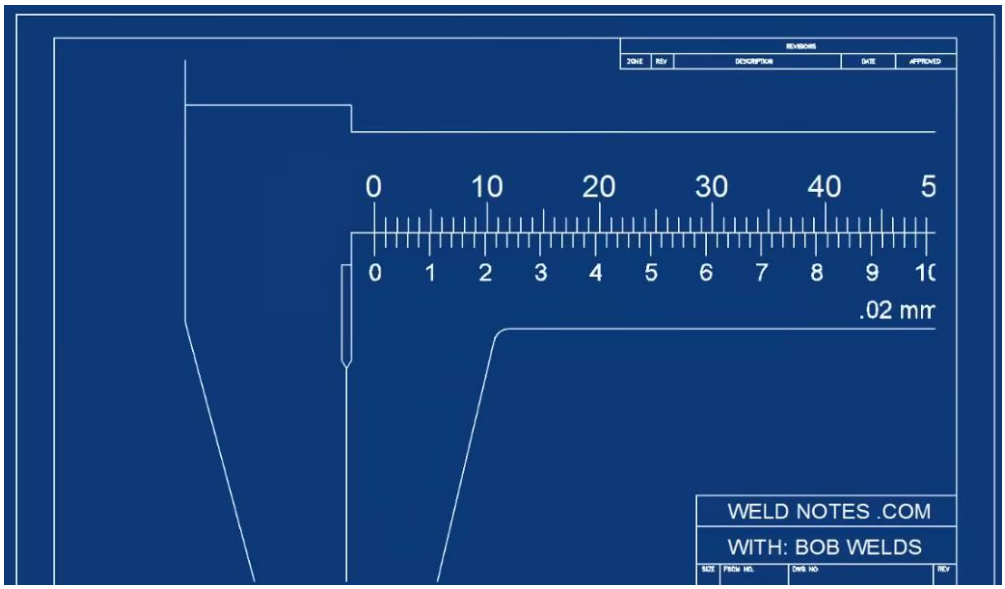

Figure 7. Examples of how to measure the thickness of a material using Vernier Callipers

Related videos: https://www.youtube.com/watch?v=vkPlzmalvN4; https://www.youtube.com/watch?v=MOivxqXYCZk

Figure 8 shows an example from equipment available in the industry to measure the thickness of a plastic film using innovative techniques with high accuracy, since the aim is to define the thickness of a very thin plastic film.

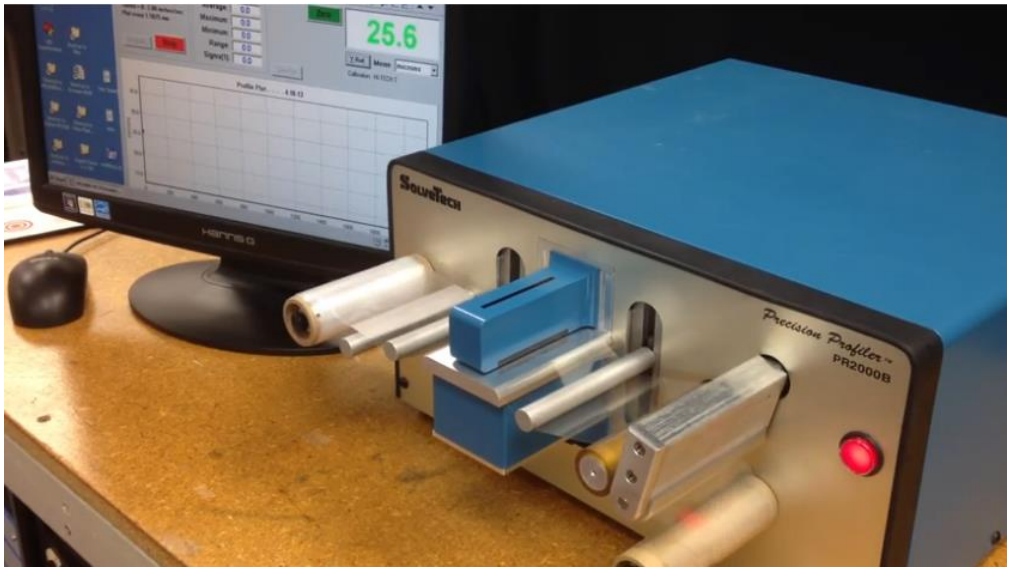

Figure 8. Examples of how to measure the thickness of a material using advanced equipment (example taken: SolveTech Inc. SolveTech Precision Profiler Model PR2000B - Plastic Film Thickness Gauge)

Related video: https://www.gauging.com/customer-resources/how-to-measure-plastic-film/

At this point, the use of **Augmented Reality (AR) technology and applications** could contribute to the better education of the learner concerning the methods of testing the characteristics of bio-packaging materials.

The use of AR technology as an educational tool is described in the "How Questions" section of the *Pedagogical Guidelines.*

For more information please visit:

https://navigator.biocompetences.eu/wp-content/uploads/2021/11/How-Guide-BioComp-v2.pdf

According to the recorded values of the examined characteristics, the materials are classified for their properties and the definition of their possible uses in the food industry. The main properties are connected to the behaviour of the material under high temperature, gas barrier, UV resistance, elasticity or flexibility, and water permeability.

Table 2. Some properties of natural polymers that can be used in bio-packaging materials (adapted from Karan et al 2019)

Natural monomer & polymer	Polymer processing	Properties		Possible Uses connected with Food
Starch	**Starch-based polymers**	Thermoplastic	Yes	**Packaging Food trays Trash bags Flower pots**
		Gas barrier	Yes	
		UV resistant	No	
		Biocompatible	Yes	
		Thermostable	No	
		Elastic	Yes	
		Rigid	Yes	
		Hydrophobic	No	
Polyhydroxyalkanoates	**PHA, PHB, PHV**	Thermoplastic	Yes	**Packaging Adhesives**
		Gas barrier	Yes	
		UV resistant	Yes	
		Biocompatible	Yes	
		Thermostable	No	
		Elastic	Yes	
		Rigid	Yes	
		Hydrophobic	Yes	
Lactic acid	**Polylactic acid (PLA)**	Thermoplastic	Yes	**Packaging Films**
		Gas barrier	Yes	
		UV resistant	Yes	
		Biocompatible	Yes	
		Thermostable	No	
		Elastic	Yes	
		Rigid	Yes	
		Hydrophobic	Yes	
Cellulose	**Cellulose-based polymers**	Thermoplastic	No	**Coatings**
		Gas barrier	No	
		UV resistant	No	
		Biocompatible	Yes	
		Thermostable	Yes	
		Elastic	No	
		Rigid	Yes	
		Hydrophobic	No	

The main advantages of biodegradable packaging regarding the properties of the material

Regarding the properties of the materials:

1. Excellent protective qualities
2. Strength and tightness that help protect food from drying out, mould, microbial contamination, etc
3. Compactness - does not take up much space during transportation and storage

Regarding environmental friendliness

4. Environmental friendliness - does not harm during production, during operation, or during disposal
5. Bioplastics from starch, cellulose, wood and sugar show great potential for reducing CO_2 emissions during production, consumption, and disposal
6. Bio-based packaging can reduce waste
7. Renewability of raw materials
8. Perception as "material of the future"
9. High abundance of cellulose resources

New concepts

1. Financial advantage - makes biodegradable polymer materials more competitive than non-degradable plastics
2. The advantage of edible cups produced in an environmentally friendly way is that their main ingredient is oats, which makes them a suitable part of a healthy and balanced diet

Example from industry: Taking into account as an example to test the hydrophobic properties of a cup: Once filled with a liquid or water, the cup can hold liquid with no leakage for up to 12 hours, and its crispness is maintained for 40 minutes. It only takes a few weeks for the glass to decompose if not consumed after a drink is swallowed. The bottom of the cup is wrapped with outer cardboard tape, which provides space for placing and gripping it. The cardboard wrapper can be used for advertising purposes by companies that order cups for corporate usage.

4. LABELLING

Certification and labelling of the materials

Packaging products often have a similar appearance and it is very difficult to clearly distinguish between conventional plastic products and bioplastics.

Following is some information regarding labelling categories and the related legislation for biodegradable materials or the CEN that they should follow.

Certification of products is a process that links the bio-packaging material with its properties and facilitates the consumer to identify and verify the claimed identities. In the case of biobased materials, the compostability or the content of renewable resources are characteristics connected with these bio-packaging materials.

Certification connects harmonised standards and independent third-party labels such as the compostability label 'Seedling' logo.

Example of compostability (EN 13432):

Certification ensures that the product can be industrially composted and that not only the plastic but also all other components of the product are compostable, e.g., colours, labels, glues, and – in the case of packaging products – residues of the content.

Testing for certification according to EN 13432 / EN 14995 encompasses:

- Chemical test: Disclosure of all constituents, threshold values for heavy metals are to be adhered to.
- Biodegradability in controlled composting conditions (oxygen consumption and production of CO2): Proof must be made that at least 90 percent of the organic material is converted into CO2 within 6 months.
- Disintegration: After 3 months' composting and subsequent sifting through a 2 mm sieve, no more than 10 percent residue may remain, as compared to the original mass.
- Ecotoxicity test: Examination of the effect of resultant compost on plant growth (agronomic test).

All tests, not merely individual sections, must be passed for the same material and the tests must be conducted by approved testing laboratories.

The association representing the interests of the thriving bioplastics industry in Europe is *European Bioplastics,* which recommends that commercial users or retailers should ask distributors about their product certification and demand the certification number. Certification guarantees high product safety and also allows a product to wear a certain label, which can help to make product information more transparent for the end-consumer. (Source: https://www.european-bioplastics.org/bioplastics/standards/labels/)

Compostable materials

A label to verify the compostability of a material is “The Seedling Logo” (Figure 9). The logo and the certificate number printed on the product assists in the decision on purchasing and disposing of a product (packaging). The certification process is offered by Belgian certifier TÜV Austria Belgium and German certifier DIN CERTCO.

Biodegradable and compostable products should be certified according to EN 13432 / 14995 standards. Independent third-party certification ensures conformity of the product with the referenced standards and certification stipulations. The Seedling label is an established and accepted identifier in Belgium, Switzerland, Germany, The Netherlands, Poland, the United Kingdom, and beyond.

Figure 9. The seedling logo is a registered trademark and it means that the bio-packaging material is compostable.

Biobased label

There is currently no obligation for producers to disclose the exact amount of biobased materials in their products. Producers can, of course, provide this information to consumers on a voluntary basis, thereby substantiating their marketing claims and allowing for an informed purchase decision for environmentally conscious consumers.

Source: https://www.european-bioplastics.org/bioplastics/standards/certification/

Two organisations in Europe provide certifications and corresponding labels based on this standard:

Figure 10. Organizations involved in the certification and Labels showing the biodegradable or biobased material.

5. QUIZ

1) A recent development regarding the regulations of the European Food Safety Authority (EFSA) for the use of biobased materials that are biodegradable is:

a. EFSA recognized the use of a new biodegradable substance
b. EFSA declined the use of FCM substance
c. EFSA revised the basic legislation for plastic materials and articles to come into contact with food

correct answer a)

2) Please select the key mechanical characteristics of a packaging material

a. Thickness
b. Migration test
c. Penetration resistance
d. Acidity

correct answer a) and c)

3) The following parameter measures the maximum force is required to penetrate a material

a. Penetration resistance
b. Seal strength
c. Weight
d. Moisture barrier

correct answer a)

4) A material with low moisture barrier properties is suitable for packaging.

a. True
b. False

correct answer a)

5) This label means that:

a. The material is a complex chemical substance
b. The material under specific conditions it decomposes to water, CO2 and Biomass
c. The material is suitable for growing seeds

correct answer b)

6) A material with high barrier to moisture could be characterized as:

a. Hydrophobic
b. Rigid
c. Elastic
d. Biocompatible

correct answer a)

6. SOURCES

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