BIOENERGY

Chapter 1. Photosynthesis. Process description.

Chapter 2. Biomass. Definition, biomass composition, biomass as a carbon dioxide storage, types of biomass.

Chapter 3. Biofuels. Introduction. Definition, classification. World markets, production, basic technologies for biofuel production. Relative production efficiency. Energy balance. Biofuels from the environmental point of view.

Chapter 4. Definition and composition of bioethanol, raw materials, production technologies, industrial processes, applications.

Chapter 5. Biodiesel. Definition, the transesterification process. Raw materials. Industrial production. Uses and applications.

Chapter 6. Definition and composition of biogas. Sources, process of biodegradation, production technologies, applications.

Chapter 7. Thermochemical technologies for solid biomass processing.

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Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

1st GENERATION BIOETHANOL

- **Raw materials:**
  - Starch-rich crops (cereals)
  - Sugar cane or sugar beet molasses
  - Raw alcohol from wine industry

- **Technology**: fermentation

2nd GENERATION BIOETHANOL

- **Raw materials:** different sources of lignocellulosic materials.
- **Technology**: fermentation after pre-treatments

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Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

1. RAW MATERIALS

1st GENERATION BIOETHANOL

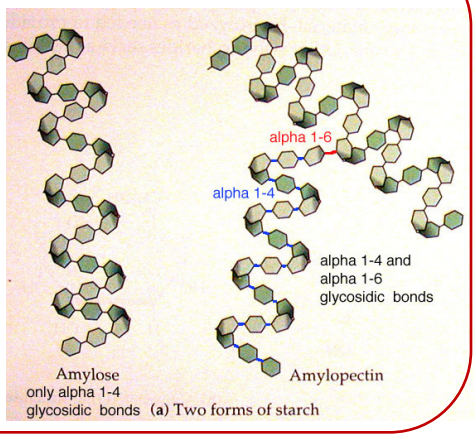
1.1 Starch-rich crops (cereals)

Starch:
Mixture of **amylose** and **amylopectin**.

Amylopectin: branched carbohydrate

The branches are formed when a one end of a chain joins with a glucose in another, forming a **glycosidic bond**.

In order to extract the glucose units it is necessary to perform different steps.



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Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

1. RAW MATERIALS

1st GENERATION BIOETHANOL

1.1 Starch-rich crops (cereals)

The proportions between amylose and amylopectin vary.
This fact determine the sugar extration process.

Starch-rich crops: cereal grains (corn, wheat, barley)
Starch quantities: corn > wheat ~ barley

E.E.U.U.: The main raw material is corn.
U.E.: The main raw materials are wheat and barley.

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Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

1. RAW MATERIALS

1st GENERATION BIOETHANOL

1.2 Molasses from sugar cane and sugar beet

The main sugar crops for bioethanol production are:

- Sugar cane
- Sugar beet


Brasil, India, Tailandia: sugar cane (16,5% sugar)
Europa (France and UK): sugar beet (20,4% sugar)

Sugar molasses present the simple sugars available for fermentation, so pre-treatment step is unnecessary.

Sugar concentrations in these juices are given in **ºBRIX**, which is a measurement that supposes that all suspended matter in the juice corresponds to sugar.

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1. RAW MATERIALS

1st GENERATION BIOETHANOL

1.3 Raw alcohol from the wine industry

These raw alcohols are are surplus from the wine industry and are 92º.

The fact that the raw material is already an alcohol simplifies greatly the whole production process.


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Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

2. RAW MATERIALS
2nd GENERATION BIOETHANOL

1.4 Lignocellulosic materials

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Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

2. TRANSFORMATION TECHNOLOGIES

2.1 Depending on the raw material

- Technologies based on the use of cereal grains.
- Technologies based on the use of sugar-rich juices (molasses).
- Technologies based on the distillation of raw alcohols.
- Technologies based on the use of lignocellulosic materials.

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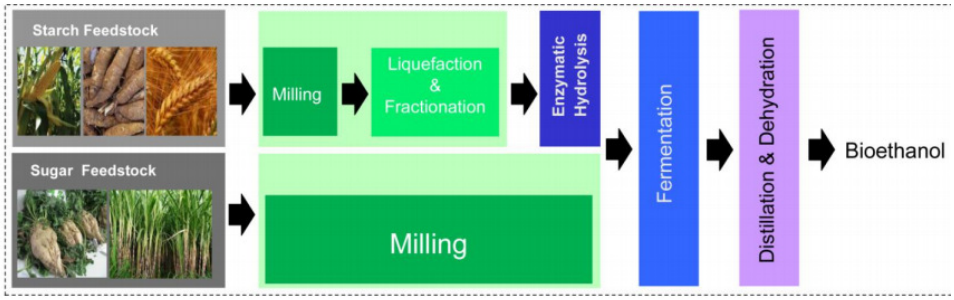
2. TRANSFORMATION TECHNOLOGIES

2.1 Depending on the raw material

Technologies based on the use of cereal grains and sugar syrups



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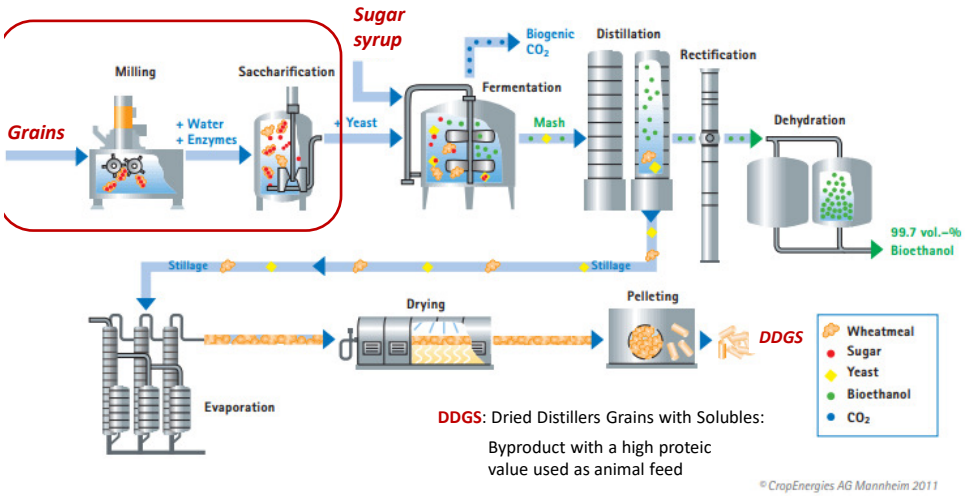
2. TRANSFORMATION TECHNOLOGIES

2.1 Depending on the raw material

Technologies based on the use of cereal grains and sugar syrups



DDGS: Dried Distillers Grains with Solubles:

Byproduct with a high proteic value used as animal feed

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2. TRANSFORMATION TECHNOLOGIES
2.1 Depending on the raw material

Technologies based on the distillation of raw alcohols

In this case, the raw material is already an alcohol.

This will be a distillation process to eliminate any unwanted compounds present and to compel with ethanol especifications (UNE EN15376).

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2. TRANSFORMATION TECHNOLOGIES
2.1 Depending on the raw material

2.1.4. Technologies based on the use of lignocellulosic materials

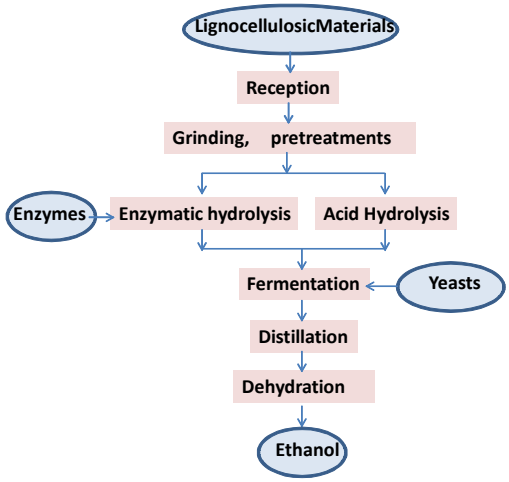

Figure 3. Obtention diagram for bioethanol from lignocellulosic materials

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2. TRANSFORMATION TECHNOLOGIES
2.1 Depending on the raw material

Technologies based on the use of lignocellulosic materials

1. **The key** in this process is the crystalline structure of the main component of these kinds of materials (cellulose), because it limits the access of enzymes responsible for breaking down the structure. To ease the way, **pre-treatments** will be necessary to break the bonds between glucose units.

2. **Shreding** of the lignocellulosic material to facilitate de procedure in the next steps of the process.

3. **Hydrolysis** to break down the molecular structure of cellulose to obtain the glucose. This can be done in two different ways: **enzymatic or acidic.**

4. Once the glucose has been obtained, we will go on with the **fermentation** to obtain the alcohol.

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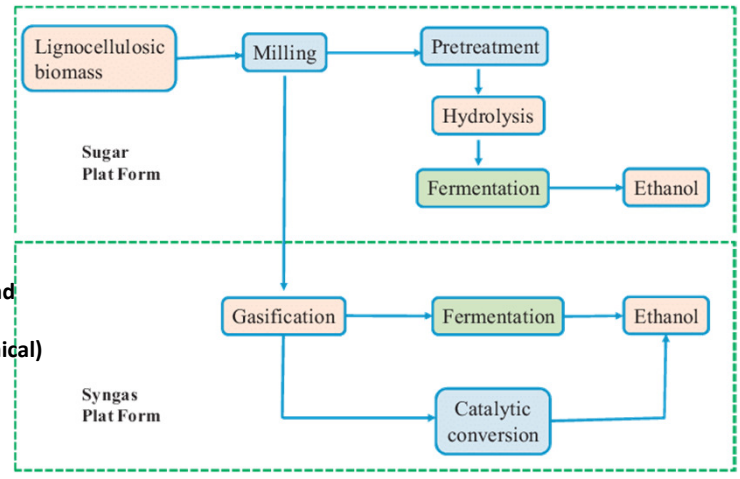
Chapter 4. Definition and composition of bioethanol, prime materials, production technologies, industrial processes, applications.

2. TRANSFORMATION TECHNOLOGIES
2.2 Depending on the technologies used

1. Enzymatic hydrolysis and fermentation (Biochemical)

2. Gasification and fermentation (Thermobiochemical)



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2. TRANSFORMATION TECHNOLOGIES

2.2 Depending on the technology used

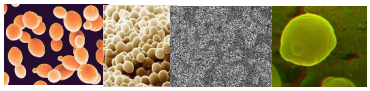
2.2.1. Enzymatic hydrolysis and fermentation (Biochemical)

Fermentation: the obtention of alcohol and carbonic gas from sugar using microorganisms.

2.2.1.1. Microorganisms for Alcoholic fermentation

- **Yeasts** are the most used microorganisms for alcohol production because of their high productivity. They also create less amounts of toxic elements and are easily separated.

Most common species: S*accharomyces cerevisiae*, *S. ellipsoideus*, *S. anamensisi*, *Candida seudotropicalis*, *S. carlsbergensis*, *Kluyveromyces marxianus*, *Candida bytyrii*, *Pichia stipatis*, *Schizosaccharomyces pombe* and *Pichia membranaefaciens.*



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2. TRANSFORMATION TECHNOLOGIES

2.2 Depending on the technologies used

2.2.1. Enzymatic hydrolysis and fermentation (Biochemical)

2.2.1.1. Microorganisms used for alcoholic fermentation

Factors influencing fermentation microorganisms:

1. *Alcoholic tolerance*
2. *Tolerance for high temperatures*
3. *Tolerance for high sugar concentrations*
4. *Alcoholic yield*
5. *Fermentation effectivity and productivity*

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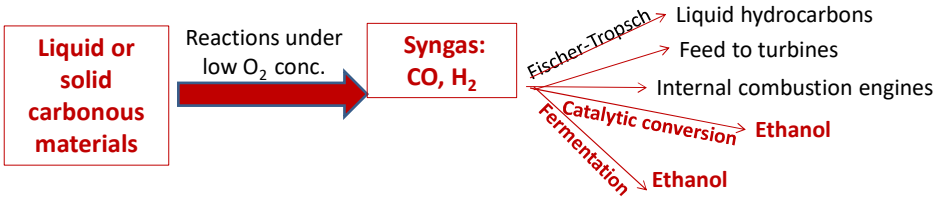
2. TRANSFORMATION TECHNOLOGIES

2.2 Depending on the technologies used

2.2.2. Gasification and fermentation or catalytic conversion (thermobiochemical)

Gasification: It is a thermochemical process where a carbon based substrate (liquid or solid organic residues) is converted into a combustible gas (synthesis gas or syngas).
- Syngas composition : mostly, **hidrogen and carbon monoxide (CO).**
- It has a low calorific capacity
- Process: series of reactions at high T (800-1500 ºC) at oxygen concentrations lower than stoichiometric ones.
- Combustion of the syngas is more effective than for the initial substrate.



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2. TRANSFORMATION TECHNOLOGIES

2.2 Depending on the technologies used

2.2.2. Gasification and fermentation or catalytic conversion (thermobiochemical)

- After biomass **gasification**, it is possible to obtain **bioethanol by:**

1. Syngas fermentation and subsequent distillation.

- Some anaerobic microorganisms (acetogens in anaerobic conditions) are able to produce bioethanol from CO and H_2 as substrates.

Reactions:

$$6CO + 3H_2O \rightarrow C_2H_5OH + 4CO_2$$
$$2CO_2 + 6H_2 \rightarrow C_2H_5OH + 3H_2O$$
$$3CO + 3H_2 \rightarrow C_2H_5OH + CO_2$$

2. Syngas catalitic conversion

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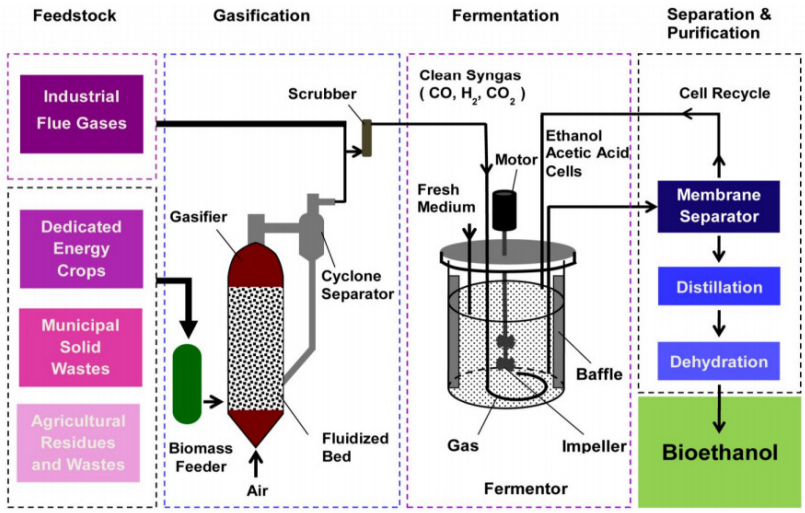
2. TRANSFORMATION TECHNOLOGIES

2.2 Depending on the technologies used

Syngas fermentation and subsequent distillation



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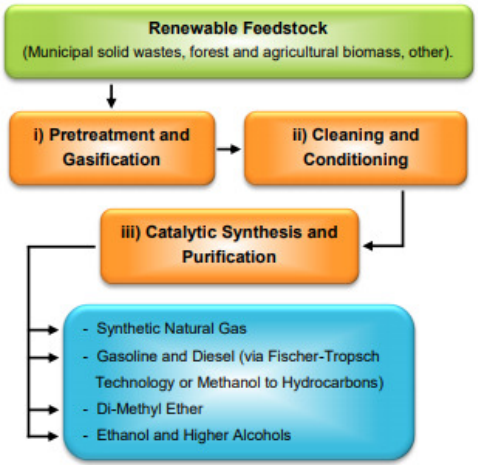
2. TRANSFORMATION TECHNOLOGIES

2.2 Depending on the technologies used

Syngas catalytic conversion



Catalytic conversion of syngas to ethanol and higher alcohols over Rh and Cu based catalysts. Luis Gagarin Lopez Nina. Doctoral Thesis in Chemical Engineering KTH Royal Institute of Technology

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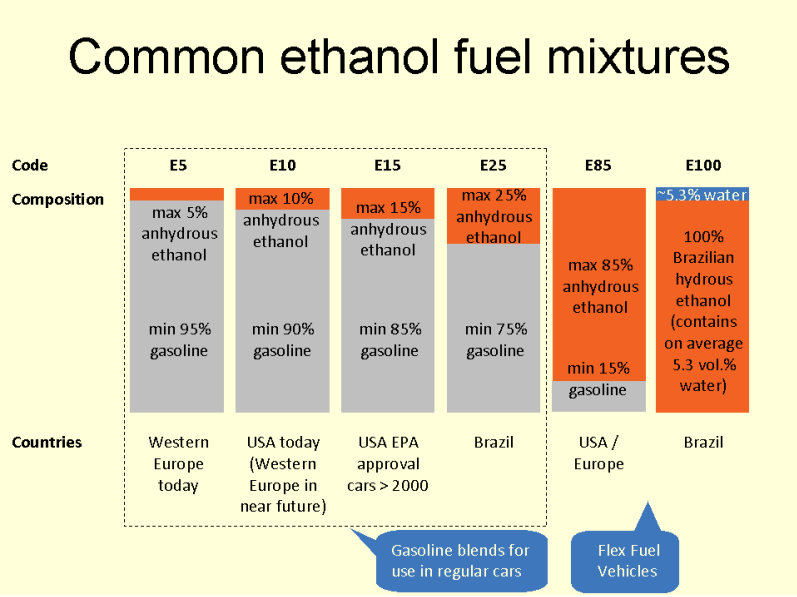
4. Uses for Bioethanol



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4. Uses for Bioethanol

Uses in the ETBE form (ethyl tert-butyl ether)

Ether: Oxygenated compounds that are used as gasoline additives to make them more oxygen rich (to improve combustion) and increase their octane level (a parameter to measure the quality of the fuel).

ETBE: It is obtained when bioethanol reacts with isobutylene. Isobutylene is a petroleum derivative product.

ETBE, was introduced as a substitute to MTBE and lead, that were withdrawn from the market because of health and environmental concerns.

New legislation regarding Fuel Quality Up (Directive 70/98/CE) enables to increase the amount added up to 22%. All gasolines used in Spain nowadays have ETBE in their composition.

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4. Uses for Bioethanol

4.4. Use in diesel engines

There have been some experiences in the usage of bioethanol directly in Diesel engines:

- Pure
- Mixed with gasoline up to 95% for heavy duty engines (Buses and trucks).
- Mixed with gasoil in small quantities, 10 to 15% in most cases, forming a new type of fuel: **E-diesel**.

Example of usage of pure bioethanol (or mixed in high quantities): The BEST project, Financed by the European Commision, The City Council of Madrid and E.V.E. In this project they are studying 5 SCANIA diesel engine buses that will be running on pure Bioethanol.