


SYSTEMIC DESIGN 2019

POLITECNICO DI TORINO

Collegio di Design

Systemic Design Master Degree

MATERIALS OBTAINED FROM BY-PRODUCTS OF AGRO-FOOD INDUSTRY FOR BIOBASED PRODUCTION

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- Abstract -

According to the book "*The Limits to Growth*", a report of the Club of Rome, the worldwide population will increase exponentially as time progresses. Afterwards, most of the people will become consumers of productive sectors, such as the agro-food industry, which will continue to increase its production and decreasing the base raw material. This prospect makes imperative the ideation of solutions to harness the 100% of available raw material, and the creation of new productive chains based on waste. This particular research case aims to contribute to the production of bio materials, and therefore, to reduce the use of toxic products that are polluting the environment.
The topic of study is based on the concept of Circular Economy and, intents to provide an alternative source of profits for the territories that concerns the researcher, Italy as hosting country and Colombia as place of origin.
This project focuses on the importance of converting the agro-food industry by-products into value-added goods. Specifically, the purpose of this study is to develop a product mainly elaborated from starch extracted from potato peel and platano skin a by-product mostly discarded. To this end, the procedure of homemade/lab scale experiments to make bio materials from organic waste will be indicated, and the results of the test will be presented such as the creation of prototypes of materials.

Key words:
Biopolymer - Starch - Potato - Adhesive Biodegradable - Circular economy - systemic Design - Subproducts - Waste - Network materials - Sustainability - Agrofood industry -Raw materials - Italy - Colombia - Plastics.

- Acknowledgments -

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Finally, I want to thank Leslie Aguirre, Chemical Engineer who made a constant follow-up of my progress and, gave me advice on the chemical theoretical content and about appropriate written presentation.

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- Introduction -

"We have a situation in which five billion plastic bags are used every year and one million plastic bottles are bought every minute. Almost 70% or more go to the environment or to landfills and more than 13 million reach the sea every year", explains *Leo Heileman*, the regional representative of the United Nations Environment Program for Latin America and the Caribbean (UNEP).

The worldwide production of plastic is increasing rapidly; it is a daily growing business.

In 2017, around 350 million tons of plastic were produced worldwide, with 51.2 million tons corresponding to the European demand. From that amount, 39.7% was intended for packaging. Likewise, 27.1 million tons were collected as plastic waste in the EU, and more than a quarter of that waste was landfilled. After Germany, Italy was the second country in the EU that demanded more plastics, with 14% of the total amount for that year.

Looking for alternatives to reduce the amount of waste and to change the feedstock of industry, governments have turned to enact strong policies that push towards a more circular model of design and production of plastics. This means a model in which there is no waste, but resources for different sectors, and in which systemic thinking must go first.

Some examples of these initiatives include the Directive of 2015 for plastic bags adopted by the European Commission, the "Plastics 2030 Voluntary Commitment" by PlasticsEurope (the Association of Plastics Manufacturers in Europe), and the recently approved law by the European Parliament banning diverse single-use plastic products by 2021.

In all the cases, the objective of the regulations is to foster the use of sustainable alternative materials for manufacturing, to encourage the change of consumption patterns of people and to strengthen the extended producer responsibility of industry. In other words, changing the current situation requires a holistic perspective, with collaborative work making an overall positive impact, instead of individual achievements for own benefit.

Consequently, this thesis project of Systemic Design aims to reduce the imbalance between production and resource consumption by adding value to a by-product or, incorrectly so-called waste, of the agro-food industry, transforming it into an alternative sustainable feedstock, and later into a viable bio material. Particularly, the by-products selected for this study is the potato peel and the platano skin. Value would be added to the peel by harnessing its content of starch. Finally, the starch would become a substitute material to replace petroleum-derived plastics.

The research comprises two local contexts, the region that I now interact directly with, and my country of origin. On one hand, the Piedmont region, in northern Italy, where I currently reside. This an area rich in cereal crops with a large number of industries within the agro-food sector.

On the other hand, Colombia, in South America, my home country. A territory with a deeply rooted agricultural production dedicated mainly to the cultivation of tubers, and with a large volume of resources that can be intervened to generate a positive impact.

mercial ones, but with zero negative impact.

Part I
Identifies the theoretical framework around alternative sustainable materials that can be used to develop bio based products related to plastic and adhesives, with the theory pf circular economy system as base.

Part II
Describes the experimentation stage, on a homemade scale, with some agro-food by-products such as potatoes and platanos skin, to create bio-based materials that could be used as products with different approaches.

Part III
Shows the tests made with the adhesives to produce a bio-based material that can be converted into a product with similar characteristics to the commercial ones, but with less negative impact.

This image shows in a general way the current process of the production and use of potato and platano waste, in order to demonstrate what is sought to be achieved with the next project, generate a systemic approach in which waste creates a new chain that generates benefits based on the circular economy, returning to the earth and creating different positive points represented as stars.

“ Practical solutions aiming at a circular economy include eco-design, waste prevention programs, and extending the lifetime of products *(European Environment Agency, 2016)*.

“Reduce, reuse and recycle” are three important waste management options.
The minimization of raw material use, energy input, and waste production whereas the reuse principle refers to the repeated use of products or components for their intended purpose *(Ghisellini et al., 2016)*. ”

Recycling is mostly used to save energy, resources, and emissions and decrease the environmental impacts of a material's use.
The use of recycled instead of virgin material is generally also perceived as a beneficial solution *(Grosso et al., 2017)*.

In the context of packaging waste, reuse and recycling are political means to initiate a change, which is expected to deliver both economic and environmental benefits *(EC, 2015)*.

Birgit Geueke, Ksenia Groh, Jane Muncke, Food packaging in the circular economy: Overview of chemical safety aspects for commonly used materials, Journal of Cleaner Production Volume 193, 20 August 2018, Pages 491-505

Part I
- Theory research -

1. Ethics and circular economy

Currently, environmental policies are being proposed around the world to reduce the use of toxic substances and the misuse of natural resources. One strategy to achieve the environmental management required for these policies is following a Systemic Design. Through a Systemic Design, by-products (waste) from a supply chain are transformed into the feedstock of another one. In this way, not only environmental impacts are decreased and the maximum value from 100% of materials is obtained, but also new productive networks, jobs and local development systems are created, comprising economic and social benefits.

“A systemic approach is required to create a net of relationships in which a system output becomes the input for another one. The creation of a relationship network is then promoted, producing a general wellness improvement in people, activating cash flow between the various system actors, and improving production processes through a continuous transformation of matter. The cultural and value systems are so spontaneously redefined, with direct environmental benefits”. (Bistagnino, 2011).

With the determination of encouraging this concept in sustainable projects, this research has emphasized the use of peel of organic products, currently discarded from food industry processes, as valuable input for bioplastic manufacture. Today, these peels are used for other purposes such as feeding livestock or producing energy from biogas. However, their properties are similar to those of the internal product they are containing. Then, a new production chain can come from resources that many companies are disposing of.

“The circular economy promotes closing loops in industrial systems, minimizing waste, and reducing raw material and energy inputs” (Euro- pean Environment Agency, 2016; Stahel, 2016).

"What the circular economy tells us is that it is necessary to change the way we currently produce and consume, which is based on a linear economy of extraction - production - consumption - waste. What we want is to move to a circular economy in which we have to close the production cycles and maintain a constant flow of natural resources.

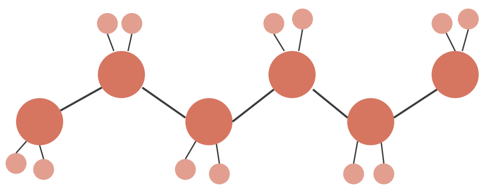
Basically, it would be to say that we have to be inspired by nature where the concept of waste does not exist. Everything that nature generates is an input or food for another organism. Think of the forest, the leaves of a tree become compost for the land; a dead animal, another comes and eats it. Everything is a closed flow in which everything flows ". (Zacarías Adriana 2017).

To achieve this system it is necessary to change the paradigm of the consumer and create a responsible society aware of the environmental consequences that over-consumption may generate in the future. According to the European Parliament, plastics represent between 80% and 85% of the objects found as marine garbage on European beaches.

This problem can be controlled by carrying out some improvement actions, including the use of natural waste for the development of biopolymers with properties similar to current products, but, biodegradable or compostable. Thus, creating a network that optimizes the activities of a region and achieves mutual benefits and a balance for ecosystems.

2. A look at polymer types and categories

A polymer comprises a network of long series of small bonded molecules, also called monomers. Thus, it can be understood as a macromolecule of monomers. The number of monomers, their arrangement, molecular weights, and forces, determine the properties of the polymers and therefore, their classification and applications.



On one hand, since many of the components found in nature are structurally polymers, the most common classification for these macromolecules relies on natural or synthetic types. Either the physical foundation for organic tissues such as collagen and lignin, the vehicles of information and biological processes, through proteins and DNA, or the fibers to make clothes such as cotton and silk, all of these constitutes natural polymers. From there, mixtures of long-chain molecules, mainly extracted from petroleum, bring about synthetic polymeric materials.
(See Table 1).

Natural	Synthetic
- Cellulose	- Polyethylene
- Lignin	- Polystyrene
- Wood resins	- Polyvinyl chloride
- Starches	- Vinyl acetate
- Proteins	- Polyformadehyde
- Nucleic acids	- Polyester
- Diamond	- Polyamide resins
- Graphite	- Polyurethane
	- Silicones

Table 1. Types of polymers

On the other hand, based on the mechanical properties resulted from molecular forces within the monomers chains, polymers can be classified into four categories: Elastomers, Fibres, Liquid resins, and Plastics [a. Thermoplastic and b. Thermosetting plastic]. *(See Figure 1).*

Elastomers

Polymeric chains held together by weak binding forces. Hence, these are thick but elastic substances, highly amorphous. These polymers retract to their original shape after stretching.
E.g. Rubber, neoprene.

Fibres

Straight polymer chains keep togheter by strong binding forces. These create long, solid and crystaline filament materials, with high tensile strength.
E.g. Polyamides such as nylon, polyesters such as terylene.

Liquid Resins

Polymers in a liquid form, mainly used as adhesives.
E.g. Epoxy adhesives and polysulphide sealants.

Plastics

These are polymers with molecular forces in-between elastomers and fibers, so they are moderately crystalline, but hard materials, that can be shaped by heat and pressure. The thermoplastic polymers can be mold anytimes by heating and cooling processes, whilst thermosetting polymers become infusible after heating and cannot be reshaped.
E.g. Polystyrene and PVC (thermoplastic), urea-formaldehyde resins (thermosetting).

Figure 1. Categories of polymers

"Gluing is the junction of two substrates by adhesive, which according to the UNI EN 923 standard is a substance capable of joining materials by surface fixing. The glue is the substance or solvent that puts the elements in contact so that they form a single whole."

-Treccani

2.1 Adhesion and Cohesion
Why is it important to analyze this topic?

Precisely because the objective is not to join or paste two surfaces, but to generate an union between particles to compact and generate a solid material as the term cohesion refers: attraction between particles or the intermolecular force of the same substance, while adhesion is the attraction between particles of different substances, such as when water adheres to a surface.
An example of these properties, regarding the topic of the project, is the fact that the adhesive substance has an internal force between its particles in order to hold them together, this effect would be cohesion, but in turn the adhesive comes into contact with polymeric particles to generate a union, this is called adhesion.

Some aspects that the glues must contain are:

a) They must behave like a liquid, at some point during the bonding.

b) They form superficial attachment through adhesion (the development of intermolecular forces).

c) They must harden in order to carry a load that is sometimes continuous, sometimes variable throughout life.

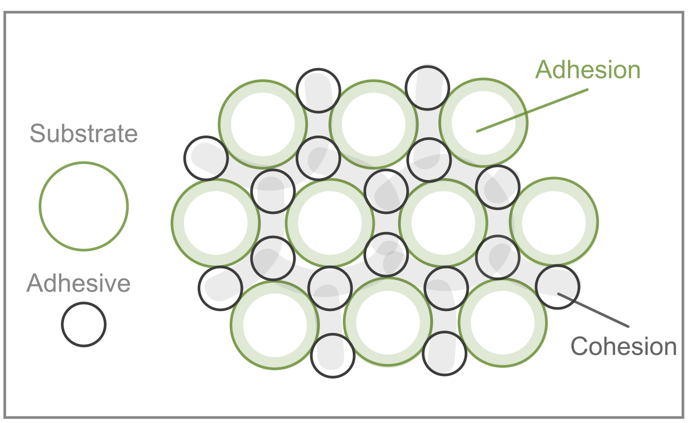


Figure 3 Substrate and husk rice particles Adhesion - Cohesion

d) They transfer and distribute the load between the elements in an assembly.

e) They have to fill in spaces and cavities.

f) They have to work with other elements of the whole to provide a durable product.

In the process of adhesion, the material to be glued is called the substrate. After binding, the substrate is often referred to as adherent (though sometimes these two terms are used interchangeably).

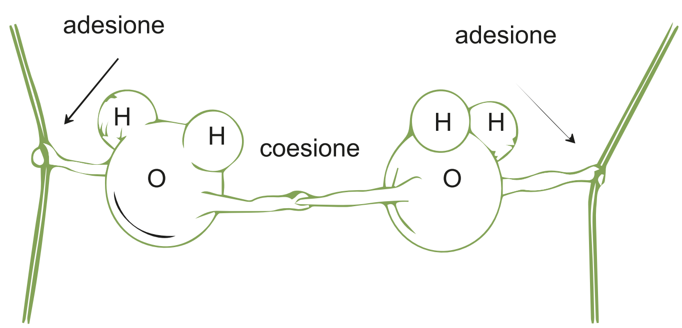


Figure 2 Cohesion and adhesion forces

The area between the adhesive and the adherent is referred to as an interphase region, this interphase region is a thin region near the adherent adhesive contact point.
The interphase region has different chemical and physical characteristics than the collective adhesive or the member; the nature of the interphase region is a critical factor in determining the properties and quality of the bonding adhesive.
(See Figure 2)

“Biodegradability is an inherent property of a material or product resulting from the action of naturally occurring microorganisms, such as bacteria, fungi, and algae. The process produces water, carbon dioxide, and biomass. No additives are needed and no fragments remain in the environment.

Composting is enhanced biodegradation under managed conditions, such as temperature, humidity, and microorganisms present. In the case of industrial composting, the requirements are clearly defined in internationally agreed standards such as EN13432, or ISO 18606. For biodegradation in other environments other standards can and should regulate the framework conditions and pass/fail criteria.”
(© European Bioplastics)

2.2 Biopolymers

The remarkable properties of many synthetic polymers, their stickiness, high strength or low density, among others, have made them not only useful but even necessary for numerous applications of daily life. Polymers have applications in areas ranging from medicine, consumer science, and industry, to sports. Manufacturing has relied on the use of polymers for its growth and development and has accustomed the population to a synthetic and disposable lifestyle. However, the environmental damage caused and the depletion of the non-renewable fossil reserves, required for the manufacture of many of the synthetic polymeric materials, has turned the attention of researchers and producers towards more natural and harmless replacement options. Thus, biodegradable polymers from renewable sources, commonly known as biopolymers, are increasingly attractive for use in the market.

Although the prefix 'bio' of biopolymers might merely refer to the renewable or natural origin of polymeric raw materials, this is not completely accurate. Despite they are obtained from natural and renewable resources, some biopolymers require synthetic processes to degrade later by biological means. The fact of being biodegradable is what leads to the use of the prefix 'bio'. Thus, a biopolymer can progressively breakdown into natural monomer units such as water and carbon dioxide, due to the action of biological processes. According to the *UNE 13432* standard, the estimated time of degradation of bioplastics is 6 months under controlled conditions of compost, while oil derivatives can degrade for up to 400 years, causing damage to ecosystems, diseases, accumulation of waste and greenhouse effect.

Based on the method used to produce biodegradable polymers, they can be classified into three different categories:

- Biosynthetic: result from natural sources, widely used to replace petroleum plastics and create biodegradable composites (e.g. starch, cellulose, poly(3-hydro alkanoates). They are limited by little mechanical properties, high water absorption and low degradation temperature.

- Semibiosynthetic: are produced from the transformation of natural monomers through a synthetic technique. These monomers are mainly obtained by fermentation. The most known type of semibiosynthetic polymer is poly (lactic acid) or PLA, which monomer form of lactic acid is originated by fermentation of corn. Although these macromolecules have water and oil resistance, they can generate brittle materials.

- Chemosynthetic: are degradable polymers essentially made by polyesters, which ease the adhesion between polymers and natural fibres, to finally creating composites. Poly(e-caprolactone) is the best example of a chemosynthetic polymer. It is a highly hydrophobic polymer (Vasile Cornelia, 2009).

Although these biopolymers commonly require the use of plasticizers to improve their intrinsic properties, they may become the best available option to reduce the consumption of synthetic plastics. At the time of use, bioplastics can be made transparent and achieve high strength properties and great barrier features, while they are still produced from renewable resources.

2.3 Biodegradation

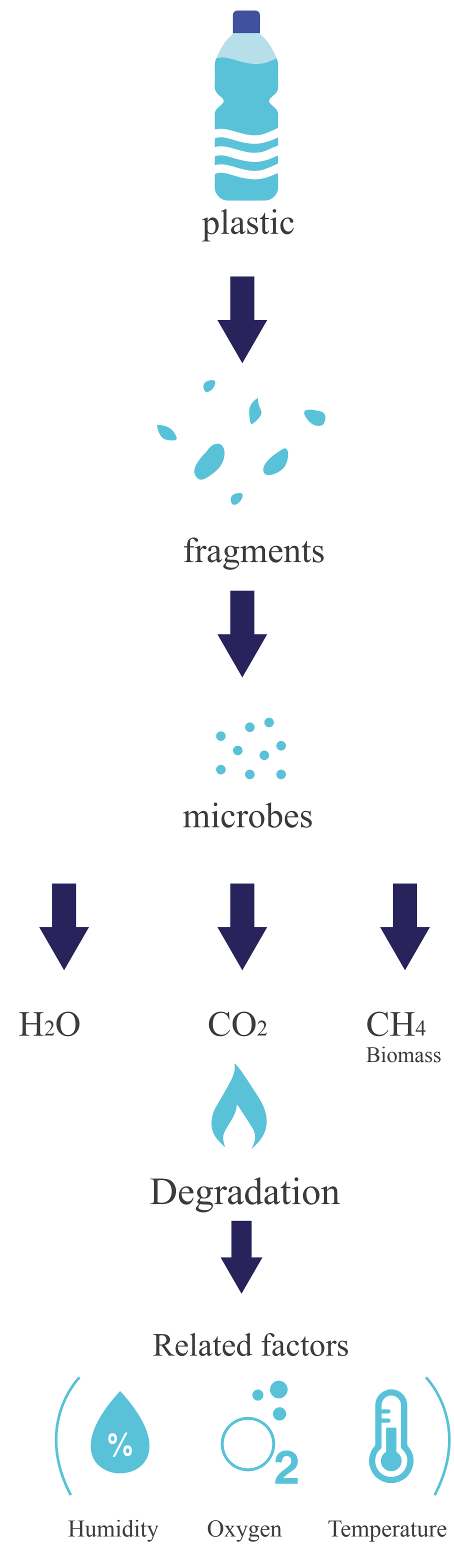
The next information has been taken from a report of the European Commission. *Brussels, 16.1.2018* **in order to differentiate the definitions according to the type of polymers.**

"Biodegradation" is a process by which material disintegrates and is ***decomposed by microorganisms*** into elements that are found in nature, such as CO2, water and biomass.

Fragmentation
This first stage of degradation prepares the oxo- degradable plastic for biodegradation by reducing the molecular weight of the plastic to the point where it may be consumed by biological organisms.
If the circumstances for fragmentation to take place are absent or insufficient, biodegradation will not take place.

While oxidising additives will, in an open environment, accelerate fragmentation of traditional polymers, the pace of fragmentation varies significantly depending on conditions determined by temperature, light intensity and moisture.

The type of material determines the type of degradation, which greatly influences the final result of the material and environmental impact, this issue will be shown in the following pages, emphasizing the different processes of plastic degradation according to the type of environment and chemical physical process.



http://ec.europa.eu/environment/circular-economy/pdf/oxo-plastics.pdf

Figure 4 General representation of a biodegradation process

2.4 Oxo plastics

Oxo-plastics or oxo-degradable plastics are conventional plastics which include ***additives*** to accelerate the *fragmentation* of the material into very small pieces, triggered by UV radiation or heat exposure. Due to these additives, the plastic fragments over time into plastic particles, and finally *microplastics*, with similar properties to microplastics originating from the fragmentation of conventional plastics.

Is better than the normal plastic?

Studies show that the entire biodegradation process varies, as environmental conditions inevitably do, and often takes (much) longer than claimed.
During this time microplastics remain in the environment, including the ocean.

As with all microplastics in ecosystems, there is a risk of bioaccumulation, including into the food chain, with potential negative impacts on human health and the environment.

Oxo-degradable plastics are designed to start fragmenting within a few months or years. Therefore, even though the addition of stabilisers can delay the intended fragmentation effect, oxo-degradable plastic packaging is - by its very design - not meant for long-term ***reusable applications***.

Adittionally do not fulfill the requirements of relevant international standards for plastic packaging and plastics recovery through ***composting***, such as *ISO 18606, EN 13432, ASTM D6400, AS 4736 or GreenPla*, as their biodegradation takes too long, and plastic fragments can remain in the compost. (New Plastics Economy).
Ellen MacArthur Foundation.

2.5 Composting

"Composting" is enhanced biodegradation under ***managed conditions***, predominantly characterised by forced aeration and natural heat production resulting from the biological activity taking place inside the material. Composting requires material not only to biodegrade, but to also become part of usable compost and provide the soil with nutrients.

The resulting output material, compost, contains valuable nutrients and may act as a ***soil improver***.

Biodegradation of materials resulting from artificial synthesis, such as conventional plastics, is theoretically possible when the material is broken down into small particles and the molecule mass of the material is sufficiently reduced to enable biodegradation.

Factors such as *light, humidity, oxygen and temperature* determine the degradation rate. In the open environment it may take a long time, up to hundreds of years, for conventional plastics to biodegrade.

Potential toxic effects on soils of residual additves from oxo-degradable plastics have been identified as a concern.11

Conclusions valid for all oxidising additives used can however not be drawn, because different oxidising additives are used in different concentrations.

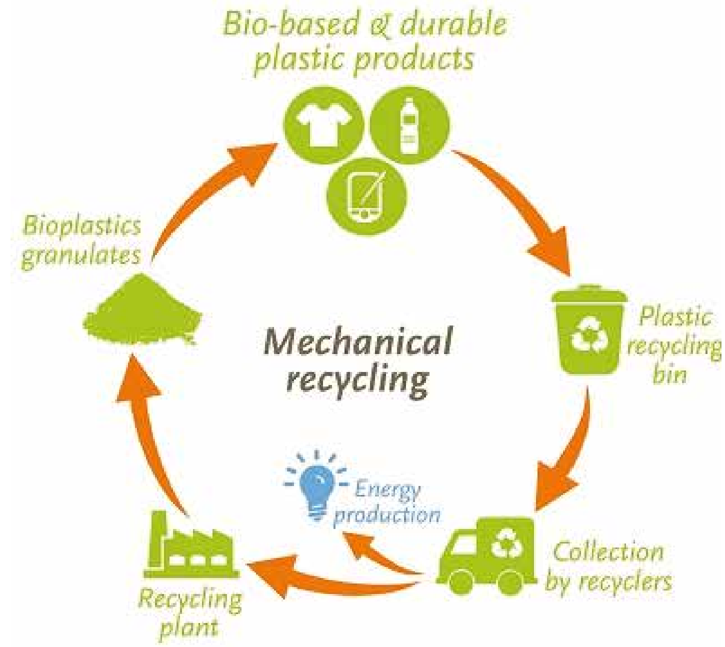


Figure 5 Bio based products

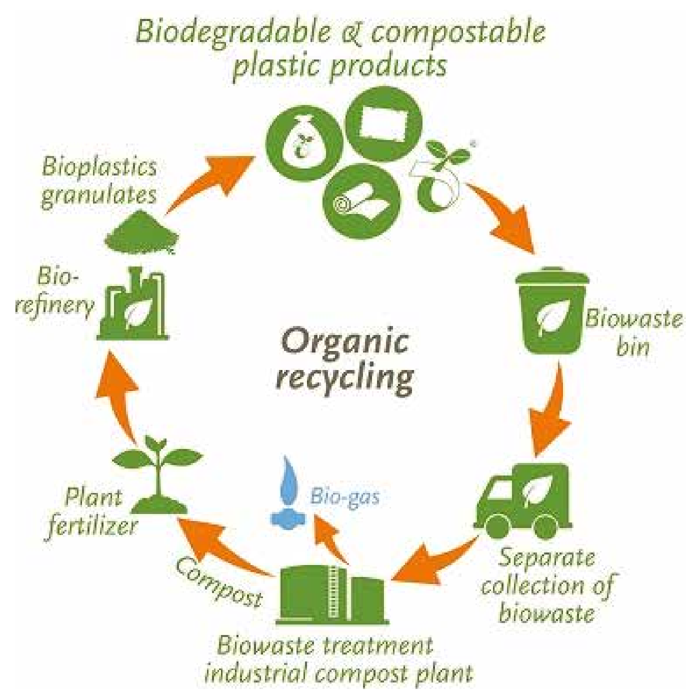


Figure 6 Biodegradable products

Source: European bioplastics (2017)
http://www.allthings.bio/dispose-bio-based-plastics/

2.6 Term Definition Degradation Table

Degradation *The partial or complete breakdown of a polymer as a result of UV radiation, oxygen attack, biological attack.* *This implies alteration of the properties, such as discolouration, surface cracking, and fragmentation.*	**Compostable** *Capable of being biodegraded at elevated temperatures in soil under specified conditions and time scales, usually only encountered in an industrial composter (European standard EN 13432).*
Biodegradation *Biological process of organic matter, which is completely or partially converted to water, CO2/methane, energy and new biomass by microorganisms (bacteria and fungi).*	**Oxo-degradable** *Containing a pro-oxidant that induces degradation under favourable conditions. Complete breakdown of the polymers and biodegradation still have to be proven.*
Mineralisation *The complete breakdown of a polymer as a result of the combined abiotic and microbial activity, into CO2, water, methane, hydrogen, ammonia and other simple inorganic compounds.*	**Recycling** *Material recycling is defined in European standard EN 13430 and EN 16848 (adapted from ISO 18604) as the reprocessing of a used product material into a new product. An example is plastic which after use can be collected, sorted and reprocessed into new products.*

3. Organic materials on market

By getting the characteristics desired to be commercialised, biopolymers have become main players on the packaging market with highly demanded applications such as bags, containers and disposable products.

In the following pages you can see the graphs that show the use of plastic according to the segment of the market, followed by the use of bio plastics and finally the percentage of use of bio plastics according to the type of material.

The materials can drastically change their properties and therefore their functional purpose according to the type of transformation and raw material with which it is generated.
Not all the materials that we know as "bio-plastics" are biodegradable, many need a strict and determined follow-up for their correct degradation because, as we saw earlier, they can be oxo-plastics with additive products or they can contain special materials for a certain type of compost.

This is why the last table of this chapter shows the different types of general waste management of this kind.

3.1 Applications in the market of Polymers

2018

The most used plastic in the market is for applications such as packaging, while the least used is in the field of agriculture.

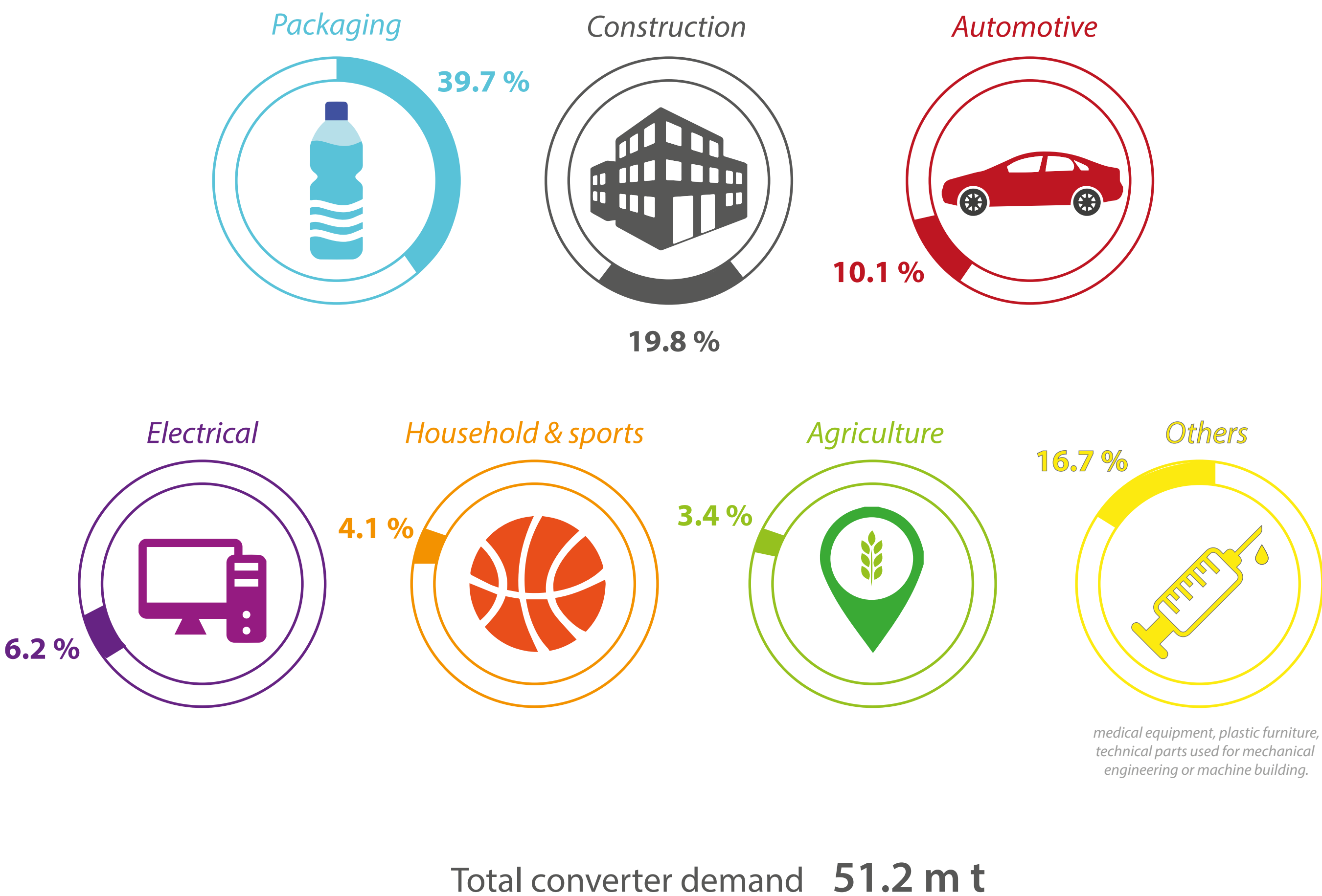
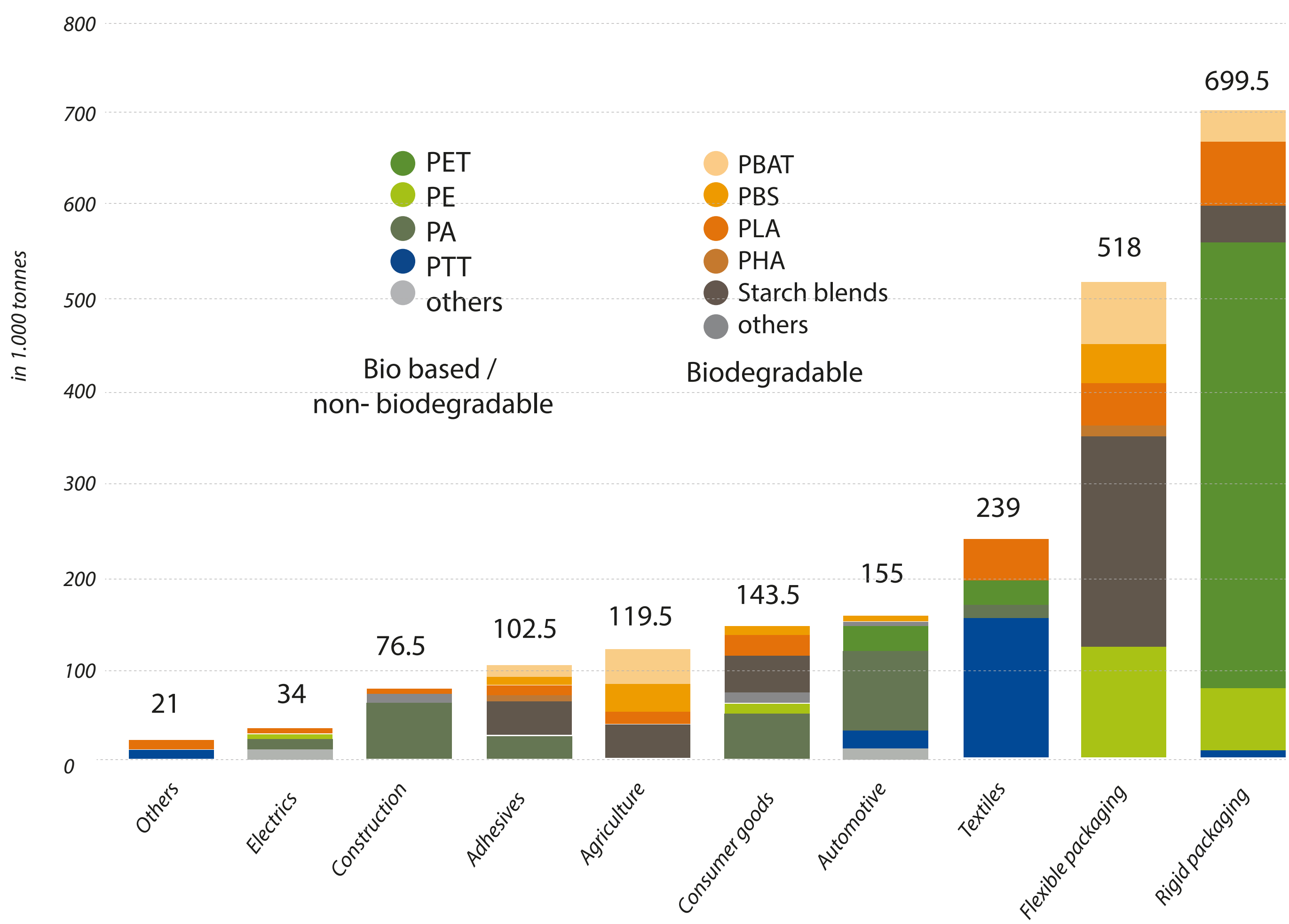


Figure 7. Current use of plastic products in the market

Source: (PEMRG), PlasticsEurope Market Research Group (2018)
https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf

3.2 Bioplastics production by market segment

According to the graph at the moment, the biobased products are used mostly for rigid packaging and the starch blend for flexible packaging, consumer goods, agriculture and adhesives.

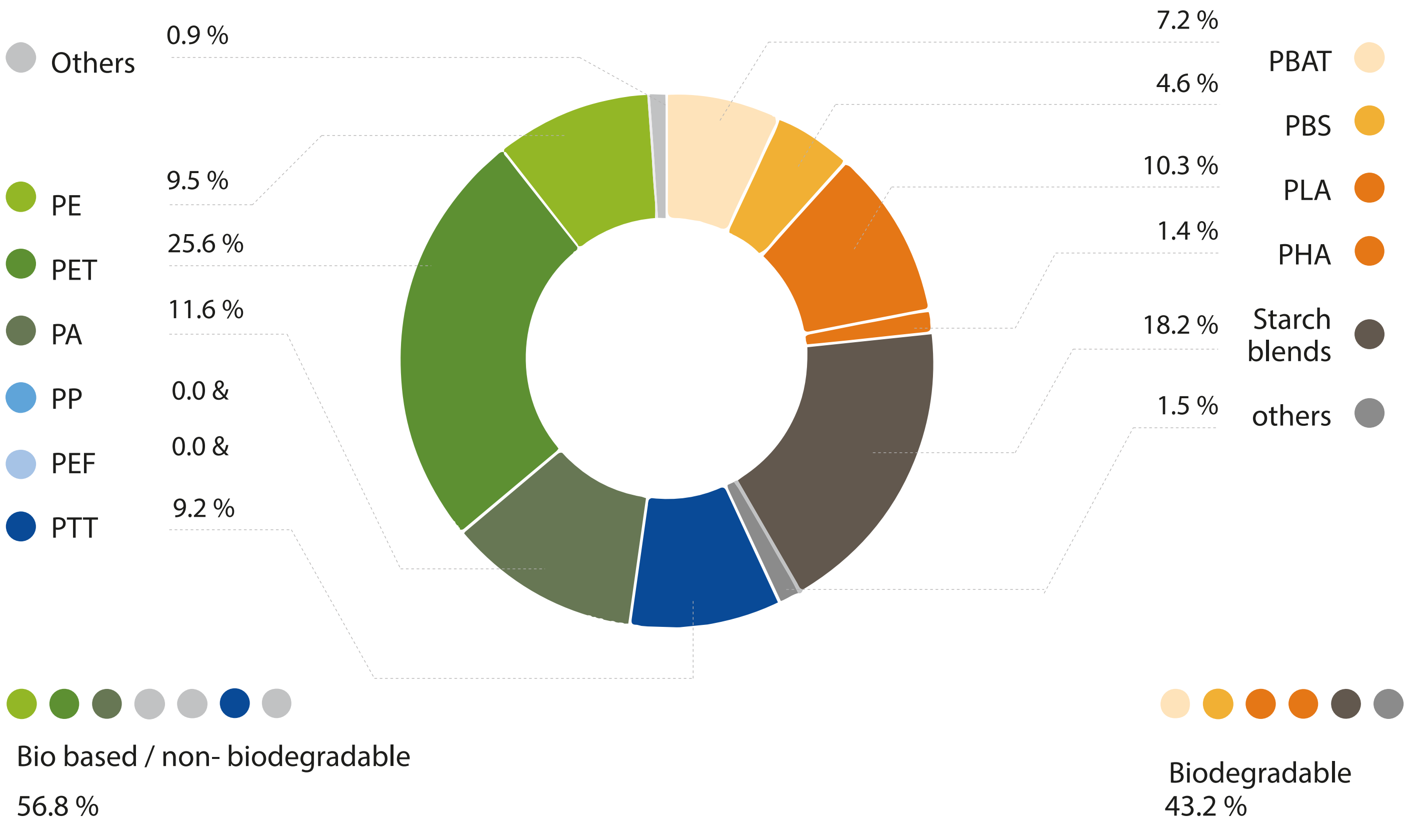


Graph 1. Bioplastics production by market segment

Source: European bioplastics (2018)
https://www.european-bioplastics.org/market/

3.3 Bioplastics production by material type **2018**

According to the graph, the most used biodegradable materials in 2018 are for first starch blend and secondly PLA.
While of bio-based non-biodegradable materials, the most used is PET, which with the current regulations prohibiting production with polluting plastic is significantly reducing the figures for the next times.



Graph 2. Current use of plastic products in the market

Source: European bioplastics (2018)
https://www.european-bioplastics.org/market/

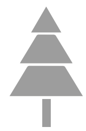
4. The Glue

4.1 A general look at natural glue

- Cellulose

It has an adhesive capacity medium-low, suitable for bonding porous materials such as paper, cardboard and fabrics. It is used as a binder for tempera and tapes. Bricoliamo

- Lignin



Being the natural glue in plants and having a phenolic nature makes lignins an attractive replacement for wood adhesives. The reason for the current interest is the high availability and low price. Hemmilä 2013

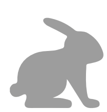
- Wood resins

It is used in the manufacture of paints, soaps, adhesives, caulking pitch, lubricants, inks, sealing wax, for electrical insulation, as a deoxidizer in tin soldering and in the textile industry.

- Starches

It is used by the pharmaceutical, textile, wood and paper industries, such as adhesive, binder, texturizer and filler, in the formulation of pastes, emulsions and creams. can be substitute for polystyrene to produce plates and packaging.

- Proteins



Created using animal tissues (skin, bone, tendons and organs) It comes in the form of solid gelatin at room temperature, easy to transport and to store.

4.2 The Adhesives

4.2.1 Animal glue

The first natural glues worked by man were derived from collagen, **Collagen** in animals is a protein with a high viscosity index that allowed to make coatings for storage, instruments, clothes and other items. Furthermore, animal blood was also used as an adhesive material due to albumin.
The animal glue is created using the tissues (skin, bones, tendons, and organs) It comes in a solid gelatin form, easy to transport and store.

The animals most used for the extraction of connective tissue useful to create animal glue are generally large herbivores, such as horses and bisons, but it is possible to use almost any animal, including rabbits and fish.

One of the favorite materials of many ancient peoples was the swim bladder of the fish, capable of creating excellent and transparent glue. This glue, called 'Isinglass', was originally produced using the bladders of the sturgeons, rich in collagen, and came in the form of shavings, in powder or gel form.

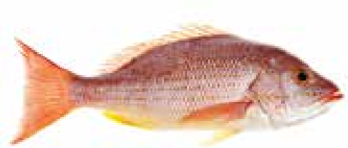
According to the history, the glue obtained from rabbit skin, however, seems to have been the favorite of Renaissance oil painters. The linseed oil often used to create colors tends to destroy the fabric of the canvas, but a coat of rabbit glue on the finished painting helps to keep it.

Collagen is currently mainly used in the food industry as a thickener but also as a strong fixative for hair like long ridges, or for gluing paper, paper products, cork, leather and wood.

Other types of adhesives are those derived from animal products such as eggs and milk:

Egg albumin is made up of numerous proteins, the main of which is albumin. It can be used in the form of flakes or powder, obtained by drying egg whites. Waterproof and resistant to moisture, it is used on paper and cardboard, for labels on bottles, to waterproof the paper. Mixed with lime powder, a high-strength glue is obtained, to attack broken objects.

Casein, instead, is a family of phosphoproteins found mainly in fresh milk, it is a yellowish powder, soluble in alkalis and in solutions of alkaline salts with weak acid; It is used for gluing wood and in particular laminates; on paper and on all paper products in general, on cork and on natural fabrics (it suffers from humidity and is susceptible to bacteria and molds.)



4.2.2 Vegetable glue

One of the plant-derived adhesives is **latex**, consisting of small particles of polymers suspended in water. Once dried, the particles are sintered and bound by van der Waals forces.

The main use is sanitary, household and medicinal, and for products such as tires, mattresses, pillows, balloons or hot water bags.

Latex

Products

Besides the latex, there are also vegetable glues based on cellulose, water-based adhesives obtained by dispersing cellulose derivatives in water. The most used are carboxymethyl cellulose and methylcellulose, mainly contained in vegetables.

Cellulose has a medium-low adhesive capacity and is, therefore, suitable for bonding porous materials such as paper, cardboard, and fabrics. It is also used as a binder for tempera.

Soja, on the other hand, is phospholipid from a chemical point of view and is therefore composed of a fat-soluble part and a water-soluble part.

Soja

Product

Precisely to this chemical composition it owes its property to keep together watery substances and fatty substances normally not mixed together.
This property is called emulsifier and is used in various industrial sectors, ranging from food (for the production of creams, sauces, ice cream, etc.) to the cosmetic and health sectors.

4.2.3 Gums, Algae and Resins

The gums are complex polysaccharides formed mainly by the disintegration of cellulose. Polysaccharides are carbohydrates made of monosaccharide unit chains. That means gums are, in other words, long chains of sugar produced by exudation from plants or extraction from seeds.

The gums are translucent amorphous colloids, broadly used in the food industry for thickening agents, emulsifiers, and stabilizers.

Gum Arabic, also known as Acacia Gum, is the most widely used of the water-soluble gums. It is a major ingredient in food, arts, cosmetics and textiles applications.

On the other hand, resins are solid or semi-solid organic materials, amorphous, insoluble in water, brittle, transparent or translucent, with a high molecular weight, and characterized by specific mechanical properties.

They are mostly formed in the resiniferous canals of plants (such as Conifers, Terebintaceae, Burseraceae), in the form of more or less viscous solutions. They can be obtained by incision of the trunk, bark or branches, and by simple transudation.

Gum

Natural Resin

Resin flakes

Conservation

The most representative example of resins is Colofonia or Rosin, a solid, yellow translucent plant resin, and residue from the distillation of turpentine from pines, firs, and larches. It is used in the manufacture of paints, soaps, adhesives, caulking pitch, lubricants, inks, and sealing wax; also for electrical insulation, as a deoxidizer in tin soldering and in the textile industry.

Nevertheless, there is an unusual case of a resin with animal origin. The shellac is a fragile and scaly secretion of the insect Kerria lacquer hemitteri. It is used as a final covering for the construction of small objects such as ornaments or frames. Apples, citrus fruits, pills, sweets, pastry and even chocolate are polished and protected by this kind of gum.

Mainly, two types of resins can be classified according to their consistency and application:

Spirit-soluble
(or Balsams)

1. With viscous consistency, pungent taste and pleasant smell. These are used in pharmacies and perfumery, optics and microscopy.

2. Consistent solids, often used for paints and lacquers.
Oil-soluble (or Oleoresins)

Oil-soluble
(or Oleoresins)

They are comparatively more fluid terpenic resins, coming mainly from Pinaceae:

1. Turpentine for solvents, fragrances and polyterpene resins.

2. Rosin for adhesives, inks and paper products.

Food Additives

Lastly, the algae are another potential source of natural adhesive, although they are mainly used as an aggressor, rather than as an adhesive, for gastronomic purposes. Algae are essentially aquatic plants.

The most recognized alga is Agar, obtained from the drying of red algae as an amorphous and translucent product. It is a polysaccharide found as flakes, powder or bricks, and is widely used as a natural gelling agent for food and cosmetics.

Another type of adhesive from algae is Algin or Sodium Alginate. This is a polysaccharide extracted from brown algae, mainly used for surface coatings and for paper and food additives. In storage, it is added to glue or used as a suspension medium for dyes.

4.2.4 Cellulose

The production of bacterial cellulose generated by low-cost agri-food waste has been one of the most significant contributions to the development of natural materials.

The scientific Mayra Garcia Sanchez, of the University of Guadalajara (UdeG) in Mexico, has developed a bacterial culture that feeds on mango pulp and, once the microorganisms consume fruit, produces a biopolymer that can be useful for the health sector.
The project, explained Garcia Sanchez, is creating a breeding ground for bacteria from mango waste, bacterial cellulose, with which it reduces about 65 percent of the cost of production of this biopolymer.

Cellulose has different uses since it has a high capacity and fluid retention. As a high purity material, it can be used for treatments in the health sector.

4.2.5 Pectic Substances

Pectin is the main binding element of the cell wall of vegetables and fruits. It has the property of forming a gel in acidic medium and in the presence of sugars.

For that reason, it is used in the food industry in combination with sugars as a thickening agent, for example in the manufacture of jams and jellies, as well as in the stabilization of beverages. In addition, it is used as an emulsifier of ether oils and in the production of ice cream.

Conversely, the carob is a fruit that has made the flour its appearance and which use is similar to that of cocoa. It belongs to the family of legumes. In carob, we find in fact the pectin as a natural gelling thickening, very useful in the culinary and the food industry, for instance for desserts or soups. However, it does not have the necessary properties to generate an adhesive.

Mango

Carob

Source: Mayra Garcia Sanchez, of the University of Guadalajara (2018)
https://www.mexicampo.com.mx/transforman-desperdicio-de-mango-en-biopolimero/

Can fruit be used to generate pectin-based adhesive?

As the fruit matures, the cell walls dissolve, releasing the juices contained. This makes the fruit more "juicy", even if in reality the water container has not increased.

During ripening, some fruits convert starch into sugars: sucrose, fructose, and glucose. This happens for example with kiwi and apples. To take advantage of fruits pectin content, we should use their first buds, thus wasting a food resource. The same process occurs with the pumpkin pulp, which contains several active ingredients such as carotenoids, mucilage and pectin substances.

4.2.6 Fig Latex

The milky white liquid that flows when a fig is torn from the tree is latex. In its composition, there are different enzymes and about 12% of rubber. It has the property of coagulating milk in the same way as animal rennet, a reason for which it has been used for a long time as a vegetable coagulant in cheese production.

The vegetable rennet is obtained from plants, especially from flower or latex enzymes (fig tree). The green leaves and figs contain latex (a milky liquid) with a mixture called enzymes (esterase, ficina, fucomarine). This substance has the ability to destroy milk proteins (caseins) by coagulating the milk and forming an irreversible gel (curd).

The enzymatic coagulation consists of a series of physico-chemical modifications of casein, which lead to the formation of a clot. The active ingredient in rennet is quimosin (Bedolla, 2004).

This material can be used only when the plant is intervened before its maturation, because of this, its not an option as raw material for the elaboration of this project.

Figs

5. Territory

It is important to analyze the territory as an essential part of the circular economy projects, the next image has been taken from the systemic approach foundation of which the professor of the Politecnico di Torino, Luigi Bistagnino, is part.

They relate the different actors, from the type of raw material, to the possibility of generating work for the local people and new production activities.

In this chapter, will be made the description of the territory chosen for the development of this project, which will be divided into “current territory” and “territory of origin”.

This project is carried out in Piemonte, Italy, the region in which I currently live and for which reason I have carried out the study with the most used products in the area and with which the objective of producing bio materials from waste can be achieved of the agro-food industry.

The second territory to be examined is my territory of origin, Colombia, a country rich in raw material and natural elements completely different to Italian crops, which can generate a good analysis contrast to test mixed results and create value chains for the project.

According to the theory of systemic design, the territory allows showing the social and cultural identity of a community.

The market is based on exports and imports between different regions, which generates a large amount of packaging and CO_2 due to transport; the systemic design seeks to generate an increase in the production of the local chain to position the industry of the territory as a quality option and with km 0, benefiting the economy and with the purpose of sharing this culture of awareness for our products and then share it with world level and move from a local culture to a “glocal” culture, giving value to each territory and its products.

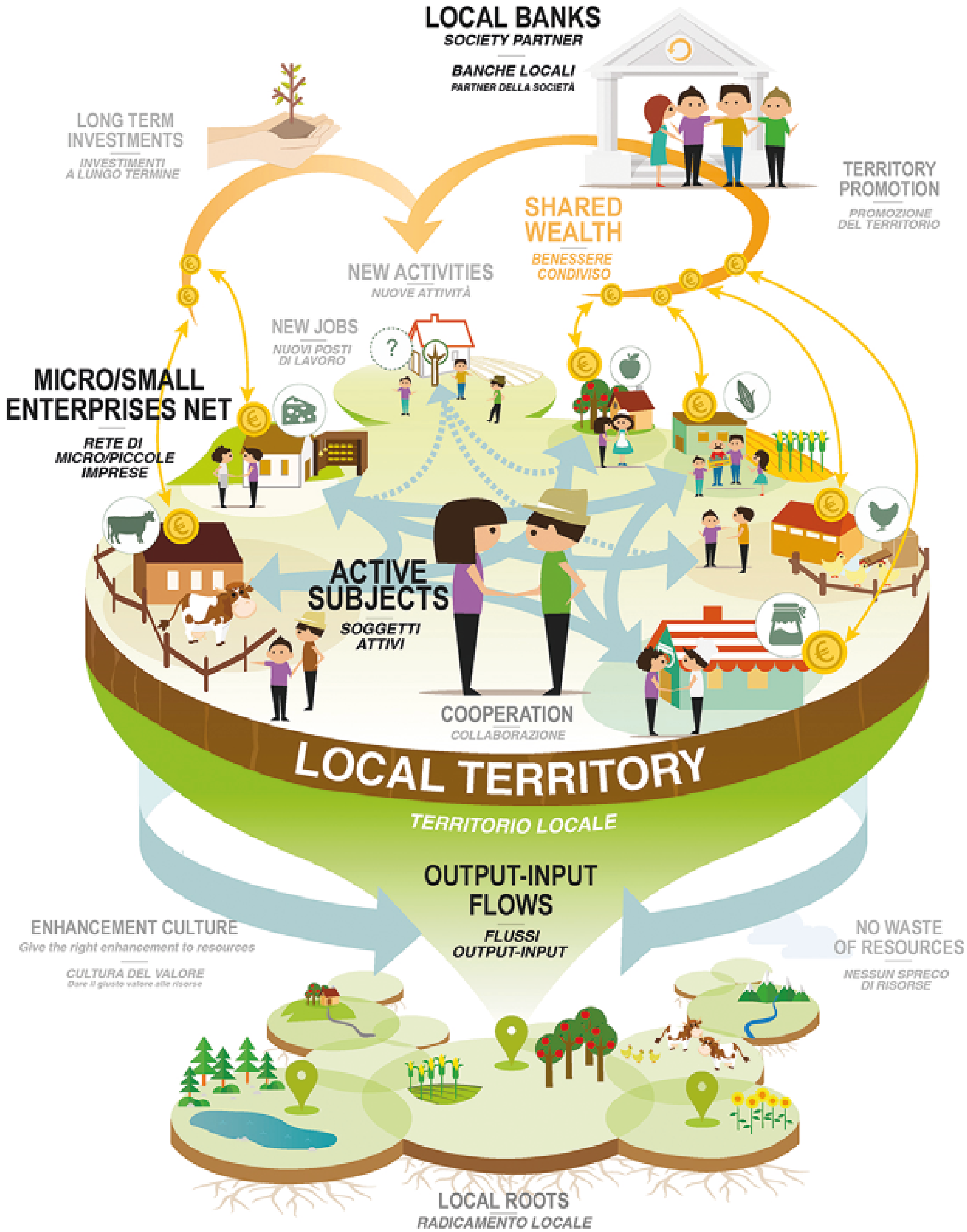
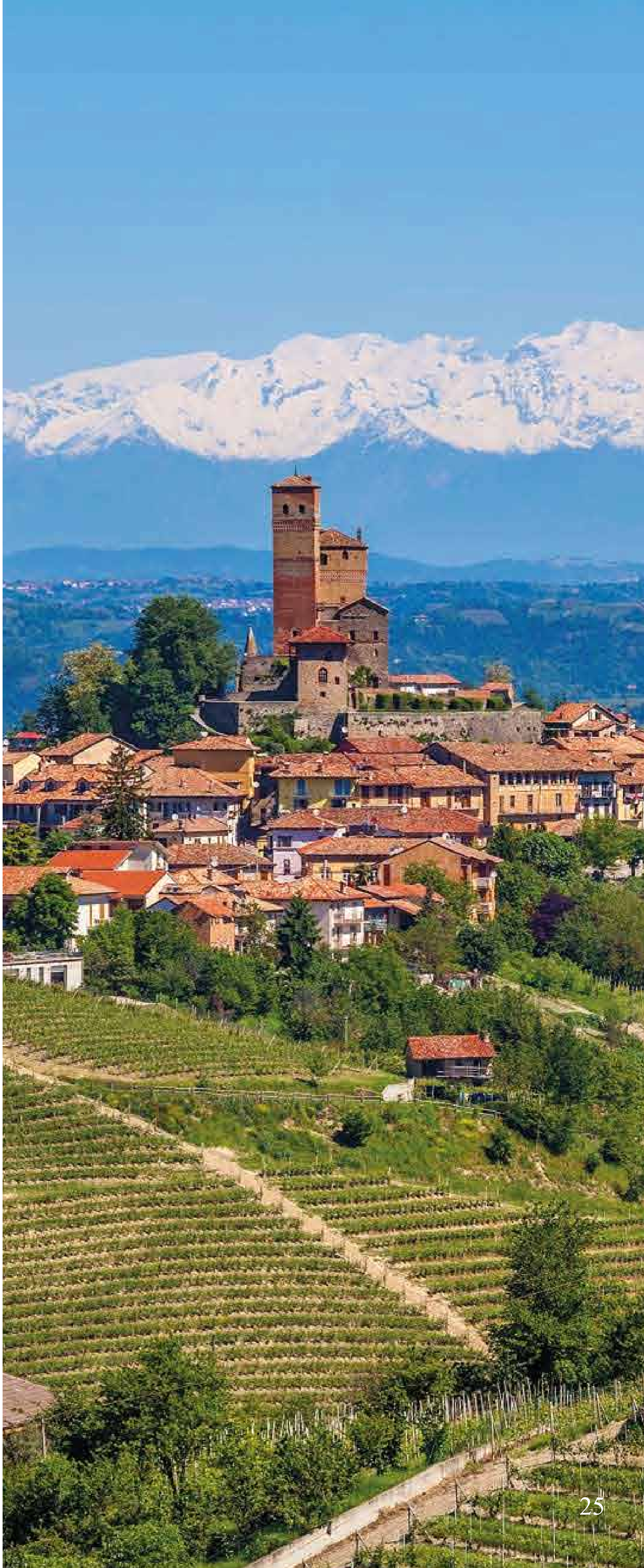


Image 1. Systemic Design Theory, Local territory

Source: S.A Foundation (2016)
http://www.systemicfoundation.org/about-us-2/

5.1 Current Territory
(Piedmont, Italy)



Territorial Analysis

With an area of 25,400 square kilometers, Piedmont is the second Italian region by extension, preceded only by Sicily.
In terms of agriculture, according to the CREA analysis of the gross margin of main herbaceous crops, the gross marketable production places the zucchini and the pumpkin first.
(See table 2).

However, as explained in paragraph 3.4.2, although these resources have pectic substances that allow the creation of adhesives, the process must be done with the internal component and not with the waste, so the objective would be lost sight of. of the project to work based on sub products to maintain the concept of the circular economy.

In next place is the potato with 5,508 euros per hectare, followed by rice and corn; being the latter discarded as research material due to its current positioning as a biopolymer in the market for applications such as the textile industry, the medical industry and especially in the packaging industry.

Next, an investigation will be carried out as an example of the use of rice residues for the transformation and development of biopolymers; for the next point to give importance to the analysis of the potato as the main local material for the experimentation of this project, and also the richest product in the substance necessary for the development of the adhesive that is sought, in this case, the starch.

Gross salable production Euro/ha. (CREA 2015)

Wheat	1.034
Corn	1.329
Barley	553
Rice	2.224
Soy	1.010
Potato	5.508
Pumpkin	4.146
Zucchini	19.059

Table 2. Piedmont agro production

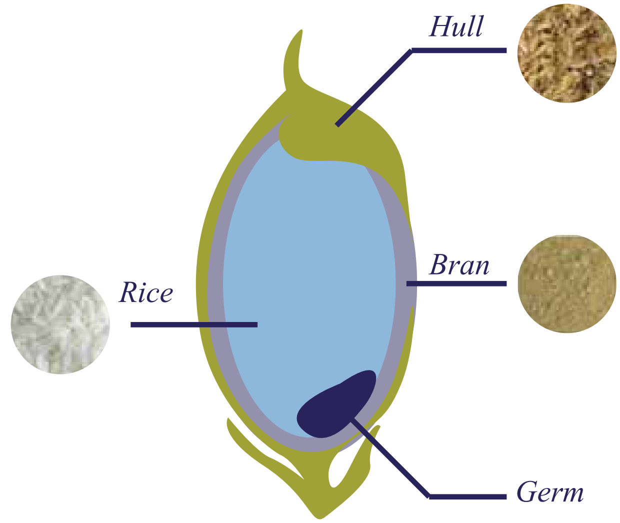
5.1.1 About Rice

Rice, edible starchy cereal grain and the plant by which it is produced. Roughly one-half of the world population, including virtually all of East and Southeast Asia, is wholly dependent upon rice as a staple food; 95 % of the world's rice crop is eaten by humans.

The by-products of milling, including bran and rice polish (finely powdered bran and starch resulting from polishing), are used as livestock feed. Oil is processed from the bran for both food and industrial uses. Broken rice is used in brewing, distilling, and in the manufacture of starch and rice flour. Hulls are used for fuel, packing material, industrial grinding, fertilizer manufacture, and in the manufacture of an industrial chemical called furfural. The straw is used for feed, livestock bedding, roof thatching, mats, garments, packing material, and broomstraws.

A typical proximate composition of defatted rice bran in the United States is 15–20% protein, 0.5–1.5% fat, 10–15% crude fiber, and 9–12% ash.; the starch can vary from 10 to 20%, depending on the amount of rice breakage and degree of milling (Hargrove, 1994). The adhesive properties of protein and starch have long been recognized. Rice bran could be developed into adhesive with industrial applications that could increase its economic value

Despite the interesting characteristics and starch content on rice, potatoes continue to position themselves in the first place in regional production, in addition, it is one of the agro-food industries with the most organic waste in the transformation phase into production, this is one of the reasons for which this tuber will be analysed next.



Improve adhesive property of rice bran

◦C	ph
120	12
100	10
80	8

Thermal and Chemical treatments..

Influence of
sodium sulfite
sodium bisulfite

5.1.2 Why to use the Potato?

"Potato (*Solanum tuberosum L.*) is one of the most important agricultural crops for human consumption and high amount is produced worldwide every year.

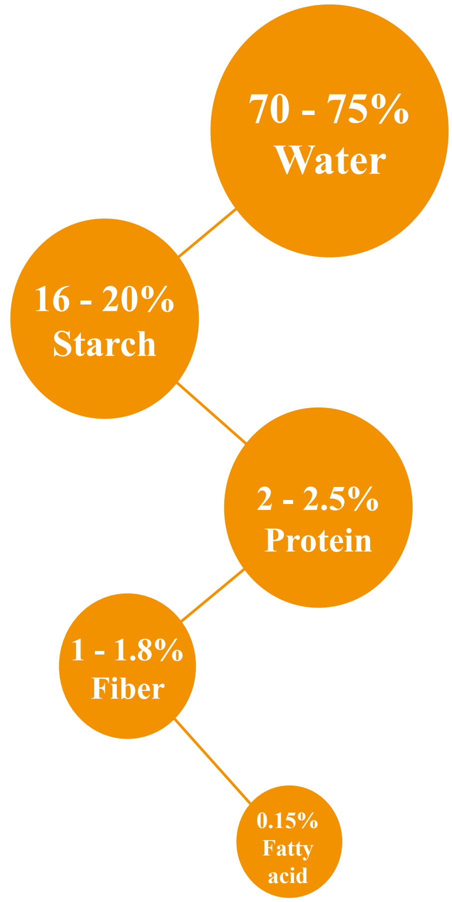
Potato peel waste is a zero value **by-product**, which occurs in big amounts after industrial potato processing and can range from 15 to 40% of initial productmass, depending on the peeling method.

Potato peel waste is not suitable for non-ruminants without further treatment because it is too fibrous to be digested (Birch et al., 1981), but as an inexpensive by-product it contains a large quantity of starch, non-starch polysaccharides, lignin, polyphenols, protein and small amount of lipids.

This makes it a cheap and valuable base material for extraction of valuable products (such as natural antioxidants, dietary fibre, biopolymers, etc.) and fermentation processes *(Arapoglou et al., 2009; Al-Weshahy and Rao, 2012; Wu et al., 2012)."*

This information was extracted from Research for rural development, 2015, Igor Sepelev, Ruta Galoburda, P. 130.

Source: FAO 2008, La papa



5.2 Territory of origin (Colombia)

Colombia, a country that thanks to its great variety of climates and land has tropical agriculture rich in starch, is characterized by technological crops by region of sugar cane, coffee, flowers, cotton, banana, sorghum, corn, rice, African palm, potato, yucca, among others.

According to the figures *Food and Agriculture Organization* (FAO) 2011, Colombia is the second country with the largest imports of "platano" or green bananas all over the world, with an annual average of about 60,000 tons.

This cultivation of platano trees can contribute in the generation of jobs, and, therefore, an advantage for the peasant sector and a contribution to the generation of one of the basic goods of more than half of the Colombian families.

In addition, fried platano production companies are continuously growing so their waste can be diverted to another goal as is the natural production of adhesives.

5.2.1 Composition of the platano

Platano is an excellent source of potassium, vitamins and starch, it is one of the most common harvests in all tropical weather countries; from whole platano tree the platano fruit is the only part consumed by human being specifically the pulp and because of this, big quantities of waste are made from not utilized platano tree parts, which contributes to the rising of microbiological and environmental problems due to the amount of moisture and nutrients within it, being the case of platano peel which has important components used in the enrichment of other food products.

In an **immature state**, the banana has a high concentration of **starch** (70%) compared to fruit in a mature state.

The main by-product of the platano industrial process is the skin which represents approximately 30% of the weight of the fruit; Potential applications for platano peel depends on its chemical composition.

The platano skin is rich in dietary fiber, proteins, essential amino acids, acids polyunsaturated fatty acids and potassium; among the efforts using the skin you haveobtained proteins, methanol, ethanol, pectins and enzymes.

6. INDUSTRIAL BIO BASED PRODUCTS

"Ecosoulife is an environmentally conscious company on a mission to deliver guilt-free disposable and reusable alternatives to the plastic and foam, which fill our landfills and waterways."

MATERIALS →

Palm Leaf

Compostable in 90-180 days. Raw materials collected from naturally-fallen Areca-nut leaves that are washed, heated, pressed and sterilized. The perfect all-natural compliment to any event.

Wheat Straw

Compostable in 30-90 days. Raw materials from wheat, a 100% renewable resource. Durable, lightweight and leak proof. It's a great alternative to paper and styrofoam.

Cornstarch & CPLA

Biodegradable in 2 years. Compostable in 90-275 days. Raw materials from corn starch. Smooth matte finish. Durable and leak proof, this material is the ideal replacement for plasticware.

Source: https://ecosoulife.com/

BIOTREM

6.2

Biotrem's modern and booming production facility offers a wide range of fully biodegradable tableware and cutlery produced from natural and edible wheat bran.

MATERIAL →

WHEAT BRAN

"Our production process does not require significant amounts of water, or mineral resources, or chemical compounds. From 1 ton of pure, edible wheat bran we can produce up to 10,000 units of plates or bowls.

What's more important, our products are fully biodegradable – through composting – in just 30 days!"

Source: https://biotrem.pl/en/

7. LAB SCALE BIO BASED PRODUCTS

PRODUCT	MATERIAL	DECRIPTION
	Beetle Shell	Coleoptera bioplastic made from beetle exoskeletons by Aagje Hoekstra: Bioplastic made using from the tough outer shell of the darkling beetle. The dead beetles are a by-product of the mealworm animal feed industry.
	Algae	D-printed biopolymer plastic by Erik Klarenbeek and Maartje Dros: are trying to establish a network of biopolymer 3D-printers called the 3D Bakery, which would mean that people could print their own environmentally friendly products.
	Agar & calcium carbonate	That's It packaging made from algae by Austeja Platukyte: has developed a biodegradable material made from algae that could replace regular crude oil-based plastic packaging.
	Algae Seaweed	Biodegradable algae water bottles by Ari Jónsson: A product design graduate from the Iceland Academy of the Arts, used algae to create an alternative to the plastic water bottle

PRODUCT IN THE CURRENT MARKET.

Source: Augusta Pownall | 9 October 2018, Dezeen

7.1 LABVA (Laboratorio Biomateriales Valdivia)

“We desing new local materials from local “waste” or byproducts”.

It is an open group to share knowledge and experimentation with natural materials or organic
byproducts in order to generate new ideas and create learning networks and possible production.

MATERIALS →

Agar
@altauach_talentos

Ground shells- Mytilus chilensis
@r.vasquezlemus

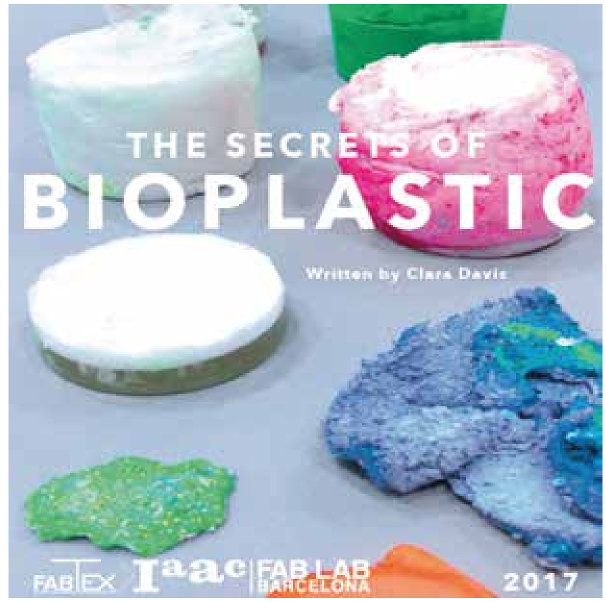
Bagasse of beer

Celullose

Ulva Lactuca

Source: http://labva.org/

7.2 Bio based materials for Fashion Industry



Fab Textiles project. Open sourcing fashion production for a global innovation ecosystem.

" In Fab Textiles we are developing and implementing a new approach on to how create, produce and distribute fashion elements, by using distributed manufacturing infrastructures and knowledge networks. We are experimenting with the human body and human culture, by recycling, hacking and sensing it, creating feedback loops with project development, where materials, aesthetics and customisation play equal and important roles".

MATERIALS →

BioBags collection, created by Clara Davis from the FabTextiles at Fab Lab Barcelona, is an environmental project

Bioplastic gelatine+spirulina sample by Margaret Dunne, FabTextiles, Fab Lab Barcelona, 2018

Textures and materials

Bio couture, Bio plastics, bioplastic, fab lab barcelona, fab textiles, material catalogue, Soft fabrication

anastasia pistofidou, bioplastics, Clara Davis, diy matter, fabtextiles, workshops fab lab

8. The potato

8.1 Production analysis

Grown at home or bought in the market, fresh potatoes are baked, boiled or fried, and used in an amazing variety of recipes: pureed, pancakes, balls dough, croquettes, soups, salads or gratins, among many other methods of preparation.

But the world consumption of potatoes is going from the fresh product to the industrial food products, with added value.

One of the main elements of this category receives the unattractive name of potatoes frozen, but includes most of french fries that are served in the restaurants and in the food chains fast from around the world.

The procedure of production is very simple: peeled potatoes are they go through some blades that cut them, then lightly cook them, dry them with air, fry lightly, freeze and pack. The global appetite for these French-fries factory in more than 11 million tons per year.
Another industrial product are the leaflets crunchy potatoes, the undisputed king of snacks in many developed countries.

United States of America have distributed as help international potato flakes to more than 600 000 people. Another dehydrated product, flour of potato, it is obtained from the whole cooked potato and It keeps a characteristic flavour. The industry uses potato flour, which does not it contains gluten but yes abundant starch, to agglomerate composite products of various types of meats and impart thickness to sauces and soups.

The modern industry is able to extract up to 96 percent of the starch that contains the raw potato. Potato starch, a powder fine and tasteless, of "excellent texture", gives higher viscosity than wheat or wheat starches corn, and allows to produce more tasty products.

It is used to thicken sauces and stews, and as a binder in cake flours, cookies and ice cream.
Lastly, in Eastern Europe and in the countries Scandinavians, ground potatoes are subjected to heat treatment to convert the starch in sugars that are fermented and distilled producing alcoholic beverages, such as vodka and typical spirits from those regions.

8.2 Fieldwork

Italy is a country with great gastronomic richness and variety in its food dishes; According to the latest surveys by FIPE, 2017, (Federazione Italiana Pubblici Esercizi) in the archives of Italian Commerce, there are 329,787 businesses connected with the food industry.

Whence a great amount of organic waste is generated that is not used in any way, because for most of these establishments, a right waste management or recycling is not required, and it will simply end up in the undifferentiated or organic mode, depending on the content.

But what would happen if these wastes were managed by a reuse initiative creating a new form of employment and production?

The data of the field work have been collected based on a restaurant in Piedmont in the city of Turin, from which we can calculate approximately the amount of waste generated, in this case of potato peels, to have an estimated measure of the material obtained for transform locally or regionally.

The restaurant

This project is carried out in agreement with the Italian restaurant "Emporio Gastronomico" located in the city center of Turin, which allows the capacity to serve more than 400 customers a day and serve varied dishes, among which is the use of potatoes.

- The restaurant is open every day and performs two shifts a day, one in the afternoon and one in the evening.

- The restaurant acquires 60 kilos of potatoes per week and its use varies according to the type of menu of the day.

- The approximate amount of potato peel waste per shift is 1.5 Kilograms, which means 21 kilograms per week.

6.1 The starch

Starch is the major carbohydrate reserve in higher plants. In contrast with cellulose that is present in dietary fibers, starch is digested by humans and represents one of the main sources of energy to sustain life. Bread, potato, rice, and pasta are examples of the importance of starch in our society. Starch has also been extremely important for centuries in numerous non-food applications, e.g., as glue for paper and wood and as gum for textile industry.

Also is one of the most versatile materials for potential use in polymer technology. It can be converted, on the one hand, into chemicals like ethanol, acetone and organic acids, used in the production of synthetic polymers and, on monomer or oligomer. Finally, it can be grafted with a variety of reagents to produce new polymeric materials, used as such or as fillers for other polymers.

Potato starch is also widely used by the pharmaceutical, textile, of wood and paper, as an adhesive, binder, texturizer and filler, and for the companies that drill oil wells, for washing the wells. Potato starch it is a 100 percent substitute biodegradable polystyrene and is used, for example, to make dishes and disposable cutlery.

In addition, it is an important factor in the production of food being raw material in this industry for its characteristics of low gelatinization temperature, low tendency to retrograde, resistance to enzymatic degradation (Sun et al., 2006), low residual fat content and proteins (<0.5% of the granules) *(Yusuph et al., 2003).*

Use of by-products

Potato peel and other wastes "without value "of the potato industry have a abundant starch content, which can be liquefy to obtain ethanol, for the production of fuels.
A study conducted in New Brunswick, a potato-producing province of Canada, estimated that 44 000 tonnes of Industrial waste from potatoes could produce 4 to 5 million liters of ethanol.

In this way, the use of by-products (tuber skin) promotes the circular economy and decreases the waste of cultivation land that can be used for food products unlike the current products of the market based on pure tuber starch, which were named in previous chapters.

If a products is marketed as biodegradable it should conform to a recognised standard defining compostability, for example ASTM 6400 (USA) , EN 13432 (European) or ISO 17088 (International)

8.4 Amylose and Amylopectin

Pure starch is a white, tasteless and odorless powder that is insoluble in cold water or alcohol. It consists of two types of molecules: the linear and helical amylose and the branched amylopectin. Depending on the plant, starch generally contains 20 to 25% amylose and 75 to 80% amylopectin by weight. (In the following pages, when analyzing the transformation of the starch to generate glue, a description of the importance of the amylose and amylopectin content in the gelatinization process will be presented). Brown, W. H.; Poon, T. (2005).

Starch becomes soluble in water when heated. The granules swell and burst, the semi-crystalline structure is lost and the smaller amylose molecules start leaching out of the granule, forming a network that holds water and increasing the mixture's viscosity. This process is called starch **gelatinization**. During cooking, the starch becomes a paste and increases further in viscosity.

During cooling or prolonged storage of the paste, the semi-crystalline structure partially recovers and the starch paste thickens, expelling water. This is mainly caused by retrogradation of the amylose. This process is responsible for the hardening of bread or staling, and for the water layer on top of a starch gel (syneresis).

This indicates that the higher the content of amylose, the greater the **leaching** process will be, and therefore the gelatinization, meaning that the result (**dextrin**) will be denser.

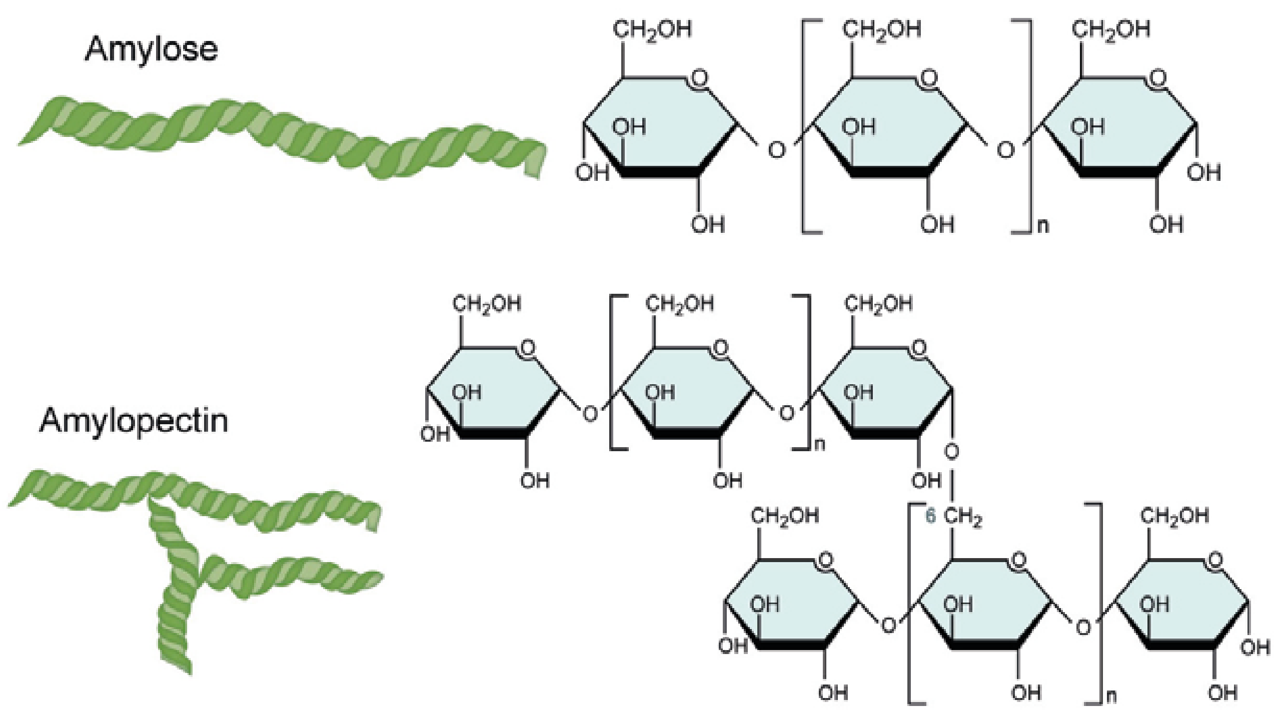


Figure 8 Chemical representation of amylose and amylopectin

8.5 Starch as adhesive

Starch and dextrin-based adhesives play a large part in industrial production, especially the packaging industry.

Starch and dextrin are principally used for bonding paper products. Most corrugated boxboard for making cartons is bonded with starch-based adhesives, and other porous substrates can be easily joined with these versatile adhesives.
Starch and dextrin adhesives are readily available, low in cost, and easy to apply from water dispersion. They are considered to be the least expensive class of paper-packaging adhesive.

Formulated starch and dextrin adhesives can be applied hot or cold. These adhesives are generally supplied as powder and mixed with water prior to use to form a relatively thick paste.

Since these adhesives cure to a thermosetting structure, they have excellent heat resistance. Another significant advantage is their very slow curing rate, allowing ample assembly time. Disadvantages include poor moisture resistance and mold growth. Although starch and dextrin have been used as adhesives for many decades, there are several important reasons why these natural adhesives will not be entirelyreplaced by synthetic products.
The following advantages ensure that they will continue to fill particular niches in the marketplace:

• Good availability
• Relatively low cost
• Stable quality
• Good adhesion to cellulose
• Insoluble in oils and fats
• Non-toxic and biodegradable
• Heat resistant

9. Part II
- Experimentation-

The next tests are developed in a homemade scale, with basic instruments and with the objective of analyzing the properties of the chosen materials and the different ways of intervening to obtain a bio-based product.

9.1 CONTENT

TEST # 1 → **Decantation to measure the starch content**

1a → **Iodine measurement of starch content**

1b → **pH measurement**

TEST # 2 → **Obtain starch powder from potato peels**

TEST # 3 → **Glue** (with commercial starch & starch result of TEST 2)

TEST # 4 → **The function of the glue**

TEST # 5 → **Mold with heat**

TEST # 6 → **Shape 1**

6a → **Tests with different amounts of mixture**

6b → **Shape 2**

6c → **Shape 3**

TEST # 7 → **What can go wrong?**

TEST # 8 → **Mix the materials**

TEST # 9 → **Obtain starch powder from platano skin**

TEST # 10 → **Glue**

TEST # 11 → **The function of the glue**

TEST # 12 → **Mix the materials**

TEST # 1 Decantation to measure the content of starch

According to the conservation method

OBJECTIVE: Compare the level of starch obtained with the decantation method in 4 different samples of potato skin preserved in different ways.

MATERIALS:
- Water
- Vinegar
- Balance
- Mixer
- Beakers
- Chronometer

-Potato skin (Agata type):
A) Dry skin
B) New skin
C) Wet skin
D) Frozen skin

Description:
A) Dry skin (one week stored in the refrigerator at 4ºC in a vacuum-sealed plastic bag).

B) Freshly peeled potato skin

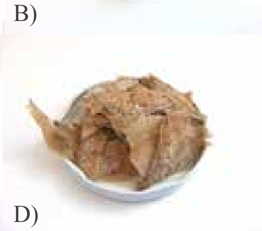
C) Potato peels preserved in water, vinegar and lemon for a week in the refrigerator at 4ºC
(100 gr of potato skin, 100ml of water, 50ml of vinegar).

D) Potato peel preserved in a hermetic bag in the freezer at -16ºC for a week


A)


B)


C)


D)

TOTAL TIME: 7 hours

METHOD: Decantation
(A process for the separation of mixture due to the density of each material).

PROCESS:
Grind the solid (potato skin) with water until obtain a homogeneous mixture.
Use 100 ml of water per 100 gr of potato skin.
Pour the liquid substance into the beaker and record the immediate result.
-(After 6 hours of decanting record the changes.)

Repeat this process with the 4 different samples (A - B - C - D)

Starch density
1,5 g/cm³
Water density
1 g/cm³

RESULTS:
(Immediately)
VISUAL INSPECTION

A) The division between solid and liquid particles is clearly seen, in the upper part the foam has remained clear tone, followed by the solid residues of potato skin and in the background the liquid substance of dark color.

B) The content of the light colored foam diminished, taking the place of the amount of solid particles of potato skin residues and apparently the same amount of liquid substance as in phase A.

C) It has a lot of white foam created by the agitation of the liquids contained in the mixture and layers of different levels, with the solid particles in the upper part and the liquid substance in the bottom.

D) The remnants of dark colored particles were mixed with the white foam at the top, while the liquid substance was deposited on the other half with some solid particles of smaller size that formed a layer at the bottom

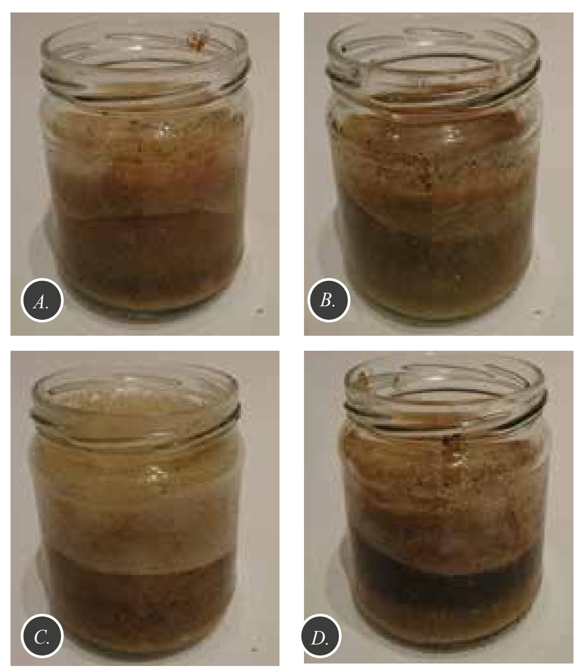
RESULTS
(6 hours later)

As general results, there is a noticeable darkening of the substance, decrease in foam and separation between large particles and smaller particles.

The liquid substance was mixed with small particles, which generates disficultad at the time of decanting only the starch particles that form a white layer at the bottom.

(Immediately results)

(After 6 hours results)



DISCUSSION:

It is recommended to filter the substance before the decantation process to separate the solid particles and generate a noticeable separation due to the density of the water in contrast to the density of the starch.

The largest amount of starch is extracted from freshly peeled potato peel.

"When a long period of refrigerated storage occurs, the starch paste generally tends to lose its water retention capacity, because the amylose and amylopectin fractions retrograde because cooling, this process is determined by the amylose ratio and amylopectin, storage temperature and concentration of starch (Barrera et al., 2003).
In case a starch paste is exposed to continuous cycles of freezing and thawing it results in a modification in the structure, due to the redistribution and the suspension of the ice crystals. In addition there is a syneresis by amylopectin, occurring a phase separation, one of them is rich in starch, while the other differs from it being the liquid phase." (Bejarano cruz, 2017)

TEST # 1a Iodine measurement of starch content

According to the conservation method

OBJECTIVE: Compare the level of starch obtained with the Lugol method in 4 different samples of potato skin preserved in different ways.

MATERIALS:
- Iodine
- Beakers
- Chronometer
- Petri dish
- Syringe
- Eye protection
- Hand protection

- Potato skin water result of **test 1**:

A) Dry skin water
B) New skin water
C) Wet skin water
D) Frozen skin water

TOTAL TIME: 7 hours

METHOD: Lugol

PROCESS:
Extract part of the substance of every sample of *TEST 1* and add the **iodine** solution to register the color change according to the concentration of starch content in each sample.
(0.2ml of iodine per 20ml of potato water)
-(After 6 hours of rest, record the changes.)

Repeat this process with the 4 different samples (A - B - C - D)

Use the iodine solution:

It allows us to recognize the presence of starch in foods such as bread, potatoes, but also in others such as various types of York ham and cheese, because they add cooked potatoes to increase weight. It is also common to find starch in paper because it is used to give it consistency.

Result of the Lugol test applied directly to the skin of the potato

RESULTS:
(immediately)
VISUAL INSPECTION

A) Is the substance with the lighter shade, so with less amount of starch, the dark parts concentrated slightly in the central part of the disc.

B) In a few seconds it acquired a dark color in a homogeneous manner, that is, it is the substance with the highest starch content.

C) Similar to the previous one, this sample acquired a dark color but some particles did not absorb this tone.

D) The liquid substance acquired the dark tone, nevertheless, it was the only sample that showed solid particles of resiudos of potato husk and little foam, which did not take the dark color as did the liquid part.

Qualitative numbering was performed, with **1** *being the* **lightest** *shade (acid) and* **4** *being the* **darkest** *shade (base)*

RESULTS:
(6 hours later)

A) The particles with the highest starch content were concentrated in the middle forming a darker colored circle.

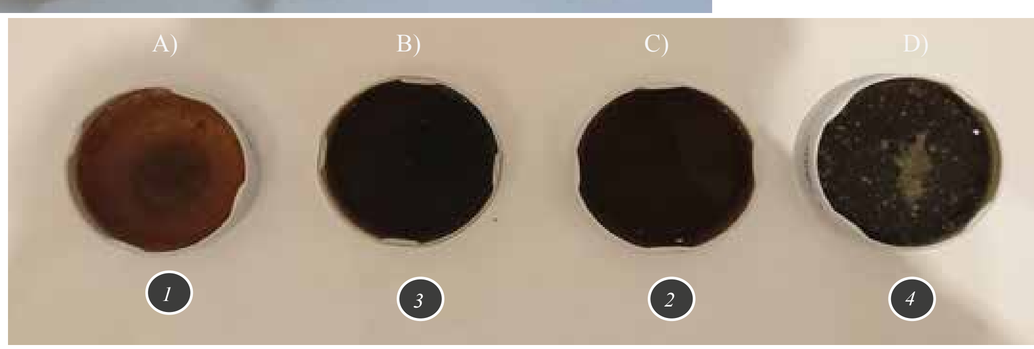
B) Dark color homogeneously throughout the substance.

C) Slightly clearer than the previous one.

D) The substance acquired the darker color, the solid particles of potato skin residues that
remained in the sample did not absorb the tone.

Qualitative numbering was performed, with **1** *being the* **lightest** *shade (less starch) and* **4** *being the* **darkest** *shade (more starch).*

(Immediately results)



(After 6 hours results)

DISCUSSION:

As expected based on the results of **TEST 1** and the theoretical analysis, the highest visible content of starch by iodine test was found in the skin of freshly peeled potatoes, because the content and properties of the starch have not been modified by environmental conditions or intervention in its structure through factors such as temperature, degradation over time, bacterial agents etc.

The Lugol reagent obtained in the next section can be used to recognize the presence of starch, because "this substance adsorbs the iodine producing an intense blue coloration, discoloration that disappears when heating, because the structure that has been produced is broken, but returns to appear when cooling."

Lugol reactive: History of Discovery and teaching applications 2013

Iodine

TEST # 1b pH measurement

According to the conservation method

OBJECTIVE: Compare the level of ph in 4 different samples of potato skin preserved in different ways.

MATERIALS:
- Universal ph Indicator
- Beakers
- Chronometer
- Petri dish
- Syringe
- Eye protection
- Hand protection
- Test tube
- Stirring rod

- Water result of test 1:

A) Dry skin water
B) New skin water
C) Wet skin water
D) Frozen skin water

TOTAL TIME: 7 hours

METHOD: Lugol

PROCESS:
Extract part of the substance and add the **pH** measurement solution and record the immediate result.

Description:
5 drops of pH measuring substance
10 ml of "potato water"
5 ml of water

-(After 6 hours of rest, record the changes.)

Repeat this process with the 4 different samples (A - B - C - D)

RESULTS:
(immediately)
VISUAL INSPECTION

A) 2 

B) 4 

C) 1 

D) 3 

RESULTS:
(6 hours later)

A) 2 

B) 4 

C) 1 

D) 3 

Qualitative numbering was performed, with **1** *being the* **lightest** *shade (acid) and* **4** *being the* **darkest** *shade (base).*

DISCUSSION:

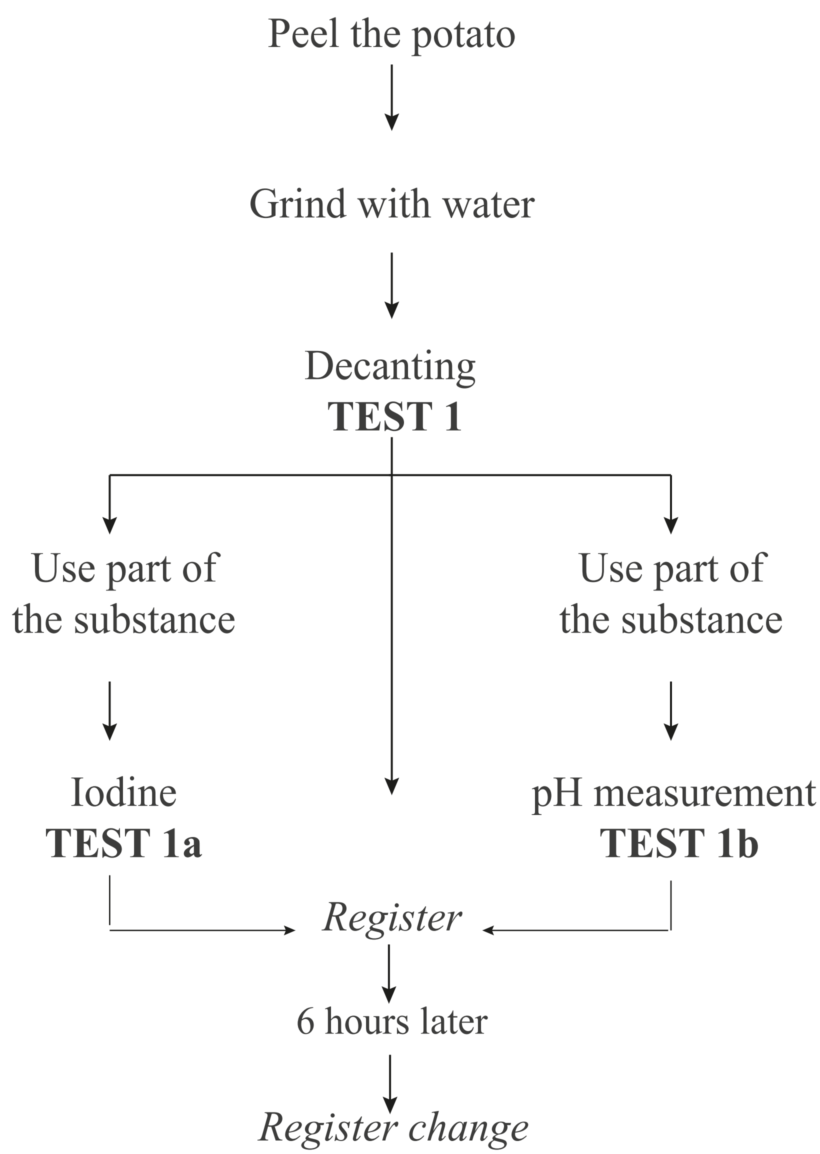
The pH measures the potential of hydrogen in a substance, is represented from 0 to 7 as acid with red and yellow colors and from 7 to 14 as a base with green and blue colors.

The immediate results are equal to the results after 6 hours, referred to the enumeration, the new potato skin is the darkest that is with the base pH, while the potato skin with vinegar, as expected, is the most acidic.

When using vinegar as a conservation additive the ph becomes very acid, to achieve a neutral substance it is necessary to add a base substrate, because in the next experiments it is necessary to add a certain amount of vinegar, and the increase in acidity can modify the properties of the final material.

Ph indicator

Graphic process



TEST # 2 Obtain starch powder from potato peels

OBJECTIVE: Obtain powdered starch with the process of decanting using a mixture with the steps registered in the TEST 1.

MATERIALS:

- Potato skin
- Water
- Mixer
- Container
- Strainer

TOTAL TIME:
6 hours process + 24 hours of drying.
METHOD: Decanting

PROCESS: Grind the solid (potato skin) with water until obtain an homogeneous mixture. (Use TEST 1 as a reference).

Filter the result to obtain the liquid substance inside the container and leave aside the solid part.

Put the liquid substance at rest for two hours, in this way the starch being more dense will remain at the bottom creating a white layer.

After the first decanting process, remove the water (1) and add the same quantity of clean water.

Leave it at rest for two hours more, and then remove the water to obtain the white layer of more defined starch and let it dry at room temperature until it is completely dehydrated.

Refine the solid material until obtain smaller particles. (Powder)

Graphic process

POTATO SKIN

↓

Grind with water

↓

Filter

↓

Use the liquid substance → Skin fiber waste

↓

Decanting (1)
[2 hours]

↓

Replace the water
with the same quantity (1L)

↓

Decanting (2)
[2 hours]

↓

Take out
the water

↓

Dry at room
temperature

↓

STARCH POWDER

RESULTS:

Analyzing the amount of material used, 1 kg of potato peel could generate 300 gr of starch powder.

The material obtained is the starch that remains in the bottom after the decantation process, the white layer dries and hardens and when extracting the material dark brown particles are observed in the upper part and white in the base.

The starch powder will be used for the development of the following material tests.

- Make a Glue -

"About 80% of the starch supplied to the industry is used as a glue in the manufacture of paper and cardboard to join the components that form the cellulosic fiber, paper, and fillers, thus avoiding the superficial detachment of the fibers, improving the resistance and providing a smooth texture."
FAO (2010)

TEST # 3 Glue (with commercial starch & starch result of TEST 2)

OBJECTIVE: Create an adhesive substance with the starch powder obtained in the previous test.

For this experiment a test will be done with potato starch, processed corn starch and skin potato starch, to observe the differences between each product and determine the properties and characteristics of the final glue.

(Processed starch is that produced industrially which can be found in the super market, usually for gastronomic use, it is obtained from the whole potato).

MATERIALS:
- Starch (corn, potato, Skin potato)
- White wine vinegar
- Water
- Glycerin
- Bowl
- Measurer
- Spoon
- Pot

BASIC COMPOSITION FOR STARCH GLUE:

-Starch 15 gr
- Water 5 ml
- Vinegar 15 ml
- Glycerin 5 ml

TOTAL TIME:
30 minuts

METHOD: Heating

PROCESS:
In a bowl, mix starch, water, vinegar and glycerin, with the specified measures
Mix until a homogeneous substance is obtained.

Pour into a pot over low heat and stir for approximately 5 minutes.

Once mixed together (you will see that having diluted the starch before it will be very fast dissolve without lumps), continue stirring.

As soon as it begins to thicken, lower the flame to a minimum and if you want a thicker mixture, leave the pot on the fire for another 30-60 seconds, stirring constantly.

When it has reached the right density, remove from the heat.

This method generates gelatinization by heat, so as the temperature decreases the material will return to its solid form and the consistency will change.

Heat

Glue

RESULTS:
VISUAL INSPECTION

The three materials met the objective; When heat was applied, gelatinization started and when the temperature decreased, the substance generated a more solid consistency and propitiated to adhere to the surfaces.

Corn starch

1) Dark white

- Consistency:
Commercial glue

- Description: Homogeneous and smooth consistency, looks like vinyl glue.

Potato starch

1)Clear white

- Consistency:
Homogeneous silicone

- Description: Transparent, with some lumps and very sticky, has a similar appearance to liquid silicone but a little more dense.

Skin potato starch

1) Brown

- Consistency:
Dark Silicone

- Description: It does not have a homogeneous consistency, it has lumps if potato skin particles, which generates less fluidity.

Preservation:

The result was preserved in glass containers at room temperature, the vinegar in the mixture allows its preservation capacity.

Due to the composition of the mixture, the material will lose adhesion and increase the cohesion when the temperature decreases, that is, it will become a homogenous, solid but sticky mass with a silicone aspect, its particles will regroup until heat is reapplied, moment in which the substance returns to the state of gelatinization and increases the capacity of adhesion.

This means that the glue retains its capabilities even after its first use, it must be heated to achieve the necessary properties.

It is normal for the mixture to lose liquids while it rests in the container, even more if it is stored at low temperatures (in the refrigerator); It should be noted that once solidified, the mixture will not have the same appearance of the first use, (soft and homogeneous) So, it is necessary to ungroup the particles before their second use to avoid the formation of lumps in the glue.

Graphic process

Starch

+

Water

+

Vinegar

+

Glycerin

↓

Mix

+

Heat

↓

Mix

↓

STARCH GLUE

TEST # 4 The function of the glue

OBJECTIVE: Test the adhesion properties of the glue created with different materials.

For the glue test will be used:
A commercial glue (vinyl) and the potato starch-based glue that was made in the previous steps, one just made it (New glue) and another that had been preserved for a month in the closed container (Preserved glue).

MATERIALS:
- **New glue**
- **Preserved glue**
- **Vinyl glue**
- Paper
- Cardboard
- Plastic
- Cotton
- Metal
- Balsa
- Wine cork
- Ceramics
- Silk paper
- Craft paper
- Low-caliber cardboard

Heat the glue

TOTAL TIME:
45 minuts

METHOD: Pasting

PROCESS:
Heat the mixture required for the glue test.

Then, have the materials in equal pieces to be united of the same material, so: paper with paper, cardboard with cardboard. etc

Use the glue heated with a stick to add the mixture to each material and proceed to paste them.

Let dry.
24 hours later the adhesion tests were performed, separating each material and observing how paste it was.

Preserved glue

Glue test adhesion capacity

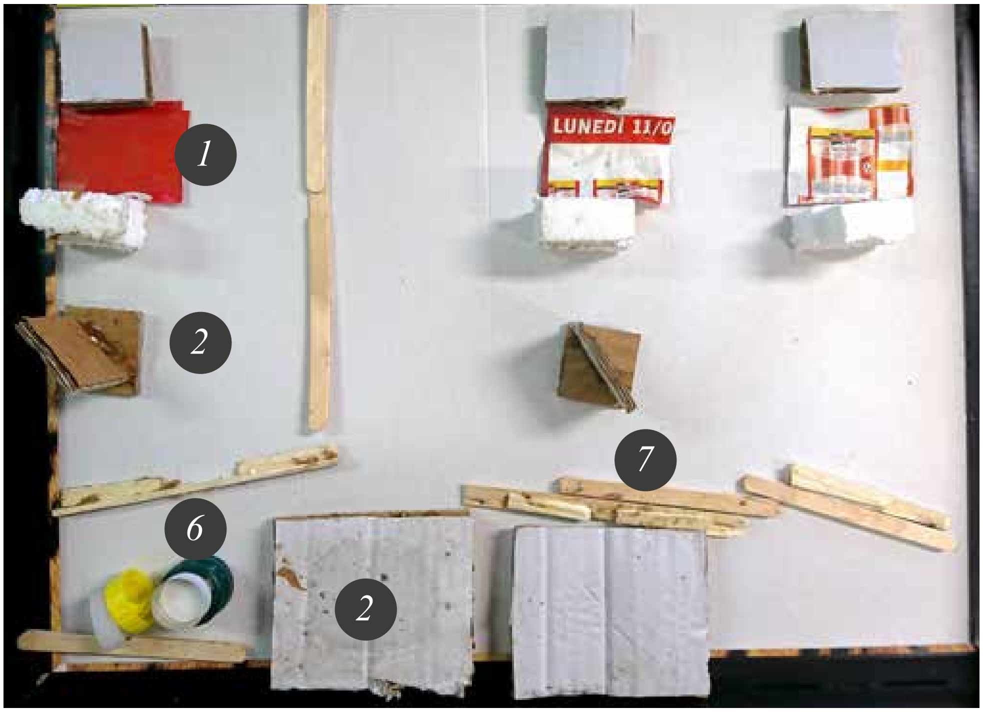
Recycled materials
(Use the glue just heated)

	Material	*New glue*	*Preserved glue*	*Commercial glue*
1	Paper	✔	✔	✔
2	Cardboard	✔	✔	✔
3	Ceramics with varnish	✖	✖	✖
4	Plastic	✖	✖	✖
5	Cotton	✖	✖	✖
6	Metal	✖	✖	✖
7	Balsa	✔	✔	✔
8	Wine cork	✖	✖	✖

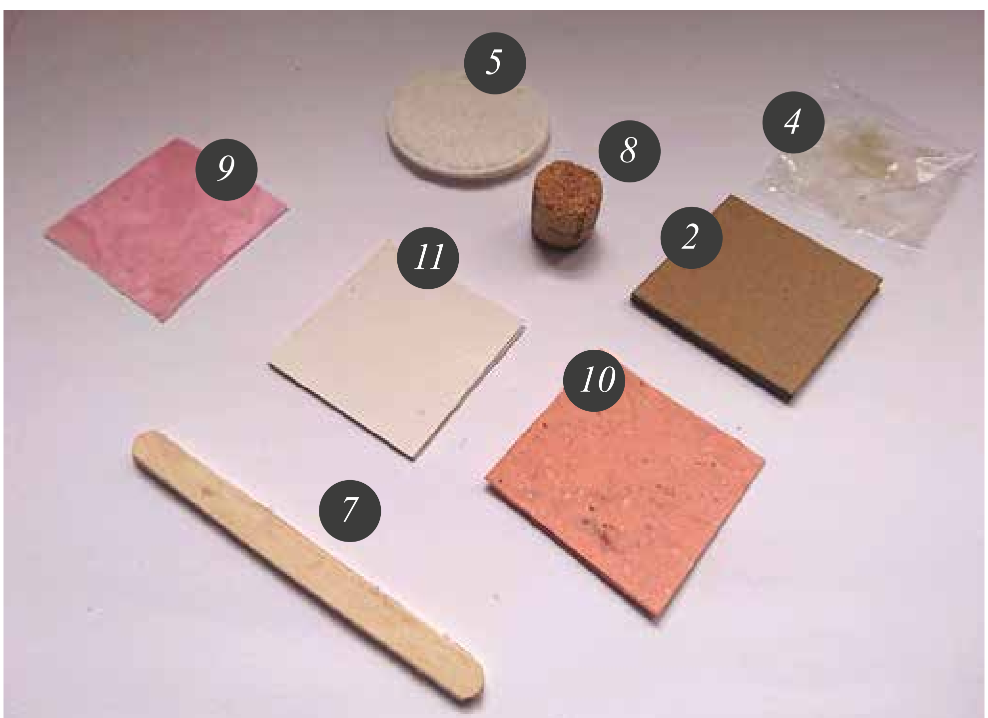
New materials: acquired specifically to perform the tests
(Use the glue just heated)

	Material	*New glue*	*Preserved glue*	*Commercial glue*
1	Paper	✔	✔	✔
2	Cardboard	✔	✔	✔
3A	Ceramics NO varnish	✔	✔	✔
4	Plastic	✖	✖	✖
5	Cotton	✖	✖	✖
9	Silk paper	✔	✔	✔
10	Craft paper	✔	✔	✔
11	Low-caliber cardboardork	✔	✔	✔

Images:



Recycled materials test



New materials

RESULTS:
VISUAL INSPECTION

- Both, new and preserved glue present adhesion results similar with commercial glue.

- There is greater interaction with porous materials such as cardboard and paper. And less interaction with NON porous materials such as plastic and metal.

- Because of its adhesion capacity, this type of glue could be used for handicrafts or in large cardboard structures, not only as an adhesive but also as an aggregant; Adhering resistance to the material and filling spaces.

- One of the main characteristics of this glue is its high percentage of moisture, which generates deformation in thin and absorbent materials such as paper sheets with low caliber.

- It is important to note that the preserved glue worked as well as the new one.


Gelatinization of glue


5 months preserved glue


New glue

Ceramics with glue

Paper with glue

TEST # 5 Mold with heat

OBJECTIVE: Use the material created above to obtain a solid form with properties similar to polymeric materials.

In the next step of the experiment it will be necessary to use the BASIC COMPOSITION FOR STARCH GLUE described before for the adhesive substance, but in this case, it will be mixed at room temperature and instead of adding heat in a pot it will be taken to the oven inside heat resistant containers so that generate a specific form.

MATERIALS:
- Potato commercial starch
- Corn commercial starch
- Skin potato starch

(BASIC COMPOSITION):

- **Starch** 15 gr
- Water 5 ml
- Vinegar 15 ml
- Glycerin 5 ml
- Oven 120º C / microwave
- Container for high temperatures

Material after the oven in ceramic

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:

Heating with oven
Mix the materials with the measurements of the BASIC COMPOSITION in a container at room temperature, pour the result of the mixture into a container to be taken to the oven.

Put the mixture in the oven at 120ºC for approximately 5 minutes.

Heating with microwave
Repeat the same steps and Put the mixture in the microwave for 1 minut.

The heat will start the process of gelatinization of the substance and will solidify progressively as it loses liquids.

Vinegar and starch

RESULTS:
VISUAL INSPECTION

OVEN — *5 minuts*

MICROWAVE — *1 minut*

Hard and dry mass of yellow color with some darker areas affected by heat.
Hard and resistant.

Yellow mass with white areas more flexible and moist than the oven material, retains its flat and circular shape.

1

Potato commercial starch

An irregular transparent circle shape with tendency to deformation of the edges. Over time it became a harder and more resistant material.

Smoother and more humid texture, visually more transparent and uniform than the oven material.

2

Corn commercial starch

Dark material with small clear particles of starch extracted, hard, resistant and with a tendency to bend the edges.

Material with similar characteristics.

3

Potato skin starch (normal recipe)

- Make a Shape -

These next tests show the different types of materials that can result according to varieties of quantity, recipe, material, temperature and times, among other factors.

TEST # 6 Shape 1

OBJECTIVE: The next test consists of using the BASIC COMPOSITION of Starch Powder obtained from the previous steps, to create a solid shape.

MATERIALS:
- Basic starch composition
- Mold
- Oven

TOTAL TIME:
20 minuts
+ one week later (to record changes)
+ one month later (to record changes)

METHOD: Heating

PROCESS:
Distribute the mixture (Basic starch composition) in molds and put it in the oven at 120ºC until it loses its liquid state, approximately 10 minutes for molds with 20 ml of mixing content.

Take out of the oven and initiating its process of dehydration at room temperature locate it on a figure so that it takes a specific form when drying.

Graphic process

(visible fragmentations in the lower part)
After 10 minuts in the oven

"Solid" shape

(Flexible layer, similar to gelatin)

Make it acquire the form, in this case: a square box

RESULTS:
VISUAL INSPECTION

One week later

After a week the material loses its square shape to the sides, because they bend outwards and the corners tend to shrink.
The material is hard and resistant and has some cracks in its thinnest parts.

One month later

After a month the material has been losing liquids, and properties such as flexibility and soft texture, has become a hard and fragile sheet to break.
It has retained the texture of the mold lines but its edges have been bent inwards and it has completely lost the rectangular shape that it obtained after remaining in the box.

TEST # 6a Tests with different amounts of mixture

OBJECTIVE: Prove that the amount of mixture poured into the mold and heated in the oven affects the result and the properties of the final material.

MATERIALS:
- Basic starch composition
- Mold
- Oven

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
The following test will show the different results of the solid material by adding layers that gradually decrease from 10 to 5 milliliters of mixture, keeping the quantities proportional to those of the BASIC STARCH COMPOSITION in a mold of 10 cm in diameter.

RESULTS:
The material with the least amount of mixture due to the lower amount of liquids, it dehydrates before the others and the heat causes it to lose its circular shape shrinking in and suffering fragmentation.

The material with the highest mixing content presents subtle and thick areas according to the position of the mold in the oven and factors that are not precise on a homemade scale (uniform temperature for all the material).

In the material with the highest mixing content the upper part is the first to dry, for this reason in the lower part a white layer is formed that is less plasticizing and has a powdery consistency.

After 10 minuts in the oven

10 ml 5 ml

TEST # 6b   Shape 2

OBJECTIVE: The next test consists of using the BASIC COMPOSITION of Starch Powder obtained from the previous steps, to create a solid shape.

MATERIALS:
- Basic starch composition
- Mold
- Oven

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
Distribute the mixture (Basic starch composition) in molds and put it in the oven at 120ºC until it loses its liquid state, approximately 10 minutes for molds with 20 ml of mixing content.

Take out of the oven and initiating its process of dehydration at room temperature locate it on a figure so that it takes a specific form when drying.

For this test we used the thickest material from the previous test, that is, the one that contained 10 ml of mixture and that generated a more uniform layer.

RESULTS:

Right out of the oven

Flexible and soft material, a little gelatinous and with transparencies

One week later
Room temperature

Rigid material, preserves the color but with areas of opacity, is not completely flat as it should.

(fixed with tape on a circular, flat mold).

TEST # 6c Shape 3

OBJECTIVE: The next test consists of using the BASIC COMPOSITION of Starch Powder obtained from the previous steps, to create a solid shape.

MATERIALS:
- Basic starch composition
- Mold
- Oven

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
Distribute the mixture (Basic starch composition) in molds and put it in the oven at 120ºC until it loses its liquid state, approximately 10 minutes for molds with 20 ml of mixing content.

Take out of the oven and initiating its process of dehydration at room temperature locate it on a figure so that it takes a specific form when drying.

For this mold we will use the material that contains 9 ml of mixture.

RESULTS:

Right out of the oven
The circle initially does not allow its right position because the shapes do not match and can cause breakage, for this reason, four cuts are generated in the circumference of the figure of three centimeters inward, to be able to bend the edges on the glass that will be mold.
After locating the material we will put a ribbon to hold it and not lose its shape.

One week later
A week later the material is solid, dry and rigid, however the tape must be removed in a delicate way because is a fragile layer, we can see the cuts made at the beginning, folded towards the sides and without a concrete shape, when drying, as it can be seen in the previous tests the material is deformed and contracted.
It contains cracks that will eventually start to open and break the material.

TEST # 7 What can go wrong?

OBJECTIVE: Use different molds, temperatures and quantities of material different from the basic composition to perform an error index test and characterize the reasons for failure during the process.

MATERIALS:
- **Basic starch composition**
- Mold
- Oven

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
The process will be the same as in the previous tests but for each example will be a factor of change).

RESULTS:


If the layer is very thin, the material loses water and it will be more fragile and will present ruptures.
- QUANTITY OF MIXING


The material will not maintain the shape of the mold during the cooling process, it will contract unless it takes a specific shape when drying.
- GET THE SHAPE


Its important to controlling the time and temperature of the oven according to the recipe. If the time is exceeded, the material will dehydrate before the gelatinization process and it becomes powder again.
- TEMPERATURE / OVEN TIME


The content of glycerin in the Basic composition acts such as plastification allowing the solidification process, if you put more than that the material will be sticky and with an excess of liquids.
- MORE GLYCERIN


The material of the mold must allow to mix the substance on the right way and be uniformly heated, if the material is porous as the ceramic the substance may adhere to the bottom or become powder when drying.
- WRONG MOLD

- Make a Mix -

In this phase we will get an intervention in the BASIC COMPOSITION with different materials in order to record changes in their properties with each of them.

For this, has been made an agreement with the Designer ***Danilo Perozzi***, who works in a project related to improve his material created with rice husk with a bio based adhesive.

Research collaboration, D. Perozzi

Starch extracted from potato skins: a natural binder?

In developing of the master's thesis in the field of valorization of the cereal supply chain carried out by ***Danilo Perozzi***, in collaboration with the *Mulino Marino di Cossano del Belbo*, we tried to integrate the natural glue as a binder in order to form a composite material together with different scraps of cereal supply chain.

Upstream of this activity, there are studies on the individual processes carried out by the Mill and the effects that they have on the environment.

The *Mulino Marino* material flows were analyzed, focusing on the waste produced by their activities.

On some occasions it has been noted that some of the waste products lacking the characteristics to be reinserted into other sectors (eg zootechnics) are considered as waste.

Residue of interest: wheat husks

The analyzed waste was the grain skins, which represent about 15% of the total grain weight.

In 2017 the quantity of processed grain amounts to 680 tons, from which 420 tons of flour, 180 tons of dash, 70 tons of wheat peel and 10 tons of organic sand were produced.

The wheat peel derives from the brushing and filtering process, a step introduced in February 2017 following the implementation of the *Atex* directives.

The peels comprise the external part of the grain, in particular surface tegument and germ leaf.
The skins, which given the current regulations cannot be considered as by-products, are collected in 25 lt bags.

They appear as an agglomeration of thin, very light, irregular and sandy leaf particles. Yellow in color with hints of brown. If you lay on the palm of your hand you can recognize whitish, compact and mealy granules.

Source: Danilo Perozzi, Ricerca sperimentale per la valorizzazione degli scarti di molitura, 2019.

Characterization of wheat skins

From the results obtained from the analyzes on the energy value, the toxicity and the composition, was found the presence of about 20% of starch with respect to the total weight, a characteristic that makes the skins suitable for experimentation for the development of a bioplastic compound from plant matrix . From the toxicological test performed all the values do not constitute a danger for human and animal health. From the chemical characterization the values of the indicators of the components such as Phosphorus, Selenium, Magnesium and Zinc are significant.

Laboratory test

The problems found in the first tests carried out without the binder extracted from potato skins were related to the cohesion and lack of stability of the compound. The laboratory tests carried out by *D. Perozzi* aimed to understand how the integration of starch could influence the compound under external stresses of different nature. Thus, cohesion and forming tests have been carried out. Subsequently, some elements necessary from a chemical / physical point of view were introduced into the recipe to manage the vegetable matrix mixture.

The tests continued until finding proportions between the elements of the dough that best respond to guaranteeing greater workability. Thermal stress tests were performed, using a heated chamber to record the behavior of the mixture at different temperatures, of mechanical stress, through pressure in the mold and extrusion to understand which potential processes were suitable for the compound.

From the results obtained by *D. Perozzi* it is possible to analyze some behavior of the material similar to thermoplastic materials. For example, once formed and brought to room temperature it can be ground or pulverized and re-heated to be reformed.
On the other hand, during the drying phase, negative aspects were found, since in the process of water loss by the compound, the geometries tend to deform in a decomposed manner and consequently reduce the volume. The deformation criticality could however be exploited to become a strength of the project, thus trying to guide the deformation in relation to the final shaping to be obtained.

TEST # 8 Mix the materials

OBJECTIVE: Use different materials to mix the BASIC COMPOSITION and obtain different properties.

MATERIALS:
- **Basic starch composition**
- Mold
- Oven
- Coffee
- Wood pieces
- Toothpicks
- Aluminum

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
Coffee: Add 10 gr of coffee to 20 ml of Basic composition and put in the oven.

Wood piece:Add pieces of wood in half to 20 ml of Basic composition and put on the oven.

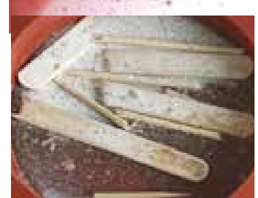
Toothpicks: Add 5ml of basic composition to 4 toothpicks put together to act as glue.

Aluminum: Create a spoon-shaped mold with aluminum and put inside 20 ml of Basic composition.

Put in the oven 10 minuts at 120º

RESULTS:

Material	Description
Coffee	Due to the density of the coffee particles, these remain in the bottom and the material does'nt dry in its entirety, so the coffee does'nt add to the mixture and the powder coffee remain at one side.
Wood pieces	The substance with the added pieces of wood did'nt hold them inside, because they floated at the time of dehydration and the material took the shape of the sticks.
Toothpicks	The sticks with less mixture content bonded very well, the substance acted as an adhesive and kept them together when drying.
Aluminum	The spoon-shaped aluminum mold left the folds in the final material but broke in the parts with less mixing content

10. The *platano*

According to the SIC (Super Intendencia de Industria y Comercio), Colombia.

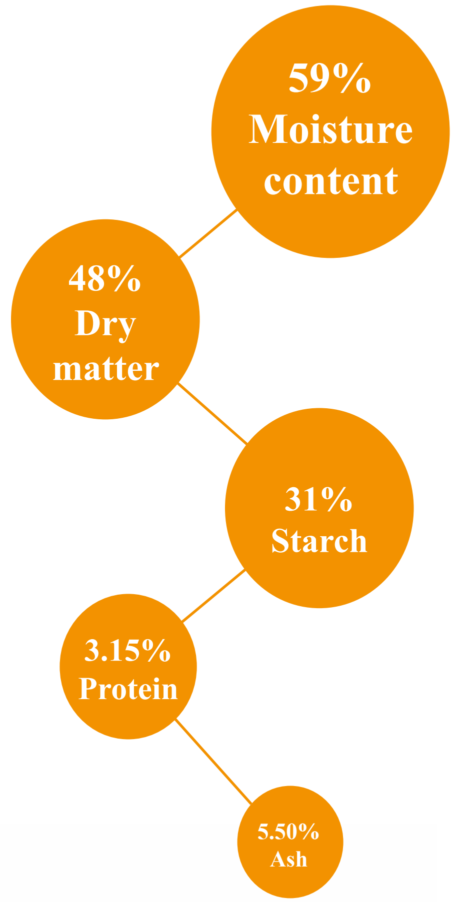
The industrial uses of plantain show that of this product are mainly manufactured salty or sweet snacks called *patacones*, and plantain flour, in the production of these are used other products like potatoes and cassava, showing that they are part of the same relevant market.

Now, for the flour production, the
plantain is very appreciated for its nutritional properties, carbohydrates, proteins, vitamins, minerals and fiber, considering it, similar to dietary fiber.

This product has been become to some extent a substitute for the wheat flour, since it lacks the gluten that contains this, plus it absorbs more water and gels more quickly.

In this way, in Colombia the plantain is a product that is processed and generates organic waste that is discarded (the skin), with which a new approach could be generated.

Source: Eleazu 2011



TEST # 9 Obtain starch powder from platano skin

OBJECTIVE: Obtain powdered starch with the process of decanting using a mixture with the steps registered in the TEST 1, but this time with PLATANO skin.

MATERIALS:
- Platano skin
- Water
- Mixer
- Container
- Strainer

TOTAL TIME:
6 hours process + 24 hours of drying.
METHOD: Decanting

PROCESS:
Grind the solid (platano skin) with water until obtain an homogeneous mixture. (Use TEST 1 as a reference).

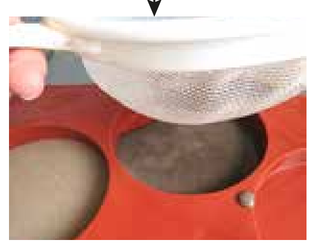
Filter the result to obtain the liquid substance inside the container and leave aside the solid part.

Put the liquid substance at rest for two hours, in this way the starch being more dense will remain at the bottom creating a white layer.

After the first decanting process, remove the water (1) and add the same quantity of clean water.

Leave it at rest for two hours more, and then remove the water to obtain the white layer of more defined starch and let it dry at room temperature until it is completely dehydrated.

Refine the solid material until obtain smaller particles. (Powder)



Graphic process

PLATANO SKIN

↓

Grind with water

↓

Filter

↓

Use the
liquid substance → Skin fiber waste

↓

Decanting (1)
[2 hours]

↓

Replace the water
with the same quantity (1L)

↓

Decanting (2)
[2 hours]

↓

Take out
the water

↓

Dry at room
temperature

↓

STARCH POWDER

- Make a Glue -

TEST # 10 Glue

OBJECTIVE: Create an adhesive substance with the starch powder obtained in the previous test.

For this experiment let's follow the same steps of Test #3 , but with Platano peel starch, in order to compare the properties of this material in relation to potato skin.

MATERIALS:
- Starch (corn, potato, Skin potato)
- White wine vinegar
- Water
- Glycerin
- Bowl
- Measurer
- Spoon
- Pot

BASIC COMPOSITION FOR STARCH GLUE:

- **Starch** 15 gr
- Water 5 ml
- Vinegar 15 ml
- Glycerin 5 ml

Platano basic composition

TOTAL TIME:
30 minuts

METHOD: Heating

PROCESS:
Heat the mixture required for the glue test.

Then, have the materials in equal pieces to be united of the same material, so: paper with paper, cardboard with cardboard. etc

Use the glue heated with a stick to add the mixture to each material and proceed to paste them.

Let dry.
24 hours later the adhesion tests were performed, separating each material and observing how paste it was.

Platano Glue

Graphic process

Starch

+

Water

+

Vinegar

+

Glycerin

↓

Mix

+

Heat

↓

Mix

↓

STARCH GLUE

RESULTS:

What is the difference between platano skin starch in relation to potato peel starch?

The platano is a larger tuber, so, the area of the skin besides being thicker, covers more space and weight than the peel of the potato, which is much more subtle and does not collect the same amount of starch to be extracted from the tuber.

One of the visible differences is the color, the banana skin generates a darker color, because the latex that contains its shell when in contact with oxygen generates an oxidation process changing its color.

Platano Glue after one weel

TEST # 11   The function of the glue

OBJECTIVE: Test the adhesion properties of the glue created tested with different materials.

For this test follow the same steps of the test # 4

MATERIALS:
- **New glue**
- **Preserved glue**
- **Vinyl glue**
- Paper
- Cardboard
- Plastic
- Cotton
- Metal
- Balsa
- Wine cork
- Ceramics
- Silk paper
- Craft paper
- Low-caliber cardboard

TOTAL TIME:
45 minuts

METHOD: Pasting

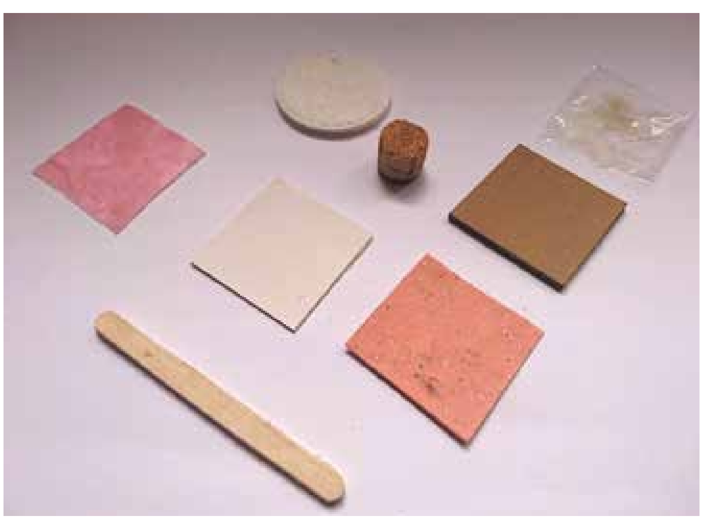
PROCESS:
Apply the same process of Test # 4

RESULTS:

The Platano glue acts the same as the potato glue, the results of the graph are the same.

The material changes visually but works equally well with porous materials.

Paper with glue



Same materias of Test #4

Ceramics with glue

- Make a Shape -

TEST # 12 Shapes

OBJECTIVE: Use the B.C (BASIC COMPOSITION) to create a shape just as it was done with potato peel starch but this time with the Platano starch extracted.

MATERIALS:
- Basic starch composition (platano)
- Mold
- Oven

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
Follow the same process as in test # 6.
In this case, 3 different tests were made. The first image shows the material with B.C but without adding water.
The second shows a subtle layer of B.C with plantain starch.
The third is B.C with the same combination of potato and plantain starch.

RESULTS:

Its evident that the properties given by water in the process of drying the material are very important, The B.C without water resulted in a gummy and fragmented material.

The material with the platano starch B.C is similar to the result with the potato starch, visually changes the color and texture with dark particles, however, as in the previous tests the material was bent and fragmented over time to dehydrate at room temperature.

The combination of potato and banana starch in B.C using the same amount turned out to be a fairly consistent material with a plasticized texture surface that loses its firmness over time.

B.C Without water

B.C with Platano

B.C with Platano and Potato starch

- Make a Mix-

TEST # 13   Mix the materials

OBJECTIVE: Use different materials to mix the B.C of platano starch and obtain different properties.

MATERIALS:
- **Basic starch composition (platano)**
- Mold
- Oven
- Platano skin

TOTAL TIME:
20 minuts

METHOD: Heating

PROCESS:
Follow the same process as in test # 8.
Add 20gr of potato skin (Solid waste left over from the decanting process described in test # 1).

RESULTS:

The product was a material with good properties in terms of strength, hardness and initial flexibility, because the platano skin is very fibrous, this helped to give consistency as a base to the starch.

Visually it is much darker and denser than the other materials, the fibers generate an undefined and unrefined texture, however, it meets the objective.

- A test was also carried out by putting in the oven only platano skin without any type of aggregator and this did not join properly and broke.

- By adding rice husk (not very refined) to B.C as expected due to the density the mixtu-re and the husk particles were divided and the material was not added correctly, so it collapsed.


Cone with Platano B.C and Platano skin

11. MATERIALS OBTAINED

12. CONCLUSIONS:

The objectives were achieved, bio-based materials were generated with the part that is discarded from some organic materials, that is, the waste of two types of raw material, based on two territorial realities, in this case the potato chosen as a tuber rich in starch, predominant in Italian agriculture (Piedmont region) and in parallel the platano with similar properties and one of the main crops of Colombian agriculture.

The experimentation process was carried out on a small scale or "homemade"; therefore the artifacts and methods used are typical of a home environment or basic laboratory, however, the results could be studied with an industrial perspective, so there is the possibility of applying the method to a larger scale of production analyzing the process of collection of the waste of the big industry as it can be the production of snacks, and also the economic, social, technological and environmental factors to continue with a network based on the circular economy.

The tests confirm that it is possible to obtain a material created with the starch extracted from the skin of the potato and the platano following the same process, which focuses on the crushing of the solid matter followed by the decantation to obtain the starch as dense material, which is then mixed with vinegar, glycerin and water with specified measures named as basic composition, wich is transformed through the application of heat; these materials differ in visual aspects and properties that can be analyzed in the description of results; one of the main differences between the use of raw materials is that the process with the platano skin generates 10 grams of starch more than the potato process, using the same quantities and methods.

After these processes, we obtain 3 types of results, which have been named Shape, Glue and Mix; respectively it can be concluded that with the result "Shape" it was possible to obtain a solid material that loses its flexibility over time, so, as it dehydrates it increases its rigidity and becomes more susceptible to breakage, however, it was not possible to give an specific shape because the material contracts when losing liquids, in this way needs another transformation method to preserve the figure.

This type of rigid material could be studied to improve its properties and achieve characteristics similar to polymeric materials of synthetic origin used in the packaging industry, the agricultural sector and construction, among other possibilities, but in this way the use of organic waste would be promoted and could generate a new option for sustainable production.

The second resulting material, the "Glue" is a gelatinous material that fulfills its function of adhering some porous materials to each other like paper, cardboard, ceramics without varnish, even after several months of preservation of the mixture; the results on a small scale can be used for crafts, decorations or children's projects, however, the adhesive fulfills functions such as filling spaces generating a layer that beyond to adhering the materials, solidifies and gives thickness, then, studies could be carried out at greater scale to analyze how the material acts in gardening or construction environments.

Its important to highlight that the basic composition and the steps in the methodology of each study can be modified to obtain materials with different properties according to the objective to which it is desired to arrive; The third result or "Mix" material mixes in its basic composition, with another type of materials such as coffee or rice husks, which must be refined and mixed correctly to avoid the decantation of the particles and, therefore, the separation of the materials, another type of mixture with which the tests were carried out was the potato starch with the platano starch, in the same amounts, which initially generated a more resistant and homogeneous material, but, after a month of dehydration at room temperature didn’t get rigidity as the material of the "Shape" test.

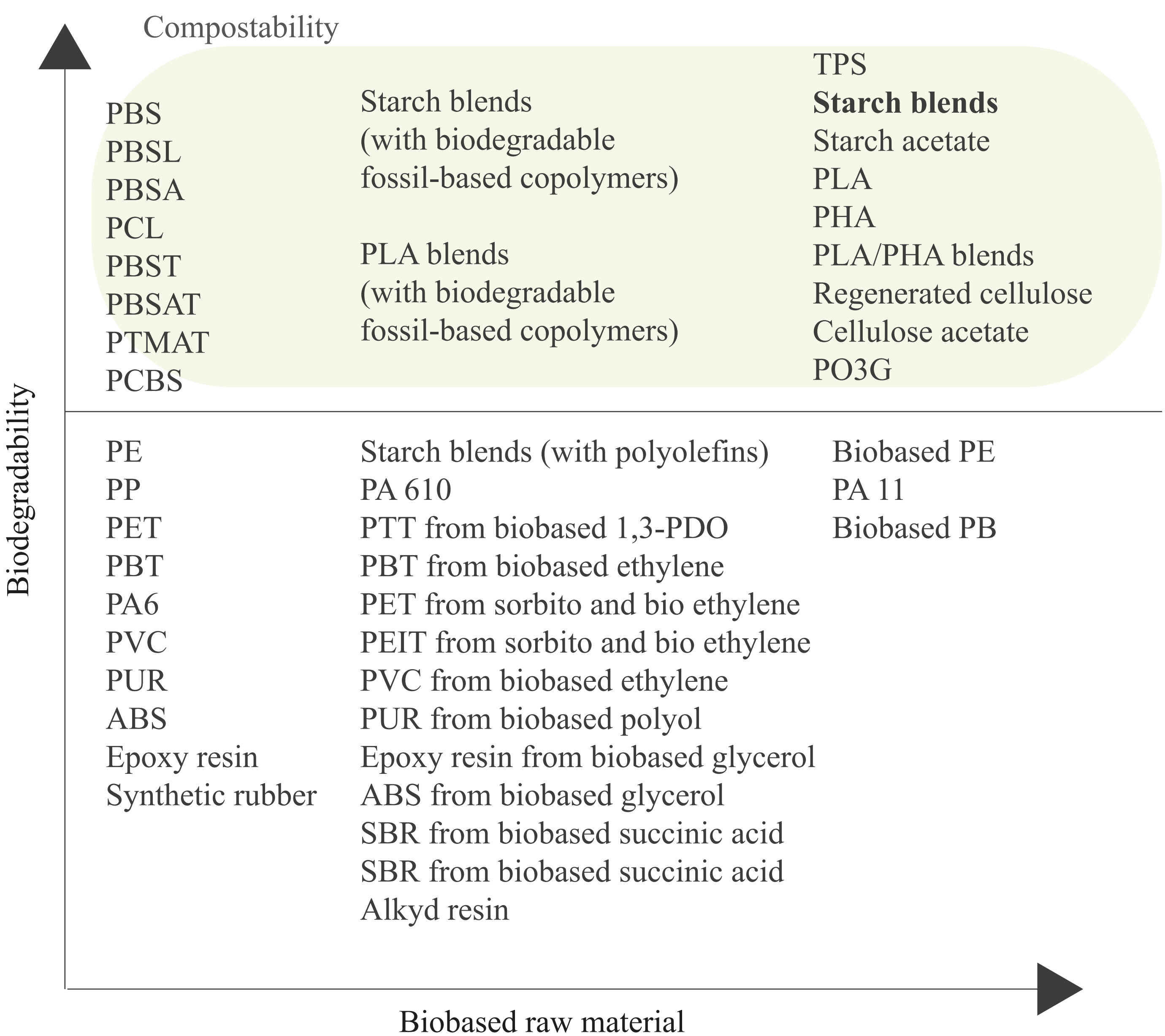
Another material for the "Mix" phase was the platano fiber resulting from the decanting test, that is, the solid part that remained of the skin, because according to the results it would give more consistency and solidity to the material and in fact the material obtained was visually more dense, dark and fibrous, gave body to the layer obtained offering the possibility of giving a shape, in this case: a cone, which after its dehydration shrunk and slightly modified the figure.

In general, during the experimentation phase, it could be concluded that the drying process to achieve a shape was not adequate to maintain, but, it was determined that the type of mold according to the material influences the properties of the product, and in the case "homemade ", silicone resistant to high temperatures is the most suitable for the procedure.

The initial theoretical research shows other materials that could be integrated into the composition of starch, such as resins, algae, some fruits and generate thousands of combinations to obtain products with different functions and properties creating networks with the local productive chains of each raw material used and creating a new system based on bio production.

13. ANNEXES:

Biodegradable and bio-based materials chart



Source: Universal Utrech 2009

Materials abbreviations list

ABS	Acrylonitrile butadiene styrene
AC	Acrylic
AcC (CTA, TAC)	Acetyl cellulose, cellulose triacetate
EP	Epoxy resin (thermoset)
PA	Polyamide 4, 6, 11, 66
PAN	Polyacrylonitrile
PBAT	Poly(butylene adipate-co-teraphthalate
PBS	Poly(butylene succinate)
PCL	Polycaprolactone
PE	Polyethylene
PLA	Poly(lactide)
PMA	Poly methylacrylate
PMMA	Poly(methyl) methacrylate
POM	Polyoxymethylene
PP	Polypropylene
PS	Polystyrene
EPS	(PSE) Expanded polystyrene
PU	(PUR) Polyurethane
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
SAN	Styrene acrylonitrile
SBR	Styrene-butadiene rubber
Starch	Starch

Behind the scenes pictures




14. REFERENCES:

Anika Zafiah Rus, M. (2010 v. 93, no. 3). Polymers from renewable materials. Science Progress. Science. pp. 285-300 Science Reviews 2000, Available in: URL:https://www.jstor.org/stable/43424247.

Bach. Aydeé mallma ñaupa,a Adahuaylas, Perú (2017), Efecto del cuajo vegetal látex de higuera (ficus carica linnaeus) en la elaboracion del queso fresco, Available in: http://repositorio.unajma.edu.pe/bitstream/handle/123456789/250/Aydee_Tesis_bachiller_2017.pdf?sequence=3&isAllowed=y (accessed 13 January 2019).

Bedolla S.& Dueñas C., (2004), Introducción a la Tecnología de Alimentos, México D.F, 315 pp.

Bejarano Cruz Rodrigo Santiago, (2017), Characterization of physicochemical and thermal properties on starche extracted from native potato (Solanum tubersum L.) cv. “Manzana”, grown in Chugay distric – Sánchez Carrion province, La Libertad department.

Bemiller, J. & Whistler, R. (2009). Starch chemistry and technology. Amsterdam. p. 149-192.

Bertolini, A. (2009). Starches, characterization, properties and applications. Amsterdam. p. 1-19

Bistagnino Luigi, Design Sistemico, (2009).

Blog, All the potato varieties you need to know about, 2014, Available in: https://www.huffpost.com/entry/potato-varieties_n_1105586.

Blog Aris, specialisti dell’imballaggio. Gli adesivi nella preistoria. (2017)
Available in: https://www.ariximballaggi.it/arixblog/adesivi-nella-preistoria/

Bressanini, D. (2008) Frutta all’etilene, Scienza in Cucina, Available in: http://bressaninilescienze.blogautore.espresso.repubblica.it/2008/08/17/frutta-all%E2%80%99etilene/ 2008

Can potato peels become the hot new eco-friendly building material?, (2019), Available in: https://potatonewstoday.com/2019/03/27/can-potato-peels-become-the-hot-new-eco-friendly-building-material/

Carvalho, A.J.F., (2013) Handbook of Biopolymers and Biodegradable Plastics, (1st Edition) Properties, Processing and Applications.

Chemical composition of potato peel waste (PPW), (2010), Available in: https://www.researchgate.net/figure/Chemical-composition-of-potato-peel-waste-PPW_tbl1_446010414.

Comyn, J., (2005) Theory of adhesion, in: Handbook of adhesives and sealants, Amsterdam.

CREA (2017) Centro di Politiche e Bioeconomia Piemonte, Available in: http://www.tal.unito.it/do/didattica.pl/ShowFile?_id=ba9t;field=file;key=rnqxgy7wkk2hqKiI
nkoEsE8psZyYQl5iQ8vJaSZT70U;t=5317

Danilo Perozzi, (2019) Ricerca sperimentale per la valorizzazione degli scarti di molitura.

Edholm, S., Hide Glue Part II: Glue making, the basic essentials (2013), Available in: https://paleotechnics.wordpress.com/2013/09/08/hide-glue-part-ii-glue-making-the-basic-essentials/.

Eleazu, Chinedum1 . O., Okafor, Polycarp, N2 ., Amajor, John2 , Awa, Ezinne1 ., Ikpeama, Ahamefula. I1 . and Eleazu, Kate. C.1 (2011), Chemical Composition, antioxidant activity, functional properties and inhibitory action of unripe plantain (M. Paradisiacae) flour.

Facultad de Ingeniería . Mérida Edo Mérida (2016), Extracción de pectina de alto metoxilo a partir de cascaras de parchita para la producción de mermelada, Available in: http://webdelprofesor.ula.ve/ingenieria/marquezronald/wpcontent/uploads/ProyectoPectiprods.pdf

FAO Food and Agriculture Organization (2008) La papa, Available in: http://www.funsepa.net/guatemala/-docs/La%20papa.pdf

García, N.L., Aranguren, M., Dufresne, A. & Goyanes, S. (2007) Efecto de la concentración de amilopectina en la respuesta fisicomecánica de films de almidón. Congreso SAM/CONAMET. San Nicolás.

Giovanni Treccani S.p.A. Enciclopedia Italiana

Potato pro blog, Available in: https://www.potatopro.com/world/potato-statistics.

International Starch Institute (2018), Available in: http://www.starch.dk/isi/starch/potato.asp
J. I. Brauman, (22 February 1991), Polymers, American Association for the Advancement of Science Stable v. 251, no. 4996 p. 853, Available in: https://www.jstor.org/stable/2874870

Laffort oenologie, (2001).Albumina e colla di pesce. (numero 9), Febbraio 2001, Available in:http://www.-viniferanieri.it/wpcontent/uploads/2015/04/Info_09_AlbuminaUovo_CollaPesce.pdf

Leoni, R. Chimica che non si vede: gli adesivi. Avisa, Federchimica. Available in: http://dipcia.unica.it/superf/Lauree_Scientifiche/Adesivi.pdf

Meadows, D., Randers, J., & Behrens, W. (1972) The Limits to growth, United States of America, Universe Books.

Miranda Ramirez P (2018), Transforman desperdicio de mango en biopolímero, Available in: http://conacytprensa.mx/index.php/tecnologia/biotecnologia/22452-transforman-desperdicio-de-mango-en-biopolimero.

Monro, J. & Mishra, S. (2019) Nutritional Value of Potatoes: Digestibility, Glycemic Index, and Glycemic, Impact in Advances in Potato Chemistry and Technology.

Myers, R.L. & Krebs, R.E. (2006). The basics of physics, Greenwood press, Westport, Connecticut.
National Science Teachers Association Stable. (December 2010). The Science Teacher: Plant-Based Plastics, Activities and investigations, v. 77, no. 9, pp. 17-19, Available in: https://www.jstor.org/stable/24146411

NPCS Board of Consultants & Engineers, Adhesives, Glues & Resins Technology (with process & formulations) (2016), Asia Pacific Business Press Inc.

Organic Potato Starch (2019), Available in: https://organicpotatostarch.com/starches-applications/

Pakerla, J. (Studying at Andhra Loyola Institute of Engineering and Technology – ALIET). (2012-2016) Plastics – the Facts 2017, PlasticsEurope (PEMRG), Available in: https://www.quora.com/What-is-polymer-How-many-types-of-polymers-are-classified-Explain-each-polymer-with-properties-and-applications

Plastics Europe (2018), Available in: https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf

Ramírez Giraldo,C.A. (2012). La celulosa bacteriana: un mundo de nanoposibilidades, Revista Universitaria Cientifica

Sepelev, I. & Galoburda, R.(2015). Research for rural development p. 130, Available in: http://www2.llu.lv/research_conf/Proceedings/21st_volume1.pdf

SIC, Colombia, Available in: http://www.sic.gov.co/recursos_user/documentos/promocion_competencia/Estudios_Economicos/Estudio%20economico%20Plantano%20++.pdf

Statista 2019, Global potato production, Available in: (https://www.statista.com/statistics/382174/global-potato-production/)

Systemic Design in simple words, un progetto per il corso di studi in Ecodesign del Politecnico di Torino, Available in: http://www.systemicdesign.org/

The Editors of Encyclopaedia Britannica, Polymer Chemistry, Available in:https://www.britannica.com/science/polymer

The Editors of Encyclopaedia Britannica, Rice Cereal Grain, Available in: https://www.britannica.com/plant/rice

Vasile, C. (2009) Environmentally degradable materials based on multicomponent polymeric systems

We are packaging fans, [web blog]. https://wearepackagingfans.com/site/cosa-sono-le-bioplastiche/

Zhongli, P., Cathcart, A. & Donghai, W. (2006) Science Direct. Thermal and chemical treatments to improve adhesive property of rice bran. Available in: https://pdfs.semanticscholar.org/9530/246b62ed1b30e2cbcf987737c394dfaa8403.pdf

Zhongli, P., Cathcart, A. & Wang, D. (2005) Thermal and chemical treatments to improve adhesive property of rice bran, Elsevier, Science Direct.

Zhu, Y., Romain, C. & Williams, C.K. (15 December 2016, v.540). Nature. pp. 354–362, Available in: https://www.ecofog.gf/giec/doc_num.php?explnum_id=988