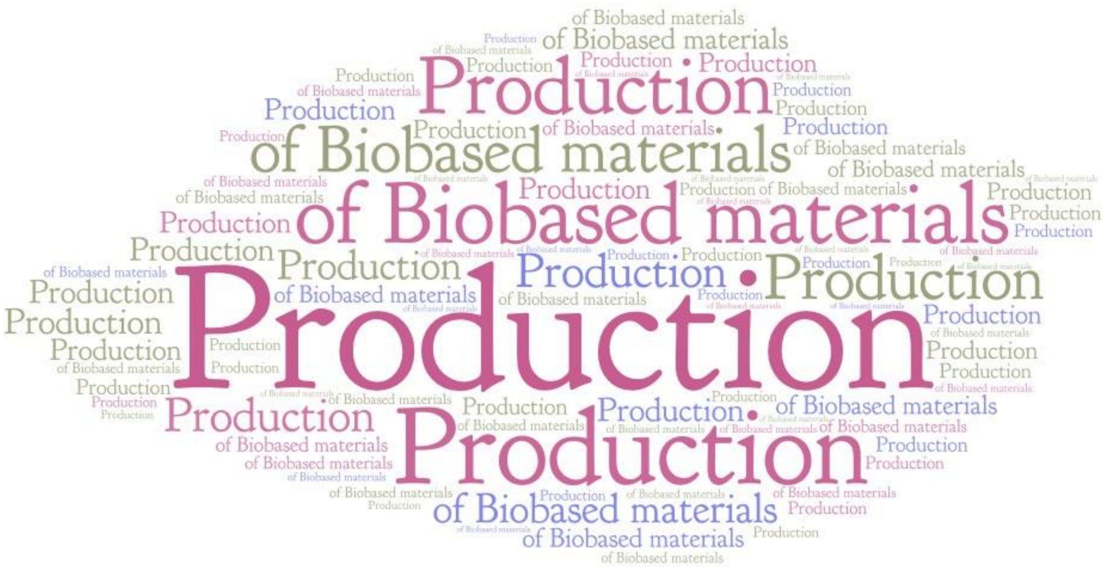
Project-N° 2019-1-CZ01-KA202-061409

LEARNING SCENARIO
MODULE 5

BIO-PACKAGING
PRODUCTION OF BIOBASED MATERIALS



COLOPHON

Authors

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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, organizization 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 5 provides a basic background on production of the main types of biobased materials, their origin according to the initial biomass source (feedstock), useful definitions, and innovative concepts connected with the biobased economy.

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 5 contains the following topics:

1. Types of biobased materials
2. Types of processing methods and outputs
3. List of the main biobased material – innovative concepts
4. Make your own bioplastic
5. Quiz
6. Sources

Biobased materials can be defined as materials that are wholly or partly derived from biomass (e.g. plants, trees, other sources).

Biomass as a resource for biobased industries can be defined as:
“the biodegradable fraction of products, waste, and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste” (2001/77/EC 2001)
(JRC-IES and Imperial College expert workshop, 2013).

Feedstock resources, (the initial source of the material used for its production) are one of the main differences between fossil-based and bio-based materials. The part of the product that is derived from biomass is defined as bio-based content. It originates **from a renewable resource** and is thus the variable describing the bio-based content. Participants in the chain – farmers, industry, regulators and consumers – need to cooperate to make the bioeconomy work.

Fossil-based materials are derived from the exploitation of non-renewable sources. These are used in the industrial process of conventional plastic production, which increases the share of CO_2 in the atmosphere (higher carbon footprint and greenhouse gas emission, GHG). The increase of CO_2, which is connected with the so-called greenhouse effect, causes an increase in the average global temperature and is linked to climate change.

Video: Use of renewable feedstock - general idea and example
https://www.youtube.com/watch?v=wFXXtO58H5M

Module 4 outlines how this renewable resource of biological origin is obtained (JRC-IES and Imperial College Expert Workshop, 2013).

Table 1. Biomass types (JRC-IES and Imperial College Expert Workshop, 2013).

Main type	Sub-type	Examples
Forestry	Primary forest products	Stemwood, thinnings
	Primary forestry residues	Leftovers from harvesting activities: twigs, branches, stumps, etc.
	Secondary forestry residues	Residues as a result of any processing stage: sawdust, bark, black liquor, etc.
Energy crops	Oil, sugar, and starch crops	Jatropha, rapeseed, sunflower seed, sugar cane, cereals (wheat, barley, etc.), maize, etc.
	Energy grasses	Miscanthus, switchgrass, etc.
	Short rotation coppice	Poplar, eucalyptus, etc.
Agricultural residues	Primary or harvesting residues, by-products of cultivation and harvesting activities	Wheat, straw, etc.
	Secondary processing residues of agricultural products (e.g., for food or feed production)	Rice husks, peanut shells, oil cakes, etc.
	Manure	Pig manure, chicken manure, cow manure, etc.
Organic waste	Tertiary residues released after the use phase of products	Biodegradable municipal waste, landfill gas, demolition wood, sewage gas and sewage sludge

But how is this initial biomass converted into biobased materials?

What are the main processes involved?

What are the main types of these materials and their classifications?

These questions are answered in the following section.

1. TYPES OF BIOBASED MATERIALS

What are the main types of biobased materials?

The types of biobased materials are several and they are classified according to different criteria; two main important criteria are:

- The initial source and production process of the materials
- The end-life scenarios of these materials

A. The initial source and production process of the materials

Biobased materials can be either produced directly, as a result of a chemical process, or due to microbial activity and can be summarized as follows:

Table 2. A summary of the most important biobased materials and their origin.

BIOBASED MATERIALS	
Naturally, Occurring Directly	*Result of a chemical process or microbial activity*
Cellulose	Polylactic acid (PLA)
Starch	Polyethylene acid (PEF)
Protein	PHA (Polyhydroxyalkanoates)
Lipid and Waxes	

The initial source of production (feedstock source), which is the raw material of the biobased material, is biomass that is a renewable source. Biobased materials are subdivided further into 3 categories (Molenveld et al., 2015):

A.1. Materials originating directly from biomass

In this category, Agriculture and Forestry initial raw materials are included. This category includes mainly wood, paper, pulp, cellulose, starch, and proteins.

A.2. Materials made from components originating from biomass through a chemical process

These biobased materials (polymers) are made from components originating from biomass through a chemical process (e.g. polymerization).

A.3. Materials that are produced through the activity of microorganisms

These biobased materials (polymers) are obtained through microbial activity. These materials (PHAs) have the potential to serve as replacements for fossil-based plastics not only due to their similar physicochemical properties but also due to their biodegradability in different environments. Another example is fermentation.

B. Classification of end-life of biobased materials:

B.1. Compostable: it is certain that they will turn to soil. This refers to specific organic recycling. The term "compostable" means that a product can break down into natural elements in a compost environment. Because it's broken down into its natural elements, it causes no harm to the environment. The breakdown process usually takes about 90 days. The term "compostables" refers to anything that undergoes degradation by biological processes during composting to yield CO_2, water, inorganic compounds, and biomass at a rate consistent with other compostable materials while leaving no visible, distinguishable, or toxic residue (American Society for Testing and Materials, ASTM).

B.2. Biodegradable: decomposes from microorganisms to simpler components but if the conditions are not appropriate this will never happen. According to the grade of potential biodegradability this can be characterized as:

1. 100% Biodegradable
2. Partly biodegradable

Not all biobased materials are 100% degradable; this is another classification criterion and a potential point of confusion.

The prefix 'bio' may refer to, on the one hand, the biological origin of the material and, on the other hand, the biological degradability of the material. However, both aspects are not necessarily related.

	Petrochemical	Partly bio-based	Bio-based
Non-biodegradable	PE, PP, PET, PS, PVC	Bio-PET, PTT	Bio-PE
Biodegradable	PBAT, PBS(A), PCL	Starch blends	PLA, PHA, Cellophane

Figure 1. Diagram indicating biobased versus fossil-based materials (Van den Oever et al 2017)

Key characteristics of biodegradable packaging:

Biodegradable packaging is cheap, environmentally friendly, "oil-independent" plastic which has a completely degraded chemical structure within a reasonable period of time (several weeks or months) when the material is exposed to microorganisms in soil and water, and sometimes in the presence of oxygen. Biodegradable polymers are produced from renewable plant materials, such as corn, potatoes, legumes, wheat, beets, tapioca, poplar, and aspen, which can be used almost continuously (**Fig. 2**).

Bio-packaging materials are biochemically decomposed into completely safe components using a compost system at disposal: water, biomass, CO_2 and other natural components that are not harmful to the environment.

it is important to mention that the term “biodegradable” is often used interchangeably with “compostable” when talking about the end life of material. To understand the difference between the two terms it is necessary to analyse the particular conditions where the biodegradation is expected to happen. According to the American Society for Testing and Materials (ASTM), biodegradables are anything that undergoes degradation resulting from the action of naturally occurring microorganisms such as bacteria, fungi, and algae. Although speed is not defined, biodegradable products break down in much less time than non-biodegradable products like plastic, for instance. Biodegradable objects can be much more than just plants, as most people assume. They can also be papers, boxes, bags, and other items that have all been created with the ability to slowly break down until they’re able to be consumed on a microscopic level (https://www.naturespath.com/en-us/blog/whats-difference-biodegradable-compostable/).

So, What’s the Difference?

Looking at the definitions of both terms it’s pretty understandable why they are so easily confused. However, there is a difference. While all compostable material is biodegradable, not all biodegradable material is compostable. Although biodegradable materials return to nature and can disappear completely, they can sometimes leave behind metal residues. On the other hand, compostable materials create something called *humus* that is full of nutrients and great for plants. In summary, compostable products are biodegradable, but with an added benefit. That is, when they break down, they release valuable nutrients into the soil, aiding the growth of trees and plants.

For example, corn starch is a renewable raw material for the production of bioplastic which is 100% compostable.

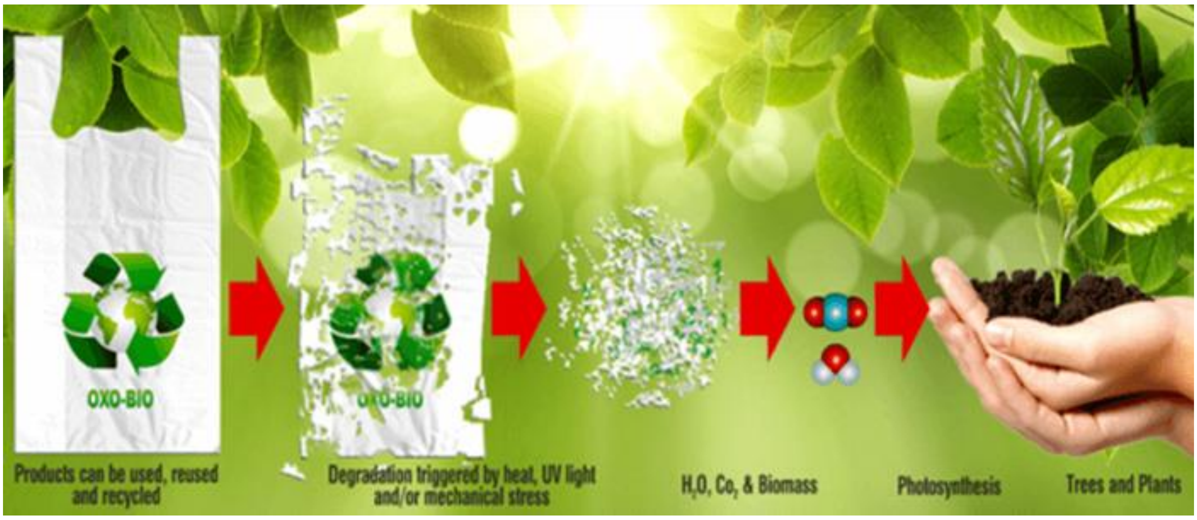

Figure 2. A visual presentation of the term 'biodegradable"
Source: https://immago.com/biodegradable-plastic-bags/

A majority of bio-packaging materials include bioplastics that are wholly or partly of biological origin. In the case of fully biodegradable bioplastic (e.g., made of corn) the life cycle is completed with final products that are renewable and harmless to the environment (Fig. 3 and Fig. 4).

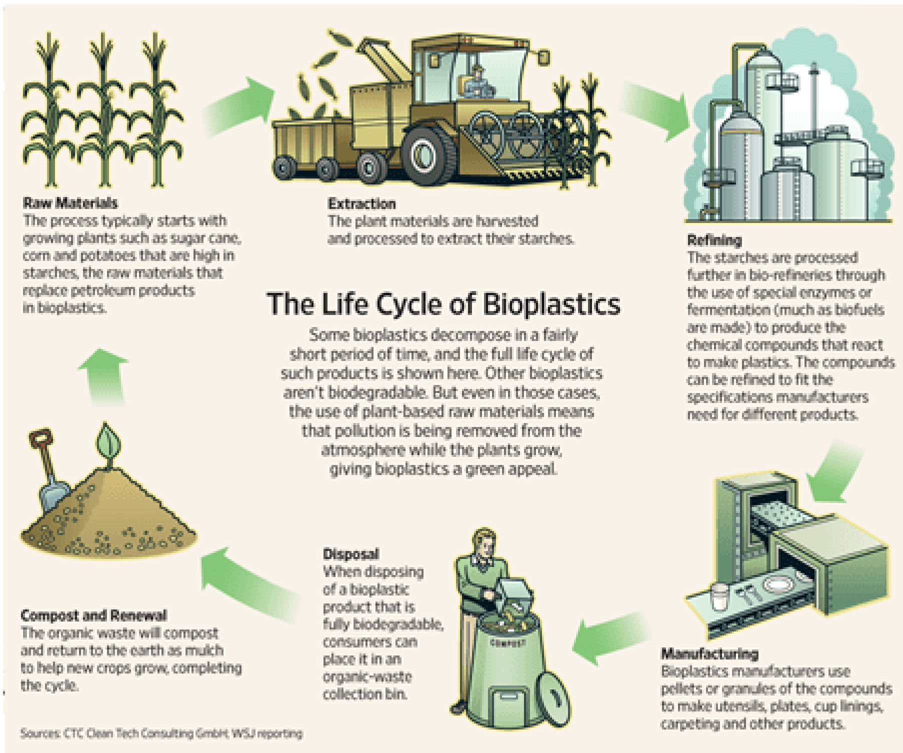

Figure 3. The life cycle of a fully biodegradable and compostable bioplastic made of corn starch. The full life cycle of bioplastics that are biodegradable is the ideal case since not all bioplastics are biodegradable. However, even in those cases, the use of plant-based material reduces pollution by a grade.

Source: https://plasticpollutionblogsite.wordpress.com/2016/10/31/solution-technology-1/

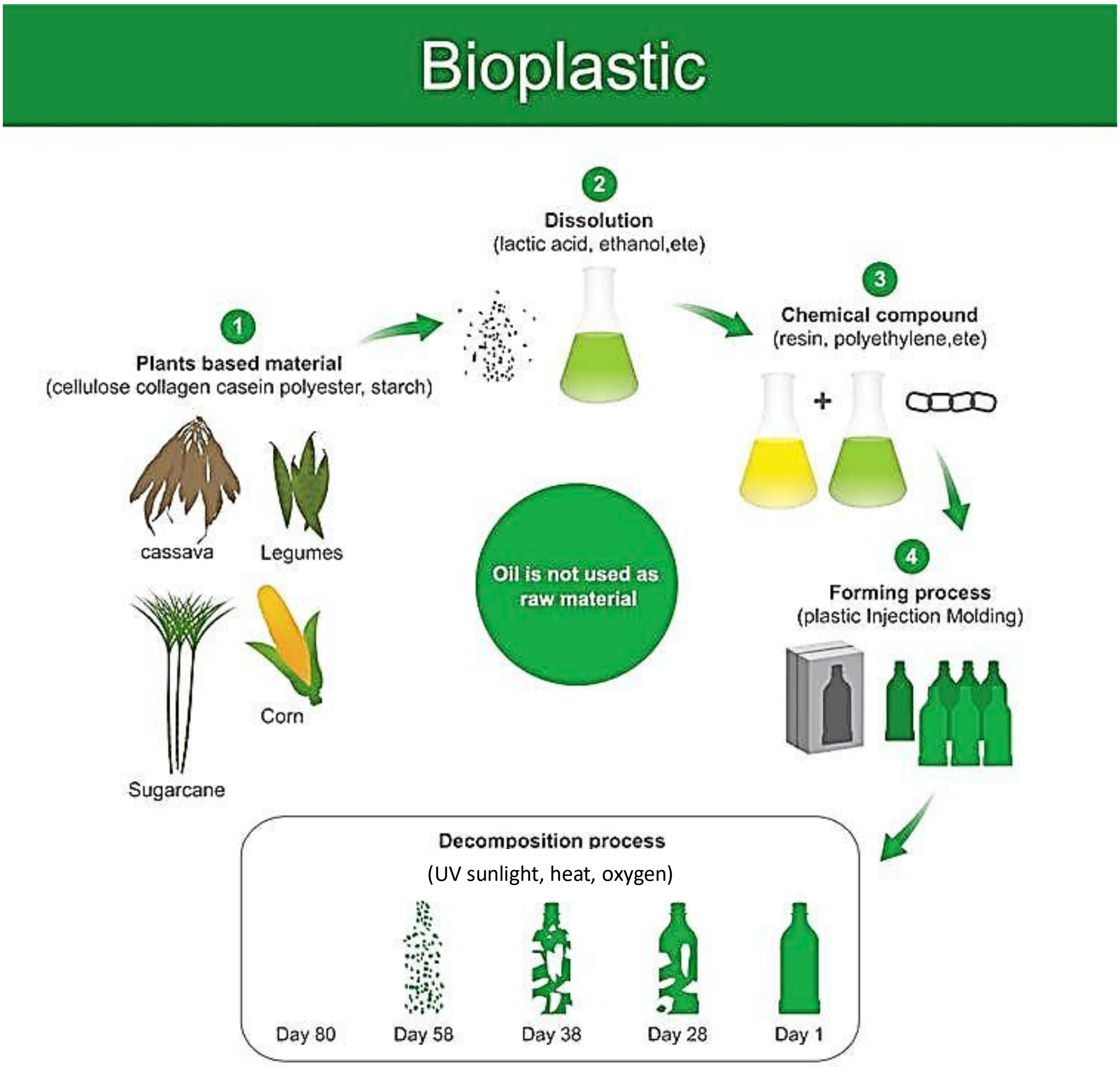

Figure 4. Life cycle of a bioplastic made of agricultural biomass through a chemical process. It is important to notice that not all bioplastics are biodegradable, only some of them are.

Source: https://www.parekhplast.com/blog/bioplastics-classification-types-uses/

But what are the chemical processes involved for the production of bio-packaging materials? This is presented in the section below.

2. TYPES OF PROCESSING METHODS AND OUTPUTS

As previously mentioned, biobased products can either be directly produced or with the interval of different chemical transformations:

1. **Polymerization** is any process in which relatively small molecules, called monomers, combine chemically to produce a very large chainlike or network molecule, called a polymer. Monomer molecules may be all alike, or they may represent two, three, or more different compounds.

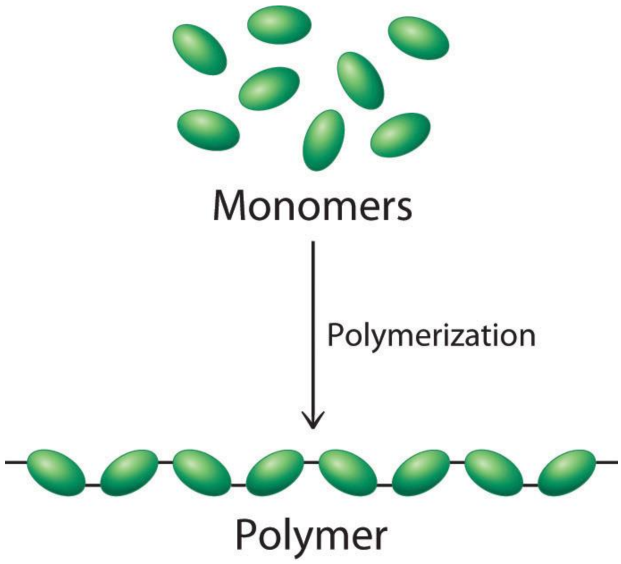

Figure 5. A simplified schematic outline of polymerization

Source: https://www.britannica.com/science/polymerization

2. **Fermentation** is a biochemical **process** by which molecules such as glucose are broken down anaerobically. More broadly, **fermentation** is the foaming that occurs during the manufacture of wine and beer, a **process** at least 10,000 years old. **Fermentation** is a metabolic process that produces chemical changes in organic substrates through the action of enzymes. In biochemistry, it is narrowly defined as the extraction of energy from carbohydrates in the absence of oxygen. In food production, it may more broadly refer to any process in which the activity of microorganisms brings about a desirable change to a foodstuff or beverage. (https://en.wikipedia.org/wiki/Fermentation)

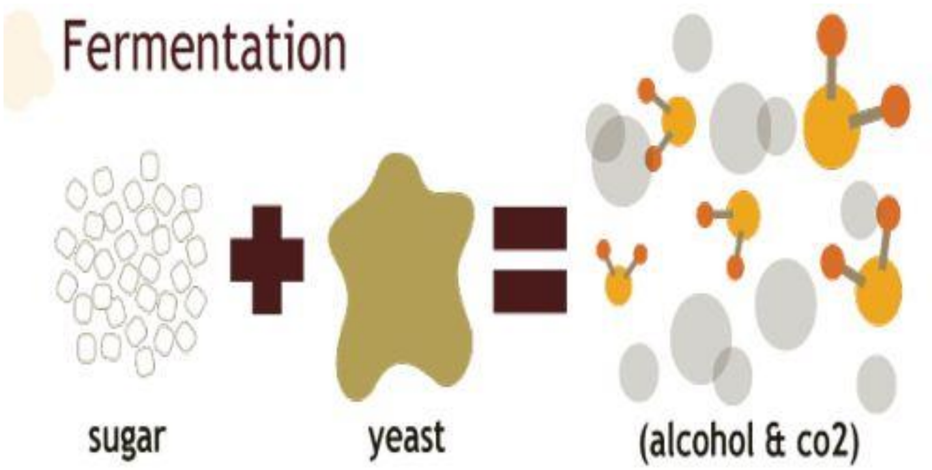

Figure 6. A simple example of the fermentation process.

Examples of well-known fermentation procedures are the production of:

Bioethanol – this is obtained as a result of alcoholic fermentation. The process of obtaining organic alcohol is quite complex, as it is preceded by a large number of technological operations related to the release of individual components from the grain: starch, gluten, embryo, and cellulose in an aquatic environment. The process chain is in many ways similar to the process for producing edible alcohol. At the same time, wet fuel technology is increasingly using biofuels.

Biogas – this is produced by fermenting biological products in an anaerobic (oxygen-free) environment - to reach methane (CH_4) and carbon dioxide (CO_2). The conversion of cellulose to methane can be achieved by mixing cultures of microorganisms. Anaerobic fermentation is a process that takes place in fermenters to produce biogas by decomposing organic material in the absence of oxygen. Methanogenic bacteria synthesize methane directly from hydrogen and carbon dioxide. Bacterial strains have been created by genetic engineering to increase methanogenic activity.

Activity:

Can you find other examples of fermentation?

3. LIST THE MAIN BIOBASED MATERIAL – INNOVATIVE CONCEPTS

A majority of biobased materials that are often used as bio-packaging materials are bio-based plastics or *bioplastics*. Bio-based plastics, as part of an expanding circular bioeconomy, can be designed to be either totally (100%) biodegradable to CO_2 over a period of time under specific conditions or to contribute to substitute components that were traditionally originated from fossil oil fuels (conventional plastic).

Currently, most bioplastics are produced from agricultural crop-based feedstocks (carbohydrates and plant materials), however, other solutions such as the use of food waste as organic substrates or organic matter from algae can also be used as potential sustainable solutions. **Figure 7** summarizes the main classes of currently developed bio-based plastics. These include, among others, plastics based on starch, polyhydroxyalkanoates (PHAs), polylactic acid (PLA), and cellulose.

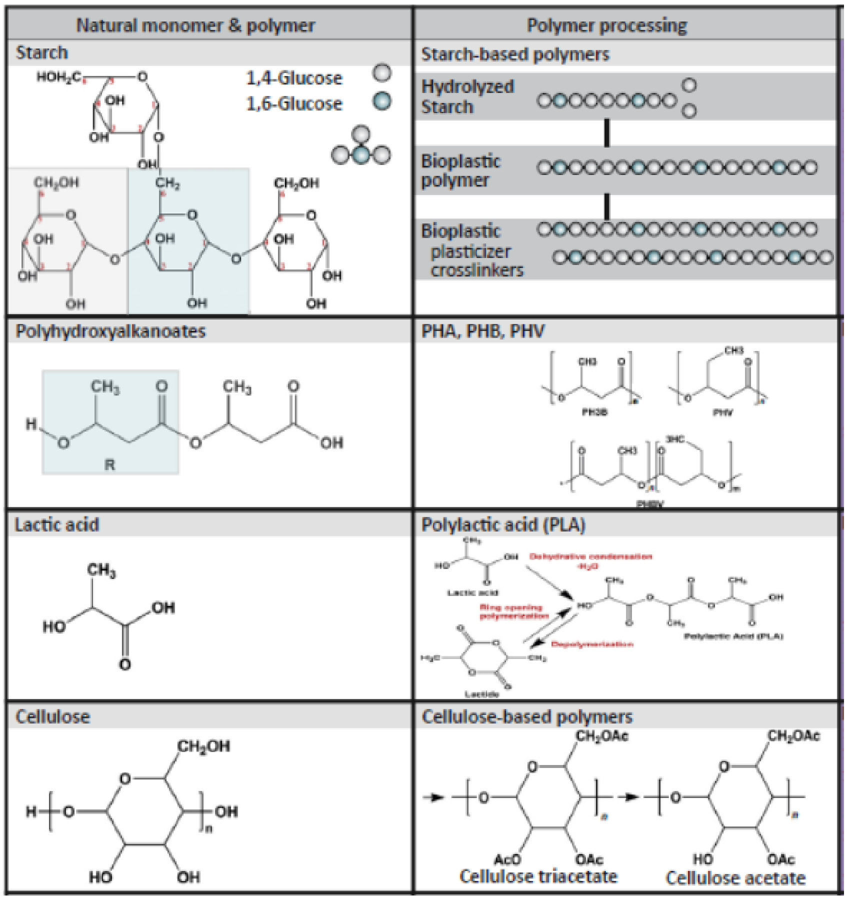

Figure 7. Important classes of currently developed bio-based plastics (adapted from Karan et al 2019)

This is the innovation adopted from companies that produce bio-packaging materials:

1. Polylactide PLA (Polylactic acid or Polylactide)

Polylactide PLA (Polylactic acid or Polylactide) is a polymer produced from renewable agricultural resources such as grain and sugar beet, i.e., on the basis of vegetable sugars. The resulting polymer has good transparency, strength, and gloss; it is an excellent protection against moisture, just like PET (Polyethylene terephthalate); it does not allow odours to pass; and the PLA polymer packaging is able to fully decompose within 45 days provided that the appropriate composting structure is in place.

BioPak produces compostable bioplastic from vegetable sugars, to be more precise, from any type of sugar, such as corn syrup, cassava (cassava flour), sugar cane, and sugar beet. Industrial corn has the largest share among raw materials. Studies are focused on other innutritious high fibre crops and even on producing polylactic acid from carbon dioxide or methane.

Stages of production:

- grinding corn
- extraction of starch in the form of glucose
- glucose undergoes fermentation to produce lactic acid
- polymerization of lactic acid and formation of small pellets

PLA has a low melting point. Therefore, it is most suitable for use with content not warmer than 40°C.

PLA is used in various production processes: it can be extruded into a sheet or film, it can be injected into a mould, or a thread can be extracted.

PLA has many applications:

- PLA coated cardboard for cups and soup bowls
- transparent cups, salad and cold kitchen boxes, saucers and lids for a variety of products
- transparent window sandwich packaging boxes and envelopes

CPLA /crystallized PLA/ for high temperature applications.

A crystallized form is used for higher temperature resistance which includes the addition of talc, rapid heating, and subsequent cooling of the PLA. The process results in a polymer that is resistant up to 90°C. The achieved sustainability does not interfere with composting in industrial conditions.

The industrial maize used for the production of PLA is different from maize for human consumption, so as not to compete with the one grown for food. The whole plant is collected and used. Protein and starch products have broad applications.
Maize is grown using sustainable farming practices without excessive use of pesticides and water.

Some of the practices required for certification are:

- Maize from soils with high biodiversity or high carbon maize from dried wetlands is not used.
- Agricultural practices (minimum use of pesticides, controlled irrigation, preparatory activities, precision equipment, etc.).
- Environmental protection (protection of natural vegetation and water sources, erosion protection).
- Social responsibility (excluding child labour, good working conditions, protection of workers, fair pay for land and water used).
- Minimization of greenhouse gases during cultivation.

2. Cupffee Ltd.

In 2018, the company started production of the first biodegradable edible coffee cups made of wafer crust. With its eponymous product, the company aims to reduce waste from disposable plastic and cardboard cups used daily to serve coffee. The innovative organic cups are made entirely of natural cereals and do not contain artificial ingredients, preservatives, or GMOs. The product has analogues around the world, but is innovative for Bulgaria. The American organic cup is much thicker than the Bulgarian one.

3. Polyhydroxybutyrate (PHB) or Poly(3-hydroxybutyrate) (P3HB)

Poly(3-hydroxybutyrate) (PHB) is a polyester produced by bacteria that feed on glucose and starch. The properties of the material are similar to those of polypropylene. PHB differs primarily in its physical characteristics. It is mainly used to produce transparent films at a melting point higher than 130°C. Poly(3-hydroxybutyrate) is biodegradable without residue.

4. Extrapack Ltd.

Extrapack Ltd. offers bags and packaging made of DEGRALEN®. The license for this technology is with the Canadian company EPI Environmental Products Inc. This technology is applied in the production of bags by folding in a special degrading additive in the process of extruding the polyethylene film. In the subsequent process of corona treatment, the latent stages of degradation are initiated. This additive acts as a catalyst for the decomposition of polyethylene under the influence of oxygen, ultraviolet rays from the sun, thermal and mechanical vibrations. The decomposition takes place in two stages: first, the polymer chains are broken into small pieces and are then attacked by fungi and bacteria which decompose the residues, releasing carbon dioxide and water. Visual decomposition takes place over a period of 2 to 3 years, depending on the climate. In the period before decomposition, the packaging retains its mechanical properties and recyclability.

DEGRALEN® technology is completely safe for human health. It can also be applied to packaging that comes into contact with food. The technology meets European safety and ecotoxicity standards.

These products have several advantages for bio-packaging and are in alignment with the circular economy concept.

- ✓ Excellent protective qualities
- ✓ Strength and tightness that help protect food from drying out, mould, microbial contamination, etc.
- ✓ Compactness - does not take up much space during transportation and storage
- ✓ Environmental friendliness - does not harm during production, during operation, or during disposal
- ✓ Financial advantage - makes biodegradable polymer materials more competitive than non-degradable plastics
- ✓ Bioplastics from starch, cellulose, wood and sugar show great potential for reducing CO2 emissions during production, consumption, and disposal
- ✓ Bio-based packaging can reduce waste
- ✓ Renewability of raw materials
- ✓ Perception as "material of the future"
- ✓ High abundance of cellulose resources

Another 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.

4.PRACTICAL ACTIVITY: MAKE YOUR OWN BIO-PLASTIC

Source: https://www.wikihow.com/Make-Bioplastic

STEP 1 Gather the necessary materials. To make this type of bioplastic, you will need corn starch, distilled water, glycerol, white vinegar, a stove, a saucepan, a silicone spatula, and food colouring (if desired). These items should be readily available at the grocery store or online. Glycerol is also called glycerine, so try searching for that if you're having trouble finding glycerol. The following amounts of each ingredient are needed to make the bioplastic:

- 10ml distilled water
- 0.5-1.5g glycerol
- 1.5g corn starch
- 1ml of white vinegar
- 1-2 drops food colouring
- Adult supervision is highly recommended.

STEP 2 Combine all of the ingredients and stir together. Add all of the ingredients to the saucepan and stir to combine with the spatula. Stir until you get rid of most of the lumps in the mixture. At this stage, the mixture will be a milky white colour and quite watery.

STEP 3 Heat on medium-low. Place the saucepan on the stove and set the heat to medium-low. Stir continuously as the mixture heats. Bring it to a gentle boil. As the mixture heats, it will become more translucent and begin to thicken.

- Remove the mixture from the heat when it becomes clear and thick
- Total heating time will be around 10-15 minutes
- Lumps may begin to form if the mixture gets overheated
- Add one-two drops of food colouring at this stage, if you would like to colour the plastic

STEP 4 Pour the mixture onto foil or parchment paper. Spread the heated mixture onto a piece of foil or parchment paper to let it cool. If you would like to mould the plastic into a shape, it must be done while it is still warm. See the last method for details on moulding the plastic.

STEP 5 Allow the plastic to dry for at least two days. It will take time for the plastic to dry and harden. As it cools, it will begin to dry out. Depending on the thickness of the plastic, it can take longer for it to dry. If you make one small thick piece it will take longer to dry than a thinner larger piece.

- Leave the plastic in a cool, dry place for this process
- Check the plastic after two days to see if it has fully hardened

5.QUIZ

1) Biobased materials:

a. are wholly or partly derived from biomass
b. are wholly derived from biomass
c. are materials used only in Organic Agriculture

Correct answer a)

2) The feedstock resource of bio-based materials originates from

a. fossil fuels that are naturally created underground from the remains of dead plants
b. animals feeding
c. a renewable resource, such as agricultural biomass

Correct answer c)

3) Please choose the biobased materials which occur naturally:

a. Polylactic acid
b. PHA
c. Protein
d. Polyethylene acid

Correct answer c)

4) Materials that will turn to soil, following a specific organic recycling, are defined as:

a. Biodegradable
b. Bio-PET
c. Compostable
d. Partly biodegradable

Correct answer c)

5) A bio-PET bottle is partly biodegradable

a. True
b. False

Correct answer a)

6) A process in which relatively small molecules are combined chemically to produce higher units is called:

a. Mitigation
b. Polymerization
c. Extraction
d. Combination

Correct answer a)

7) Polylactic acid (PLA) is produced through the polymerization of

a. Starch
b. Lactic acid
c. Cellulose
d. Proteins

Correct answer b)

8) The conversion of cellulose to methane is produced by

a. Fermentation
b. Polymerization
c. Purification
d. Hydrodistilation

Correct answer b)

9) Important biobased materials are:

a. Starch-based polymers, PHA, PLA, Cellulose-based polymers
b. PET, PVC, PHB, PP
c. Cellulose-based polymers, PS, CO_2, TetraPACK

Correct answer a)

10) Corn starch can be used to produce bioplastic material that is fully biodegradable and compostable

a. True
b. False

Correct answer a)

6.SOURCES

Karan, H., Funk, C., Grabert, M., Oey, M., and B. Hankamer. 2019. Green Bioplastics as Pat of a Circular Bioeconomy. Trends in Plants Science, 24, 237-249. https://doi.org/10.1016/j.tplants.2018.11.010

Molenveld, K., Oever, M. V.D. and Bos, H. Biobased Packaging Catalogue. Wageningen: Wageningen UR Food & Biobased Research.

Van den Oever, M., Molenveld, K., van der Zee, M., Bos, H. 2017. Bio-based and biodegradable plastics – Facts and Figures, Wageningen Food & Biobased Research number 1722.

https://www.european-bioplastics.org/pla-in-the-waste-stream/

Resource efficiency of biobased industries, notes from an expert workshop, in support to the JRC activities in the field of resource efficiency, bioeconomy and set-up of an EU Bioeconomy Observatory; organised by European Commission – Joint Research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit and Imperial College London, Centre for Energy Policy and Technology (in the framework of the IEE 12 835 Biomass Policies project)

https://ec.europa.eu/jrc/en/event/workshop/resource-efficiency-biobased-industries

https://link.springer.com/chapter/10.1007/978-981-13-1909-9_4

https://www.european-bioplastics.org/pla-in-the-waste-stream/

https://www.wikihow.com/Make-Bioplastic

https://www.european-bioplastics.org/bioplastics/environment/