Train-the-Trainer Booklet
Bioeconomy and the UrBioFuture experience

23 April 2020

Based on a workshop "*La BioEconomia e l'esperienza UrBioFuture*" (Bioeconomy and the UrBIOfuture experience), organized at CNR on the 7th of April 2020

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Content

1. Introduction

Bioeconomy is a socio-economical system that includes and connects those economic activities that use renewable bio-resources of soil and sea - such as agricultural crops, forests, animals and micro-organisms on land and sea - to produce food, materials and energy.
Bio-industry is the biggest industry in UE and has potential for further growth within the traditional and newly emerging markets and sectors, both in food and non-food sector.
In particular, it is aimed to set up and develop economic activities linked to the invention, development, production and use of biological products and processes within four macro-sectors: 1-Agro-food industry; 2. Forestry; 3. Bioindustry; 4. Marin bioeconomy
From the environmental point of view, growth of bioindustry brings opportunities and challenges.

Europe is setting actions for a resource-efficient and sustainable economy. The goal is a more innovative and low-emissions economy, reconciling demands for sustainable agriculture and fisheries, food security, and the sustainable use of renewable biological resources for industrial purposes, while ensuring biodiversity and environmental protection.
To achieve this, the European Commission has set a Bioeconomy Strategy and action plan which focuses on three key aspects:

- developing new technologies and processes for the bioeconomy;
- developing markets and competitiveness in bioeconomy sectors;
- pushing policymakers and stakeholders to work more closely together.

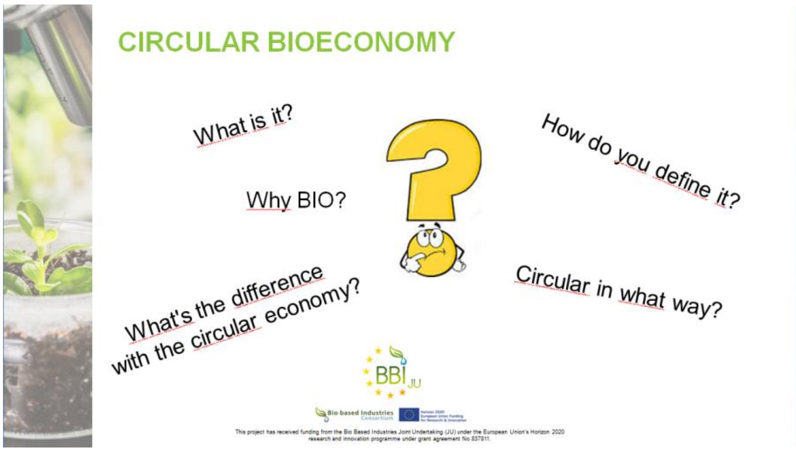
(from Bioeconomy policy of EC https://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy)

On a European level today's bioeconomy is worth 2'000 billion of Euro per year with the employment level of 20 million (Strategy for *"Innovating for Sustainable Growth: A Bioeconomy for Europe",* EC, 2012). The further growth of 40 billion of Euro with the 90'000 new jobs is expected in 2020 (*"Growing the European bioeconomy"* Third Bioeconomy Stakeholders' Conference, Torino, EC, 2014).

Objective of this training is to bring your attention, as educators, to the importance of the bioindustry and the opportunities that it creates for the young people.
In this booklet we will share with you tailored made educational and multimedia materials so you can use it in your classes and become the ***Ambassadors of UrBioFuture Experience.***

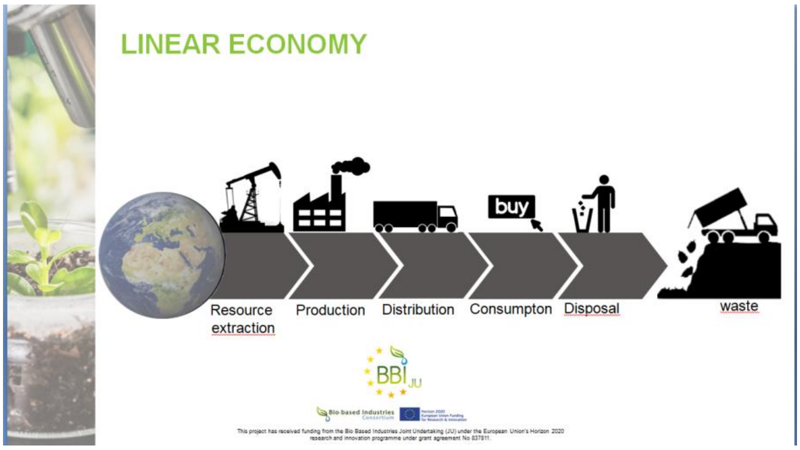
Organizing Committee

2. Bioeconomy and Circular Bioeconomy



Linear economy is traditional economy model based on a "take-make-consume-throw away" approach of resources.

This model has failed not only from the environmental point of view, unsustainable exploitation of the natural resources and waste disposal (pollution of air, water and destruction of natural resources), but also from the economical point of view. Primary raw materials are scares and costly, and it turns out that what until now was considered waste still has a potential as source of raw material and has an economical value.



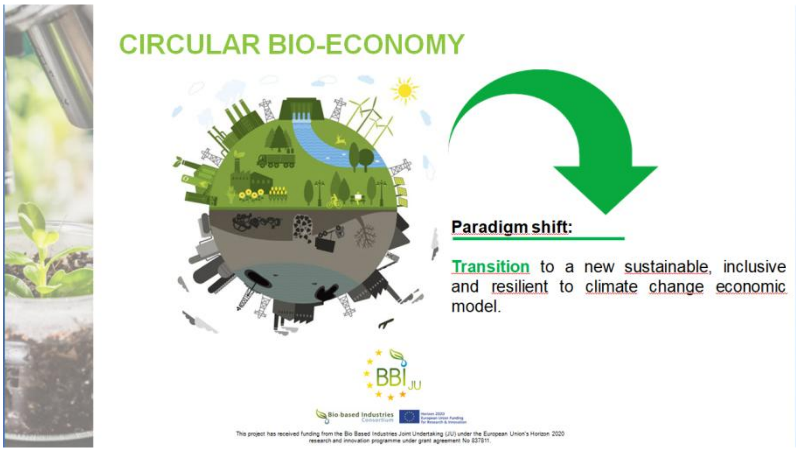
This economic model is not sustainable anymore.

Already from the 2000s European countries promote the segregation of communal waste in order to recycle as much material as possible at the same time reducing deposition of the waste in the landfills.

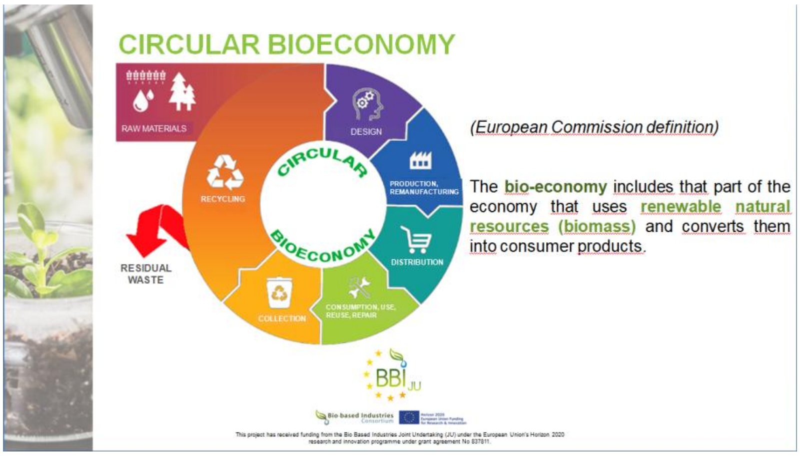
However, segregation of waste alone does not guarantee sustainable development. It is also important to change the raw materials that are used for the goods production. They have to be Eco sustainable and come from renewable sources. This is a fundament of **circular bio-economy.**

Circular bioeconomy model forces us to think in a new innovative way about each phase of the design, production, use and end of useful –life of a product.
The end of the production chain, that is, the collection of waste and recycling processing has to lead to a new beginning where the recycled waste becomes a secondary raw material.
The original design of the products and each step of its production line must be carefully fought through In order to accommodate the closure of that loop,.

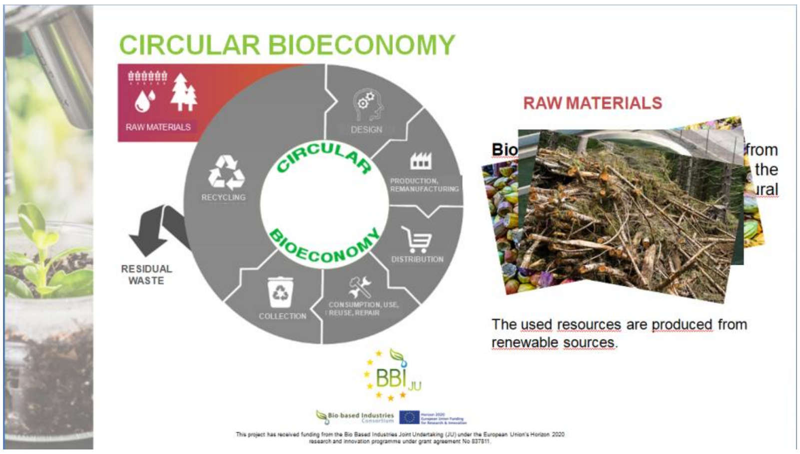
In circular bioeconomy economical and environmental sides complement each other. Reduction of the usage of the primary natural resources and contamination of the natural ecosystems translates directly to economical profit and increase of the employment rate.



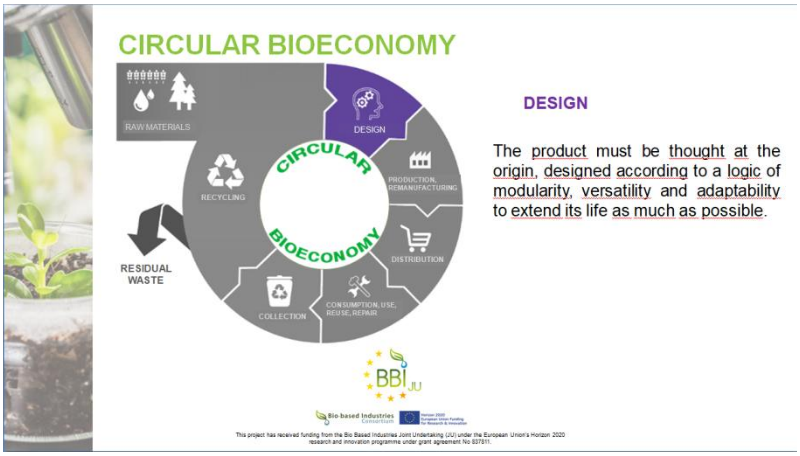
In bioeconomy transformation of the renewable recourses into food, energy, materials and fuels takes place in plants called **Biorefineries** where the sustainable processing of biomass into a spectrum of bio-based products (food, feed, chemicals, materials) and bioenergy (biofuels, power and/or heat) occur.

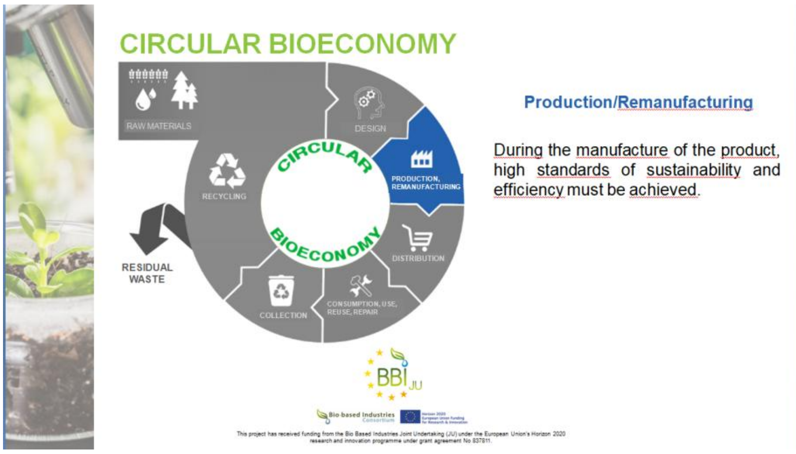


Biomass is a raw material from which bioindustrial production starts. It consists of the biodegradable fraction of agricultural residues, algae, forest residues and secondary raw materials (i.e. coming from reuse or recycling).



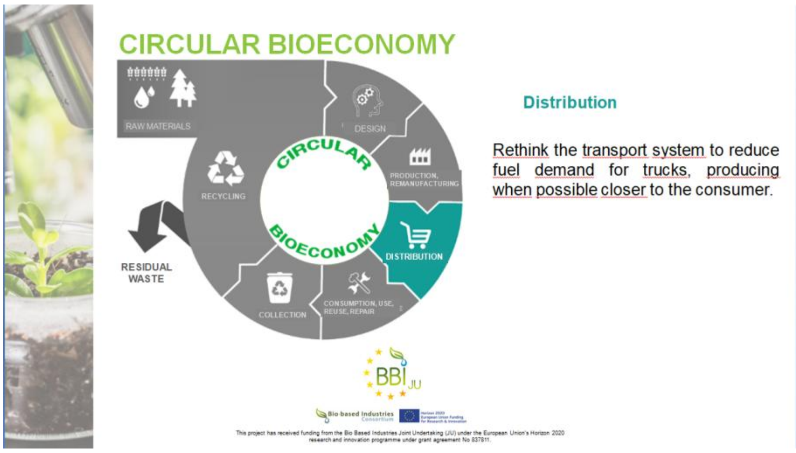
The first step of circular bioeconomy is the **design of the product**. It is a fundamental part of the circle because it has to guarantee long useful-life, possibility of repairing and at the end its recyclability.





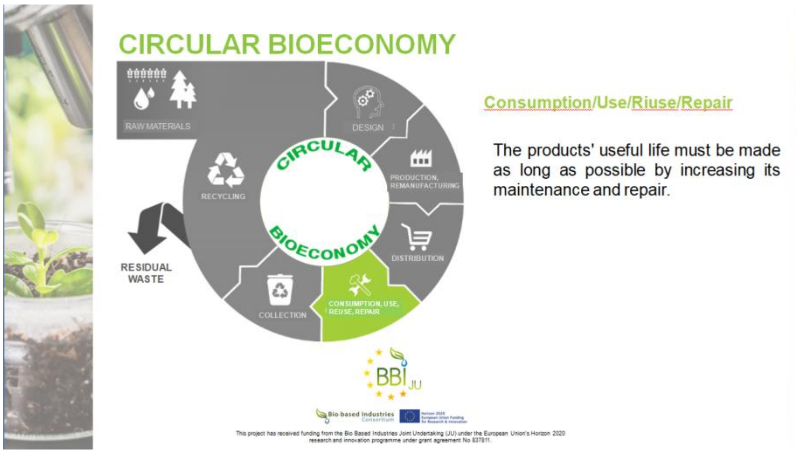
At the same time, the **production technology** has to be eco and energy –friendly.

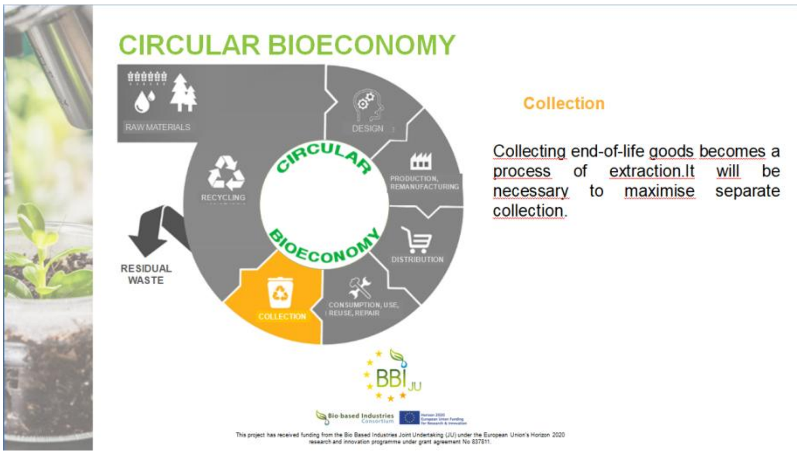
In addition, the **distribution model** has to change. This can be achieved thanks to digital technologies that offer large spectrum of tools allowing direct contact between producers and consumers. In this way, not only cost of transportation but also the waste linked to overproduction can be reduced.



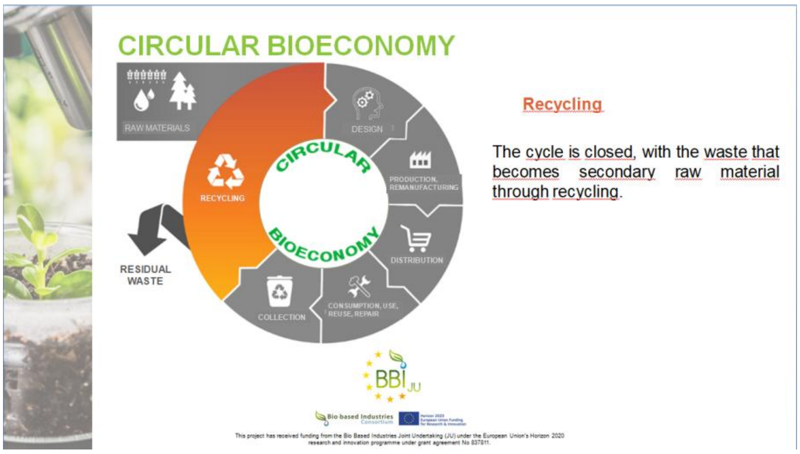
In the circular economy model, **consumer's behaviour** plays pivotal role.

Today in the rich societies, goods are frown away because they are broken or simply old and out of fashion. It is instead necessary to create a situation in which it would be in a consumer's interest (social or/and economic) to maintain in good condition and repair the goods as long as possible in this way prolonging its useful life.



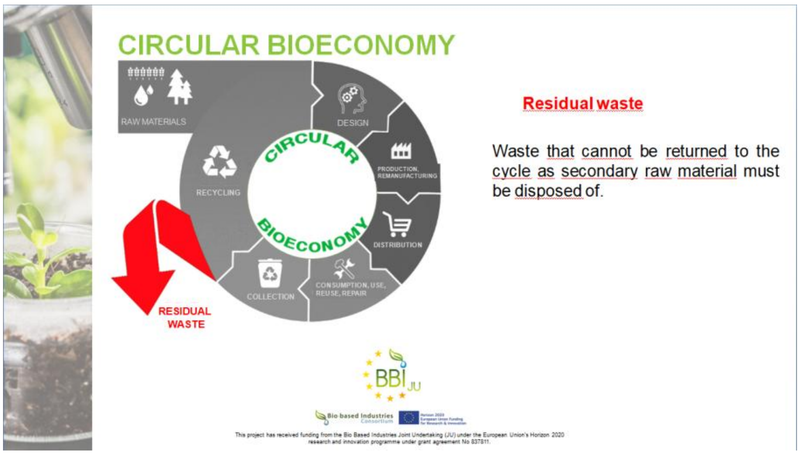


The last but not least is **recycling**. This process occurs in every step of the bio-economy circle. Its aim is to reduce to the minimum the waste and usage of primary natural resources by introduction secondary raw materials and prolonging the useful life of the products. In this way the impact on the natural ecosystems is minimized.



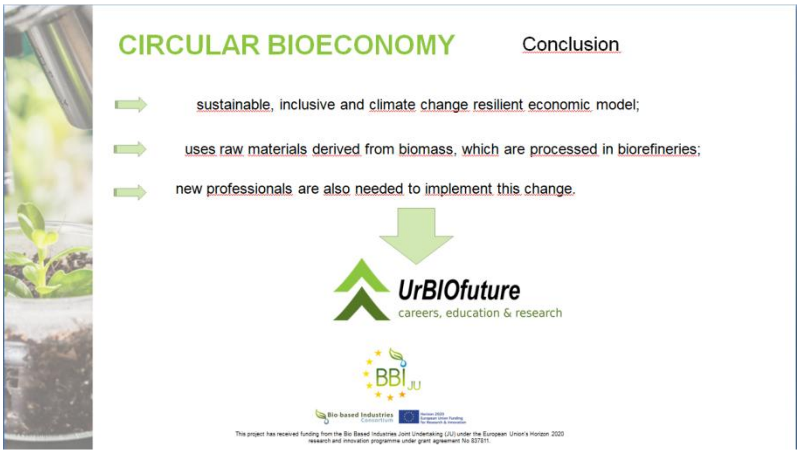
When a product reaches the end of its useful life, it should not be simply thrown away, but it should remain within the loop of the economic system, so it can be reused several times for production purposes and thus create a new value.

If there is a waste, it must be disposed; for example, through waste-to-energy methods in order to minimize landfill disposal.

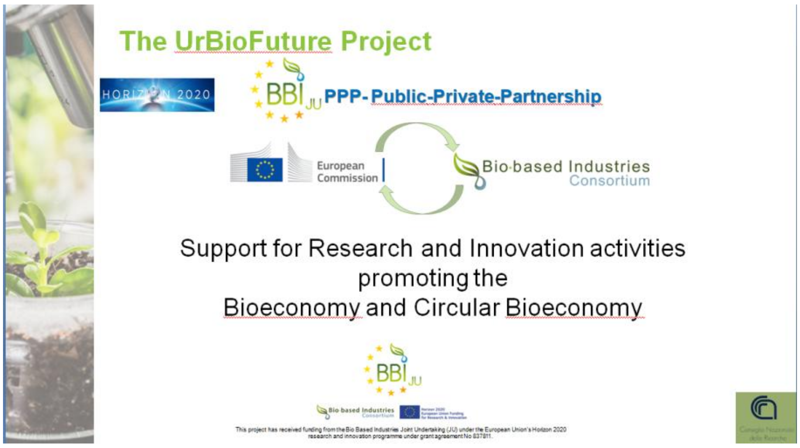


We can conclude that **Circular Bioeconomy** puts together the philosophy of the circular economy model with the usage of renewable (bio) raw material and biotechnology.

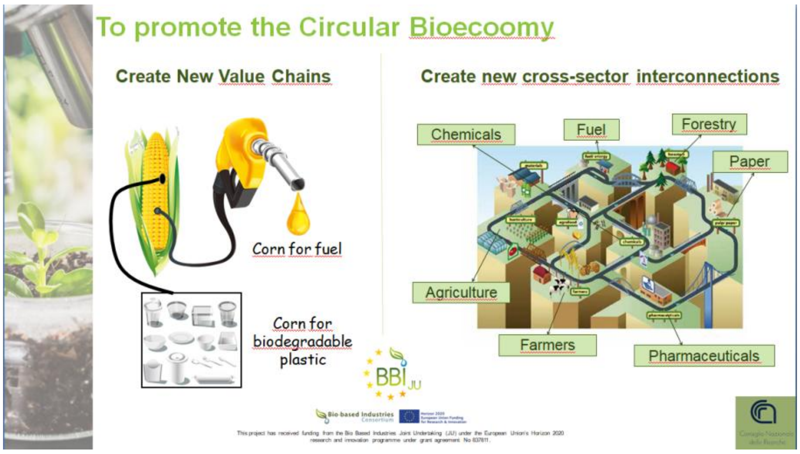
This model is revolutionary not only because gives us independence form the fossil recourses but it also forces structural changes on the economic and cultural level – involving policy makers, industry and us citizens.



3. UrBIOfuture



UrBIOfuture project is financed from the Bio-Based Industries Joint Undertaking (BBI-JU) under the European Union's Horizon 2020 research and innovation programme that is a partnership between public sector and consortium of bioeconomy sector industries.
The main objective of this program is to sustain research and innovation activities within the field of Bioeconomy and Circular Bioeconomy.

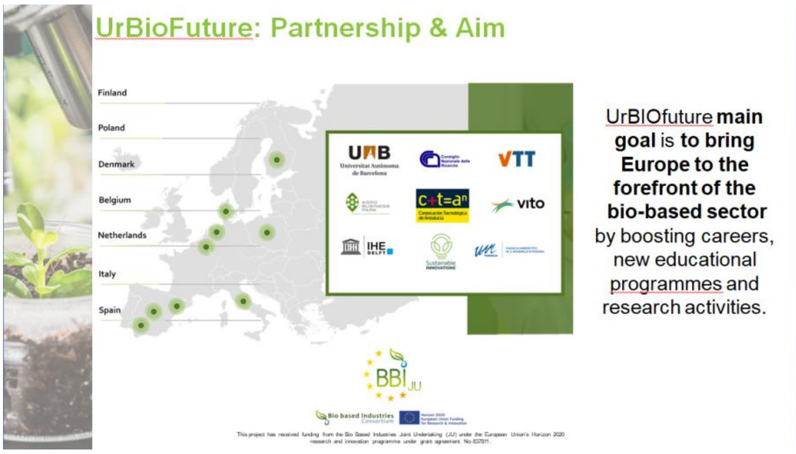


Promoting the circular bioeconomy means trying to create new value chains (new production chains) and new transversal connections between different industrial sectors.
Use of corn for fuel is an example of value chain, which connects agriculture sector with the energy sector.
However, to make bioeconomy sustainable, the usage of the biomass cannot go over the certain limits. This is why it is important to combine bioeconomy and circular economy into a new concept called **Circular Bioeconomy.**

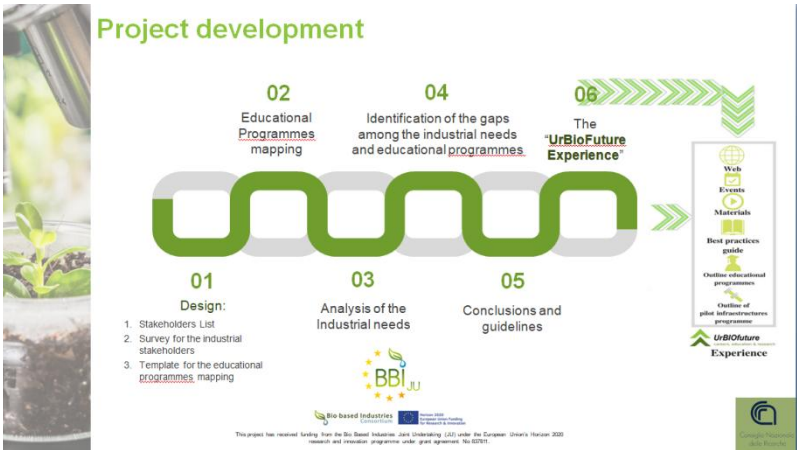
Circular Bioeconomy model requires new connections between the different sectors of industry where waste or by-product of one sector becomes raw material of another one.

3.1. Objectives of the project

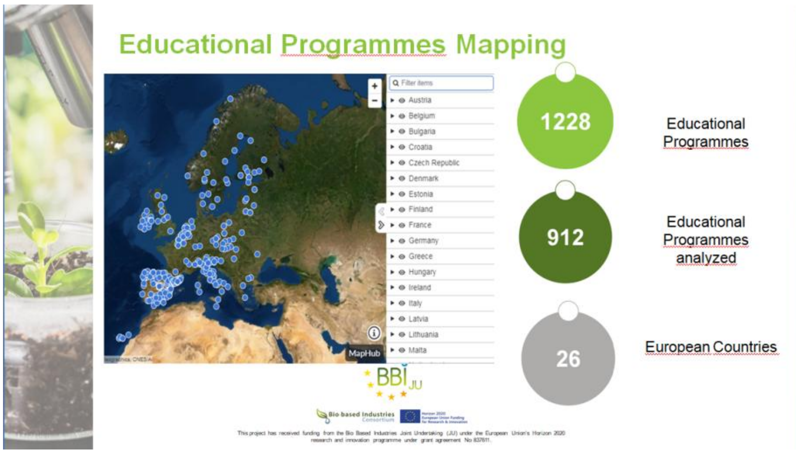
Main goal of "UrBIOfuture" project is to bring Europe to the forefront of the bio-based sector by boosting careers, new educational programmes and research activities.
The consortium consists of 9 partners from 7 different European countries with the different fields of expertise; from the education sector, academia to bio- industry.



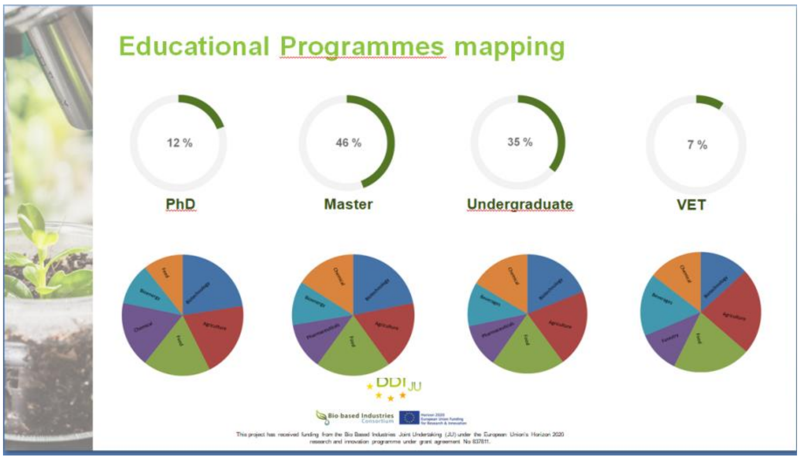
The project was developed by means of six important phases.
In the phase one, a survey was prepared and sent to bio- industrial subjects in order to identify their needs in terms of the qualification (and request skills) of the employees in the future.
At the same time, the data from all over the Europe about the active educational programs in the bio-sector, according to the predefined guidelines, was gathered.
After the profound analyse of the needs of industry partner and the educational offer on the market gaps were identified.
Finally, the road-plan of the action has been prepared in order to fill up those gaps.
This led to the creation of the "UrBioFuture Experience", or another words package of educational material (such as brochures and websites) and actions (e.g. events and workshops) aimed at the general society.



The mapping of the educational programmes in Europe has identified 1228 relevant bio-courses in the 26 European countries but at the end, only 912 were taken under the consideration since many of the programmes offered the same curricula.

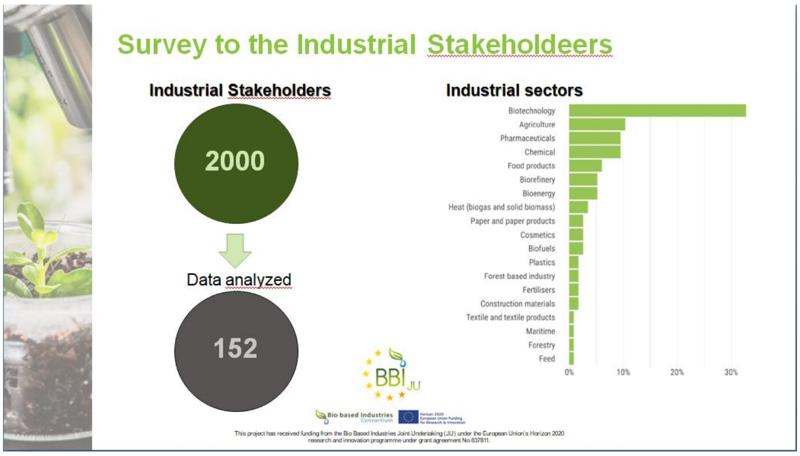


The analysed data included programs of different educational levels, from PhD courses to VET (vocational education & training) courses that are proposed by Higher Vocational Training Institutes. In our research, we were concentrating only on the courses linked to biotechnology, agriculture and food production.

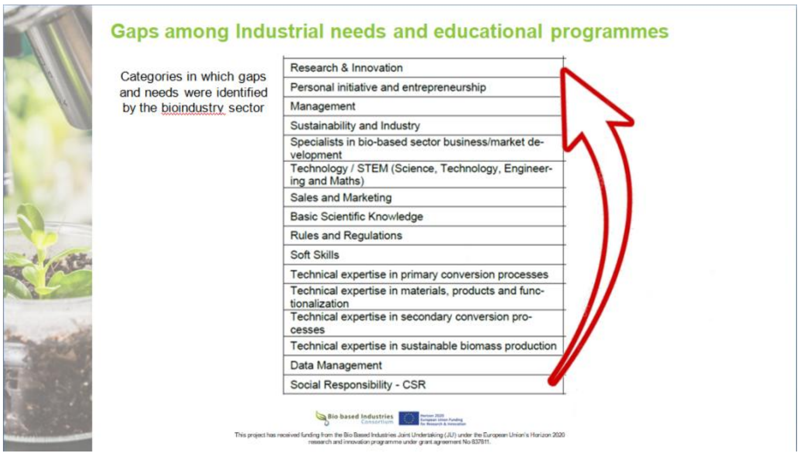


3.2. Results

Around 2000 companies were asked to participate in the survey on the needs of the bio sector in the future, but only 152 completed the questionnaire. Nevertheless, it provided significant amount of data to analyse. The 152 companies were mainly those from the field of biotechnology, agriculture, pharmaceuticals and chemistry.



The survey in the bioindustry sector identified gaps between industrial needs and training programs in 16 different categories, which are listed in order of importance in the table below.

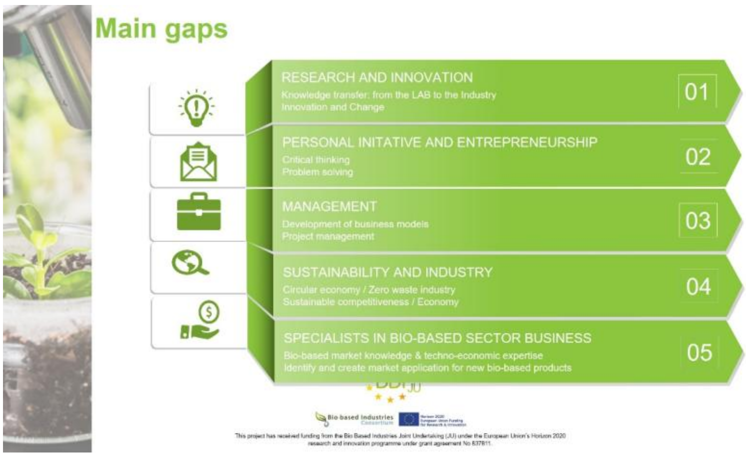


The figure below shows the 5 categories where the biggest gaps have been identified.

The need for the specialists in bio-based business, circular economy or management is understandable what emerges from that survey, as an interesting result is that the most critical needs come from the **research and innovation** category and **personal initiative and entrepreneurship**.

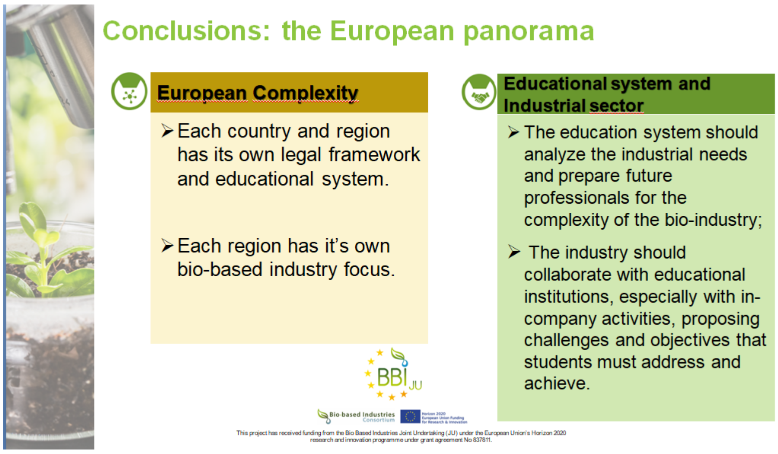
The crucial missing link was identified in the field of Innovation and Technology Transfer, another words upscaling of technological processes from the laboratory level to the industrial level.

Another critical point is that related to personal initiative of the employees, i.e. critical thinking and problem-solving skills



3.3. Action's roadmap

Drawing conclusions and setting guidelines was quite difficult, as it emerged from the survey, every country has its own unique educational system, which focuses on its own regional bioeconomy problematic. Therefore, it is very difficult to come up with general rules and proposals for the whole Europe.
A common aspect is that close collaboration is needed between the education system and the industry. That is, the education system should analyse what the needs of the industrial sector are and prepare future professionals for the complexity of the bio-industry.
On the other hand, the industry should collaborate with educational institutions, i.e. by organizing in-company activities, proposing challenges to students and supporting schools and universities by offering them some trainings on equipments.



In the end, the following five actions, necessary to strengthen the Bioindustry sector, were identified:

1. **Educating people with interdisciplinary skills** i.e. skills related to industry 4.0, digital skills, standard requirements for new bio-products, critical thinking and problem solving.
2. **Reshaping classroom learning** and developing flexible teaching by including experiences that **stimulate creativity and problem solving skills**.
3. Proposing **Case-Study** or **Project-Based** courses on bioeconomy and bioindustry
4. Creating strong links between European and national policy makers in order to lobby for the reduction of the administrative and financial restriction that compromise creation of traineeships in research centres and industries.
5. Promoting the training activities for educators in the bioeconomy sector.

3.4. Bio-Based Industries (BBI) programme

A strong industrial development of the bio-industry would significantly reduce Europe's dependence on fossil-based products and would help the European Community to achieve the objectives related to the problems of climate change and would lead to more environmentally friendly growth. The key to the success in that field is development of new bio-refinery and bio-processing technologies in order to transform renewable natural resources (biomass) into raw materials, fuels and consumer products in a sustainable way.
It is expected, that the bioindustry sector will grow rapidly in the near future creating new markets and jobs. It is already attracting significant investments in the United States, China and Brazil. The European Community has the industrial, research and renewable resources potential to compete in the global race for the Bioeconomy.
The objectives of Bio-based Industries (BBI) in Europe programme are:

- Raw materials: promoting a sustainable supply of biomass by higher productivity and the construction of new supply chains;
- Bio-refineries: research and development on the optimization of the efficiency of the processing, efficiency demonstration , and economic feasibility in both demo and flagship bio-refineries;
- Markets, products and policies: developing markets for bio-based products and optimizing the strategic political framework

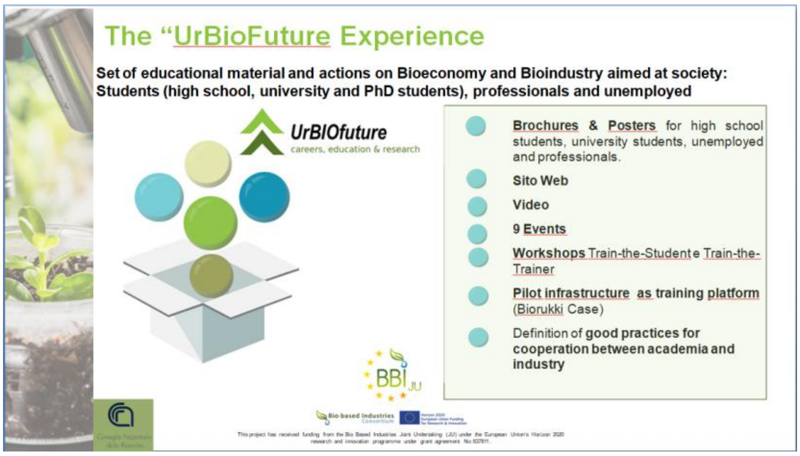
The expected effects are:

- Utilisation of the potential of bio-waste and agricultural and forestry residues;
- Diversification and growth of the farmers' income;
- Replacement by 2030 at least 30% of chemicals and fossil-based materials with biodegradable ones.

- Creation of infrastructure and jobs; 80% of which are expected to be in rural and underdeveloped areas;
- Creation of bio-based products that are comparable or/and superior to fossil-based products in terms of price, performance, availability and environmental benefits.
- Production of new bio –based products should lead to reduction of CO_2 emissions, on average, by at least 50% compared to production of the goods out of the fossil based raw materials.

4. UrBioFuture Experience

The "UrbioFuture Experience", is a package, which consists of the didactic and informative material, and a series of events focused on the Bioeconomy and Bioindustry. All the materials and initiatives in this package are the direct result of the work carried out under the umbrella of UrBioFuture project.



The aim of "UrBioFuture Experience" is the promotion of the bioindustry sector among young people as a possible career choice.

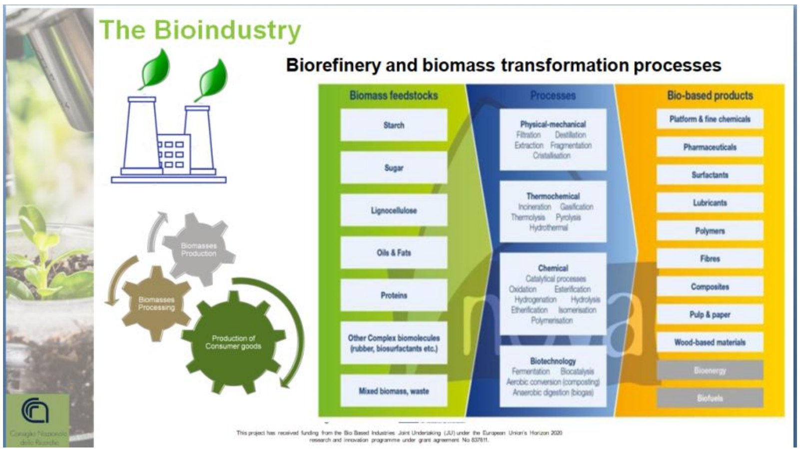
The material in that package is tailor made for the different target groups such as high school and professional school students, post-graduate and graduate university students, and new carrier or employment seekers.

The teaching material includes not only classic paper material like brochures and posters, but also digital and interactive material, which is available on the project website (https://www.urbiofuture.eu).

Under the events tab there are workshops and seminars (together with the calendar of that events) on the topics related to the bioeconomy and the circular economy prepared for students and educators.

Bio-industry plays a fundamental role in the bioeconomy. The term bio-industry refers to all those industrial activities involving the transformation of biomass (or industrial biomass) into consumer goods (such as biofuels, bioplastic cosmetic products, pharmaceuticals, etc.) through the so-called "biorefinery processes". For the purpose of creating consumer goods from organic and renewable raw materials and replacing the fossil-based versions defined as non-renewable, thus increasing the sustainability of industrial processes.

Examples of bio-based products are shopping bags, waste bags, bioethanol, compostable capsules, etc.

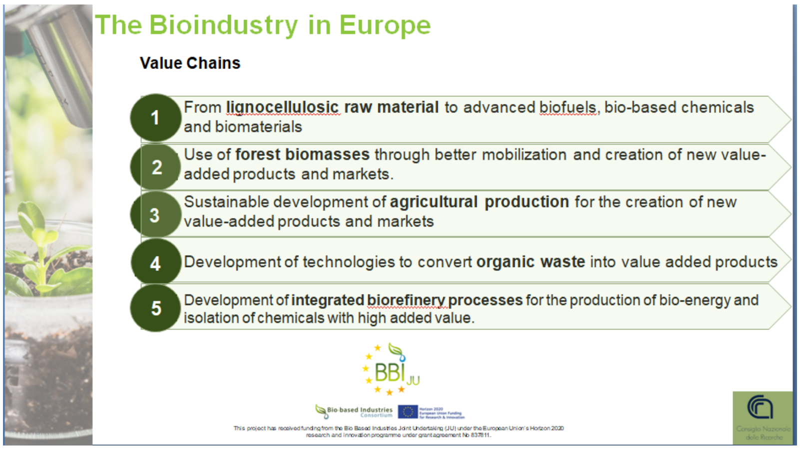


Furthermore, bio-industry plays an important role in promoting sustainable development. Therefore, it is essential to strengthen Europe's competitiveness, reindustrialising and revitalizing rural and coastal areas, through the conversion of brownfield sites and the creation of new development opportunities, thus allowing the creation of thousands of job opportunities.

The "VALUE CHAINS" in which the European Union is investing through the Research and Innovation projects are:

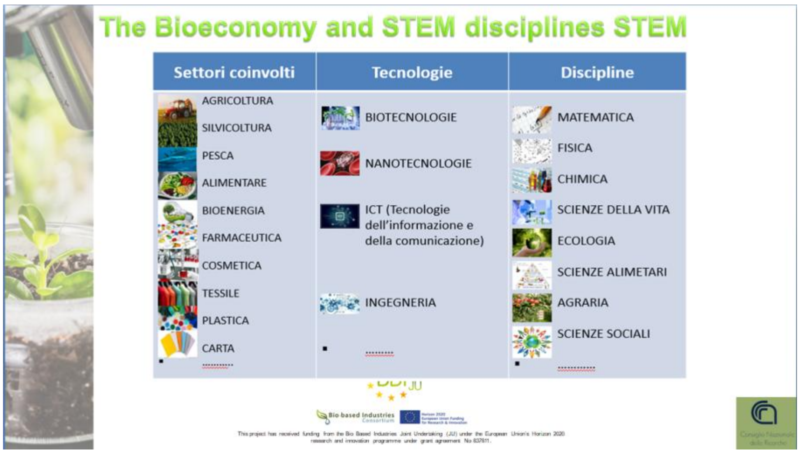
1) The utilization of lignocellulosic as a raw material in production of biofuels, chemical products and bio-based biomaterials
2) The utilization of biomasses deriving from the forestry to the production of new added value products
3) Sustainable development of agricultural production;
4) Development of new technologies which use processes of converting organic waste into value added products;

5) Development of integrated processes of bio-refinery for the production of bioenergy and the isolation of high value –added chemical substances.



The objective of the actions and tools developed within the UrBioFuture Experience is to promote especially, among the young people, bioindustry as an emerging sector, which in the near future will open new career paths and new job prospects.
The objective of this training is to share with you educators the teaching and communication material in order to make you aware of the importance of the bioindustry so you can become **ambassadors of the UrBioFuture Experience** and pass the massage to your students while helping them choosing their career.

Growth of the bioindustry comes from the recent development in biotechology and nanotechnology. These two areas of research are based on STEM subject. In this way elements of the BIOECONOMY and BIOINDUSTRY can be introduced within classic scientific subjects already covered by traditional courses. It is important to make students aware that economic development and environmental sustainability are inseparable and the EU promotes this economical model.



4.1. The project's web-site
Web – https://www.urbiofuture.eu/

The project's website is used as communication and information platform. It contains all the data, news and events generated by the project. Furthermore, it acts as a platform of the projects legacy: "UrbBioFuture Experience".

"UrbBioFuture Experience" is a fundamental tool for promoting new career opportunities in the bio-based sector in Europe. It is the result of the mapping of the educational offer in the field of bio-economy and bio-industry in Europe combined with the survey on needs of the bio-industrial stakeholders.

It contains:

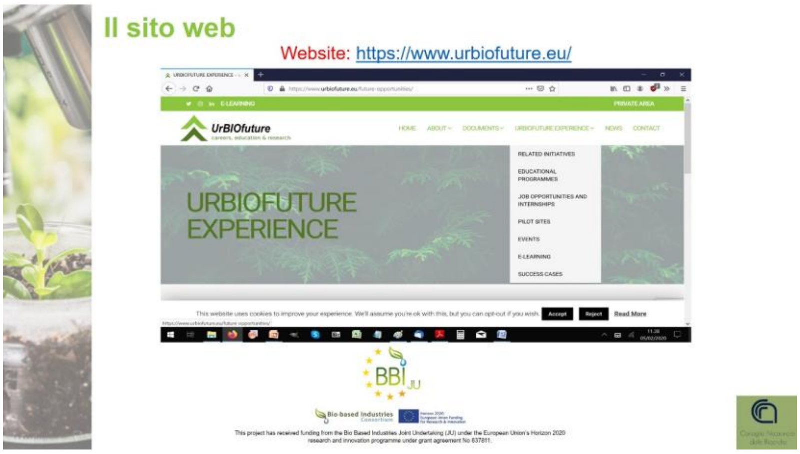
• Overview of the **trainings and workshops** related to the bio-based industry carried out in Europe

• Selection of **job opportunities and internships**;

•List of all existing open access **pilot and demo-infrastructures** across Europe related to bio-economy

•An **"e-learning"** platform where one can find educational material tailor made for teaching at schools, universities or adults who are seeking new job opportunities;

• A section **"Success cases**", contains recent success cases related to Bioeconomy from EU-funded Research and Innovation Programmes



By clicking on "UrBIOfuture Experience" it is possible to find information related to the European bio-industrial sector, job and traineeship opportunities, educational programs and research topics.

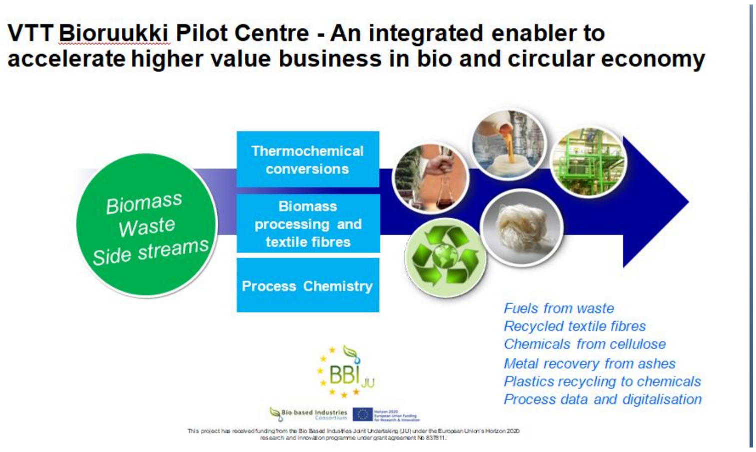
Under "Educational Programs" tab, one can find the overview (in a form of an interactive map and a table with the search engine) of the training offer regarding the bioeconomy and the bio-industry provided in Europe. This list contains information about course content, structure, location, organizing institution and it is constantly updated.
This tool was created to support young people and their advisors to have a better overview on the possibilities of training in the bio-sector, and thus to promote quality teaching in biosciences.

4.2. An example of the pilot site Biorukki – Finlandia

The VTT applied research centre in Finland has set up a Pilot Plant Centre for biorefinery and biomass transformation processes in order to offer students demonstrations of practical examples of the processes characterizing the bioindustry.
The VTT research centre has a long history in helping industrial partners to create and develop new industrial processes in all the stages of the producing line; starting from the initial idea, passing through the laboratory scale phase, up to the demonstrations on the pilot scale.
The VTT centre offers:

- thematic visits for institutes and schools,
- internships;
- possibility of carrying out internship for undergraduates;
- training activities for educators.

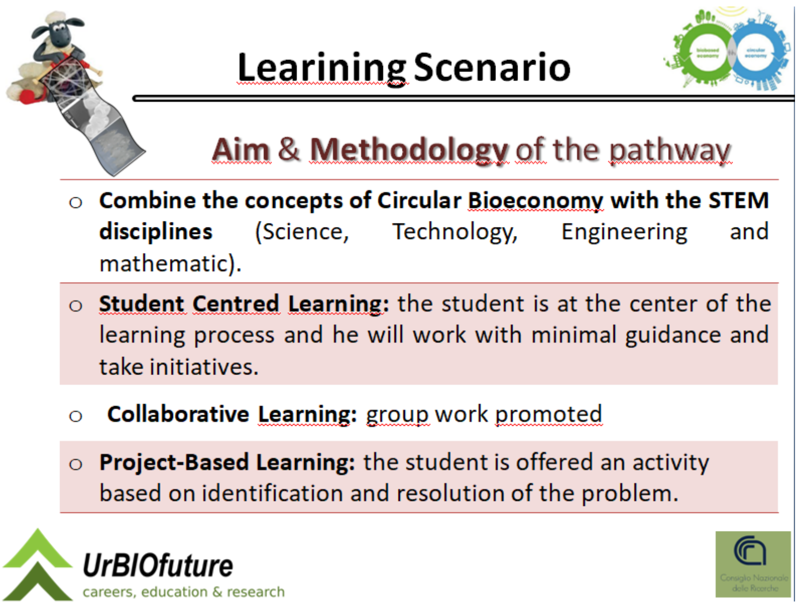
Biorukki plant offers to students hands-on, up to date practical knowledge in the bioeconomy sector and in this way create a new generation of technicians, scientists, managers and policy makers who will be able to face global challenges such as climate change, sustainability and efficient use of resources.



5. Experimental activities

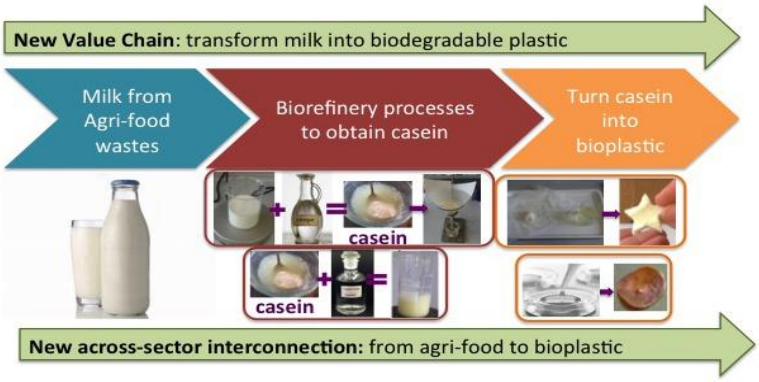
The activities proposed in this section are practical examples of Circular Bioeconomy, which can be proposed to the middle and high school students. These are laboratory experiments, demonstrating how to transform biomass into new bio-based products.

The main objective of these experiments is to show that the bio-industry sector seeks scientific knowledge and creativity.



1. Waste wool from agro-food industry - from waste to resource: simple experiments on how to use the behaviour of proteins in acidic-basic environments in order to transform wool into protein-based cosmetic soap.

2. Plastic from milk: experiments showing how milk protein (casein) can be transformed into an hard plastic or into flexible film by means of reactions with acidic and basic reagents.

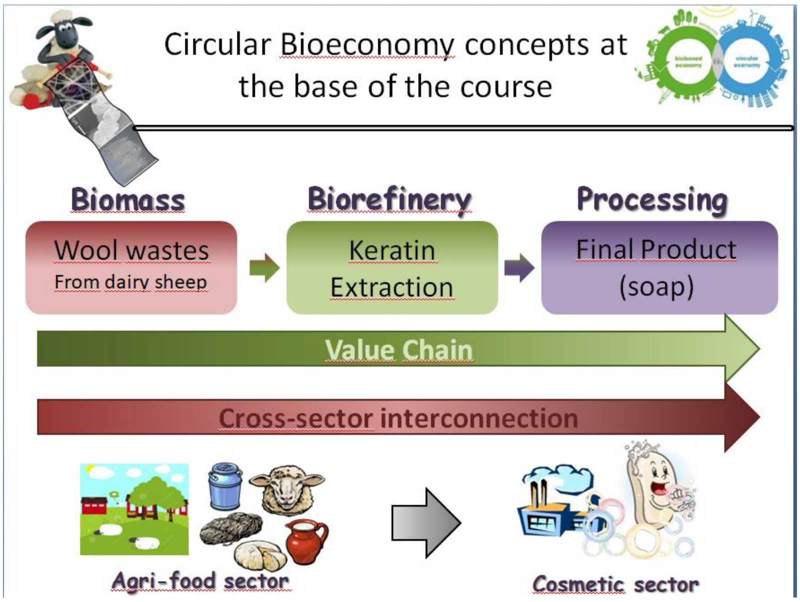


5.1. Waste wool of agro-food industry – from waste to new resource

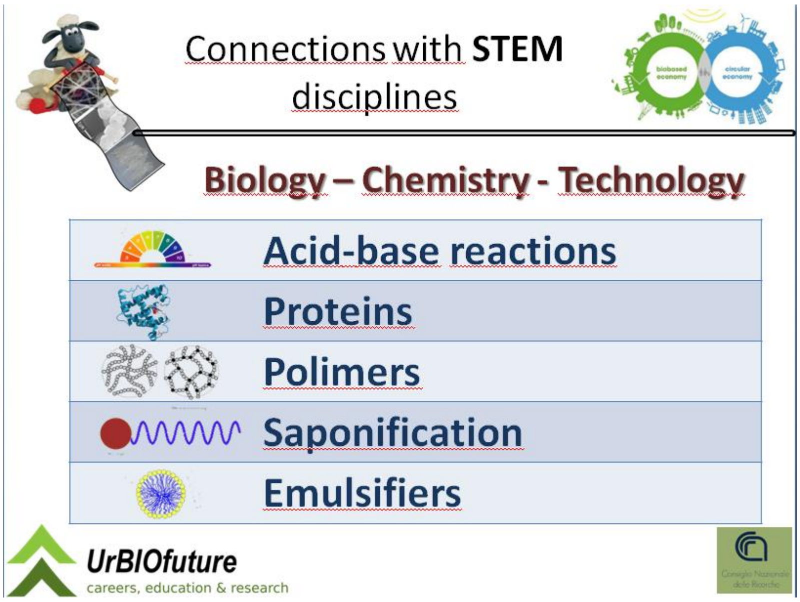
The concepts of Circular Bioeconomy in this experiment:

a) New value chain i.e. transformation from waste to resource of waste wool (biomass) to raw material: protein used for production of cosmetic soaps, through biorefinery processes and transformation (processing).

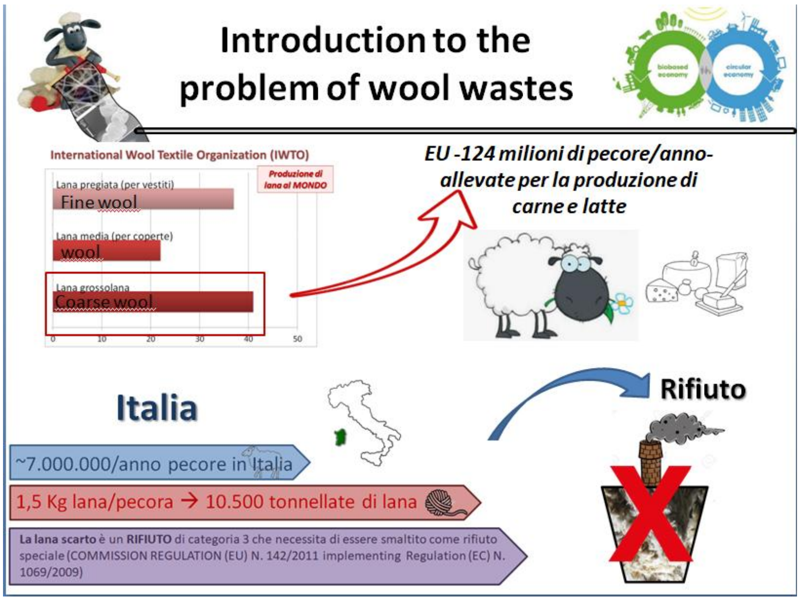
b) Creation of a **cross-sectoral connection** that connects the agro-food sector with cosmetic industry.



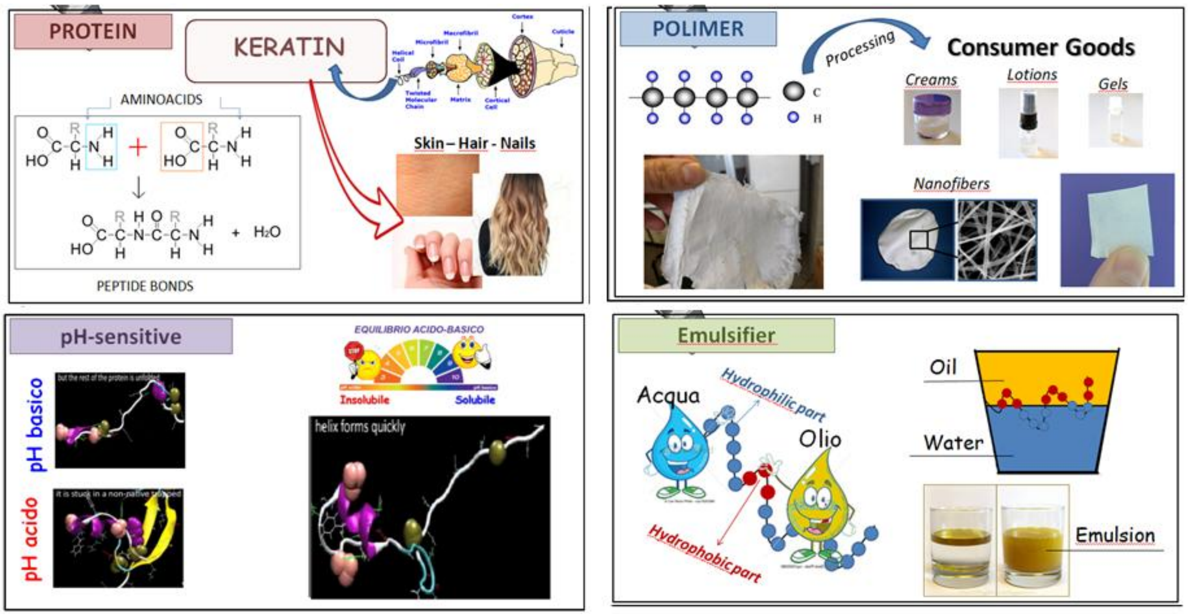
This experiment is connected also to STEM disciplines, mainly to biology, chemistry and technology (see the table below).



Introduction to the problem of a waste wool. 40% of the wool produced in the world is a coarse wool that does not have adequate chemical and physical properties for the textile industry. This wool derives from sheep (only in Europe there are 124 million/year) raised for the meat and milk production.
Only in Italy 10'500 tons of wool waste is annually produced. This wool is classified as special waste that needs to be disposed and cannot be burned, as combustion of it develops toxic substances.



But what kind of waste is wool? From a chemical point of view, wool can be described in various ways. Firstly, it is a protein composed by an amino acid chain, called keratin. Keratin builds some tissues in our body such as skin, hair and nails.
Keratin is a polymer, in which amino acids are repetitive units, and as such can be processed and transformed into different consumer goods.
Protein is sensitive to pH changes. By changing pH the keratin structure changes. In a basic environment, the protein chains are less tangled and therefore soluble. In an acidic environment the protein chains are tangled and the protein becomes insoluble.
Keratin is also an emulsifier (an emulgent) thanks to its composition. It contains both hydrophilic and hydrophobic amino acids, therefore it is able to bind with water and oil. It means that it helps to mix water with oil in this way creating an emulsion.



Laboratory activities

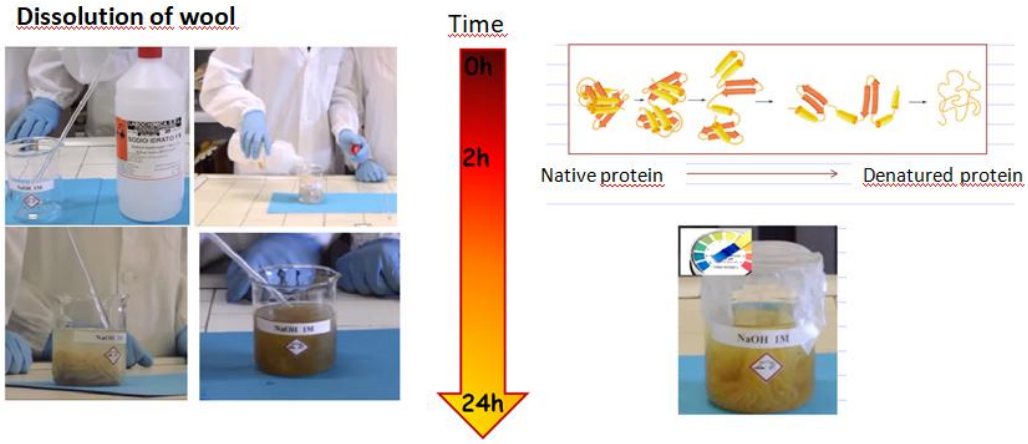
1. Extraction and flocculation of keratin from wool

Materials	
Coarse Wool	Test tube
NaOH 1M	Test tube holder
Vinegar	Gloves & Glasses
Beker (200 mL)	Protective Coat
tweezers	colander

<u>Keratin extraction phase</u>

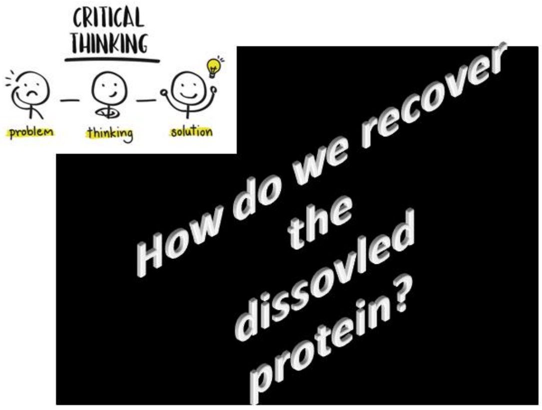
Method. The first step is to dissolve the wool fiber. Soak the wool fibers in 1M sodium hydroxide and then wait at least a couple of hours or if you can overnight. Students are asked to work in teams. They should write what they observe and try to explain the process they are observing.

Discussion. The wool fibers disintegrate; they become a gelatinous and dark. The NaOH solution has a basic pH, therefore keratin chains lose their 3D structure (denaturation), and the fibers dissolve making the solution gelatinous. The dark colour is caused by the degradation of some amino acids.

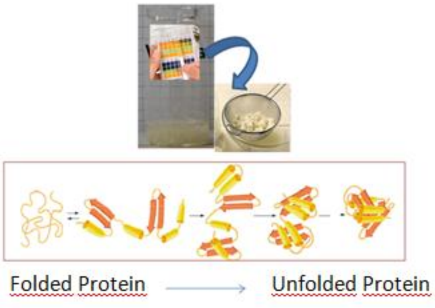


Keratin flocculation phase

Brainstorming. How do we recover the dissolved protein? We let the students work in groups and let come up with solutions.



Method. At this point, the keratin dissolved in the sodium hydroxide solution is recovered by flocculation induced by pH variation. For this purpose, it is necessary to take a sample of keratin solution and add it into vinegar (or 5% acetic acid).
Students are asked to work in teams and write down their observation and explanation of the observed processes.
Discussion. Keratin flakes precipitate from the solution. This process occurs because in the acidic environment of acetic acid the protein chains reorganize into complex supermolecular structures. The protein therefore becomes insoluble and can be easily extracted by filtration on a strainer.



2. Protein soaps out of keratin

When keratin is obtained, it can be used to prepare a protein soap.
What are the advantages of using keratin? It is a natural and eco-friendly emulsifier and an excellent substitute for synthetic emulsifiers. It is also a beneficial for the skin because of its protein nature.
But what is soap? Soap is a salt of a fatty acid, obtained by the basic hydrolysis reaction of a triglyceride caused by a strong base such as NaOH (Triglycerides are esters containing one glycerol molecule and three fatty acid chains), as shown by the following scheme reaction:

$$\begin{array}{l} CH_2\text{-}OCO\text{-}R \\ | \\ CH\text{-}OCO\text{-}R' \\ | \\ CH_2\text{-}OCO\text{-}R'' \end{array} + 3NaOH \longrightarrow 3R\text{-}COONa + \begin{array}{l} CH_2\text{-}OH \\ | \\ CH\text{-}OH \\ | \\ CH_2\text{-}OH \end{array}$$

trigliceride *sapone* *glicerolo*

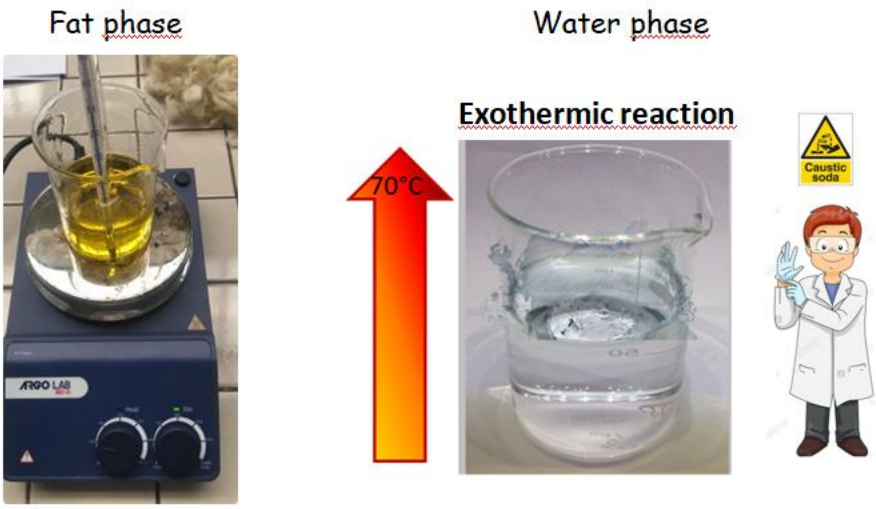
The list of necessary materials needed for the preparation of the soap is shown in the following slide. We use almond oil and olive oil as a fat phase and sodium hydroxide as an aqueous phase.

MATERIALS:

- Becher 200 mL, flask 250 mL, heating plate, mixer, balance, spatula, molds, pipette, shaker, thermomether, graduate cylinder 100 mL;
- Keratin, NaOH pellets, almond oil, olive oil, distilled water;

Method. We proceed with the preparation of the fat phase by mixing the oils and heating them up to 45° C. For the preparation of the aqueous phase, the caustic soda has to be dissolved in water. This phase is very delicate because sodium hydroxide is corrosive and the reaction of its dissolution in water is exothermic (produces heat). Therefore, it is very important to wear protective laboratory gear i.e. laboratory coat, gloves and protective glasses.

At this point we prepare the so-called trace by mixing the fat phase with the aqueous phase with an emulsifier (kitchen immersion blender). The extracted keratin powder has to be added to the trace and then some fragrances such as lavender oil can be added too. Then the tape is poured into special moulds and left to mature for 8 weeks. After that time the keratin soap is ready for use.



5.2. Bioplastic from milk

The concepts of Circular Bioeconomy in this experiment:
a) Expired milk (derived for example from distribution) or surpluses (farms and dairies) is used as BIOMASS. Casein is extracted through a biorefinery process, creating a product similar to plastic, which can be moulded into different shapes or processed to obtain films.
b) A cross-sectoral connection is created between the agro-food sector and the packaging and plastic industry.

BIOMASS

Expired milk

BIORAFFINERY

Casein extraction process

TRANSFORMATION

Bioplastic

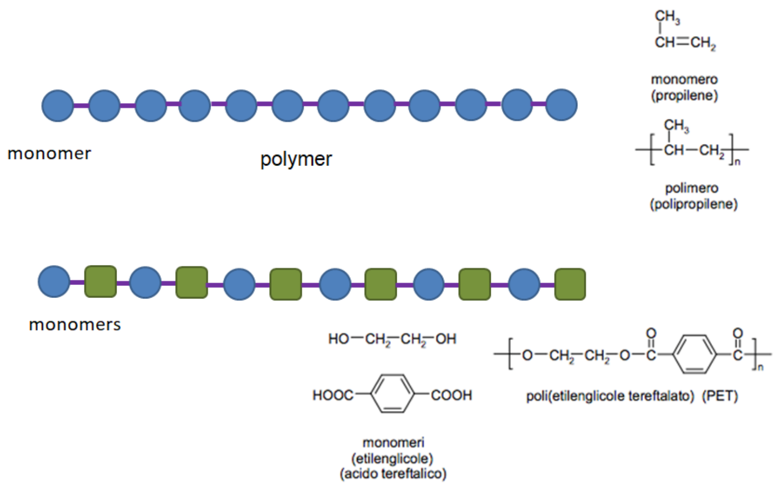
The connections with the STEM disciplines.
This experiment is connected to STEM disciplines, mainly to biology, chemistry and technology (see the table below):

Biology– Chemistry– Tecnology

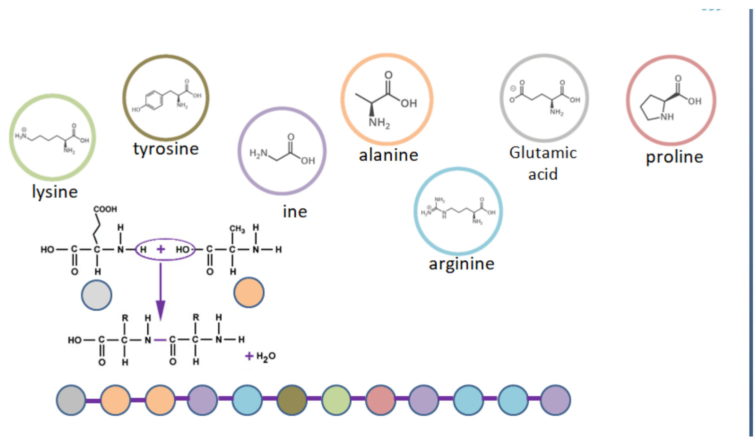
	Acid-base reactions
	Proteins
	Polymers
	Colloidal solutions

Introduction to the problematic of plastic. For years the production of plastic has followed a linear economy model i.e. produce, use (often for very short period of time) and throw away, giving rise to the accumulation of huge quantities of plastic all over the world. 290 million tons of plastic materials are produced every year where some of them have degradation time that reaches millennium.

Plastics is made up of molecules called polymers, which are made up of small molecules (monomers), linked together in long chains.

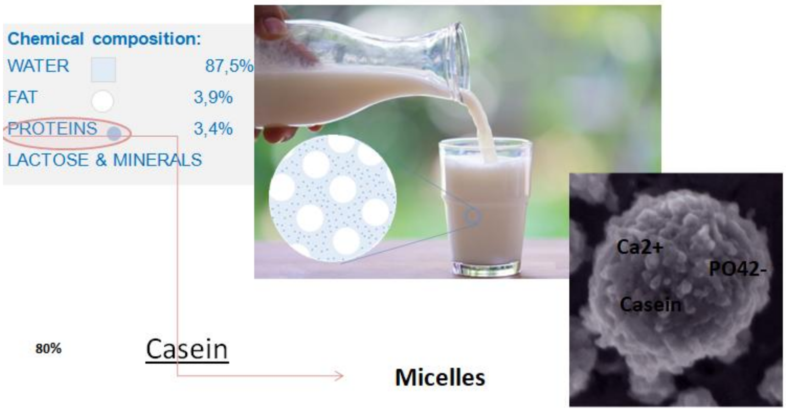


From the definition of polymer, it can be deduced that also in nature there are different types of polymers, one of them are proteins. The monomeric units are made up of amino acids linked in a long chain through the peptide bond to form the biopolymer.

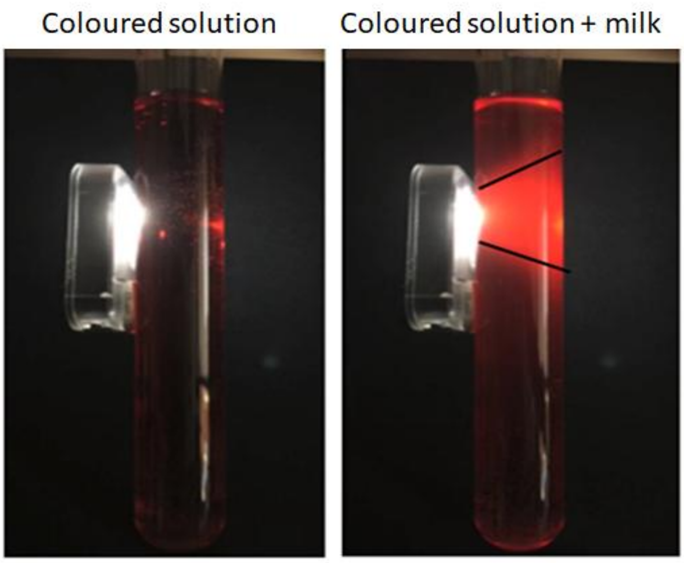


Milk, a common food that we all know, is actually a complex solution from the chemical point of view:

- it is an emulsion of fats in water;
- and a colloidal suspension of proteins;
- and a solution of other compounds, including lactose and minerals.
- 80% of milk proteins consist of casein. Casein is relatively hydrophobic and it forms micelles in water. These micelles are rather porous structures of 50-300nm size. In addition to casein, milk micelles contain calcium and phosphate, citrate, and enzymes and have the biological function of transporting large quantities of calcium and phosphate.



These micelles form a colloidal solution, i.e. a solution of uniformly dispersed nanoparticles suspended in a liquid medium. The presence of these nanoparticles, together with other biomolecules such as lipids, determines the white colour of milk, as they scatter light in all directions.



This effect is called the "Tyndall effect". When a beam of light passes through a pure liquid (such as water) or a solution (red dye, look at the photo), its path is almost not visible because the molecules in solution are too small to disperse the light (less than 2 nm – see left image in the Figure).

In colloidal systems, on the other hand, the particles have dimensions comparable to those of the wavelengths of the beam of light (50-300nm) and are therefore able to disperse the light. Thus, when milk is added to the dye solution, the light that hits the milk particles, is dispersed and forms a cone (image on right in the Figure)

The structural organization of milk proteins (like all proteins) is determined by both electrostatic and hydrophobic interactions that allow the stability of the emulsion.

There are several methods of breaking this stability, widely used in the dairy industry i.e. in the process of the yogurt or cheese production.

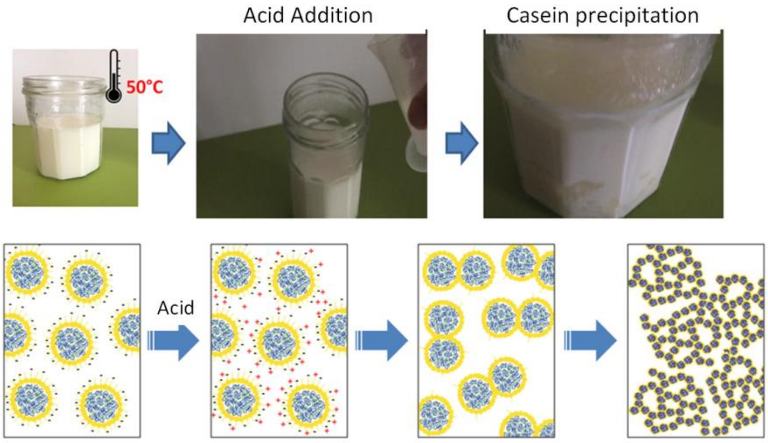
The change in protein structure is called **denaturation** and it changes the secondary, tertiary or quaternary structures of proteins without changing the composition and sequence of amino acids (peptide bonds are NOT broken).
Main methods of denaturation of proteins are:

- **chemical denaturation** which occurs by treating proteins with chemical substances (acids, alcohol, salts etc.);
- **thermal denaturation** by heat or cooling
- **mechanical denaturation** by shaking.

Laboratory activities
Casein chemistry: coagulation.

MATERIALs LIST	
Skim Milk 80 mL	Tablespoons
White vinegar 8 mL (acetic acid 5%)	Bunsen burner or hot plate
Becker (100 mL)	strainer
Thermometer	Measuring cup

Procedure and Discussion.
Heat the milk to 50 ° - 60 ° C. What happens?
Under normal conditions, the milk's pH is 6.7 and the casein micelles are stabilized by negative charges of the COO^- residues of the amino acid side chains and of the negative hydroxylphosphate ions which are bound to caseins. Thanks to these negative charges, particles repel each other.
By adding acid, the milk pH lowers and when the isoelectric point of casein is reached (pH 4.6), the electric charge of the protein is zero. Thereupon, there is no longer any electrostatic forces between the particles that leads to their aggregation and formation of serum. The same process occurs during chees production when rennet is added.
The coagulated protein can be simply filtrated with a colander, formed to the desired shape and dried.



The protein can be also processed in liquid form. This process can be carried out by mixing about 2g of casein with 3 mL of 0.1N NaOH. Stir it for about 15 minutes or until casein is completely dissolved.

By dissolving the precipitated casein with NaOH, a viscous solution containing highly water-soluble sodium caseinate can be obtained. They can be captured with a pipette and deposited in a support / stencil.

The solution should be left for about two days to dry and then a biodegradable plastic is obtained.

By using different methods, casein can be extracted in a solid or a liquid phase and transformed into different materials.

Here is the space for your creativity! ☺


Good job everyone!

Consiglio Nazionale delle Ricerche