Chapter 5 Biomass: teaching strategy for the laboratory at university level

Capítulo 5 Biomasa: estrategias de enseñanza para el laboratorio a nivel universitario

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Abstract

Biomass is defined as that organic product of vegetable origin that can convert the energy coming from sunlight into chemical energy contained in the vegetable carbohydrates' links. Its study is important since this contained chemical energy can be used in the form of fuels, electricity and/or chemical reagents that can be used as precursors. This paper presents a proposal for teaching biomass in the laboratory at university level. The experimental proposal exposes an easy and accessible practice to meet this objective. This methodology has been applied in two different universities where engineering courses are taught. The materials used are accessible and cheap. Once the practice was finished, a survey was applied to the students to verify the subject's understanding, obtaining favorable results. In conclusion, this proposal offers an easy and low-cost methodology for teaching the topic of Biomass in the laboratory at university level.

Biomass, Methodology, Laboratory, University level

Resumen

La biomasa se define como aquel producto orgánico de origen vegetal que es capaz de convertir la energía proveniente de la luz del sol en energía química contenida en los enlaces de los carbohidratos vegetales. Su estudio es importante ya que esta energía química contenida puede ser aprovechada en forma de combustibles, electricidad y/o reactivos químicos que pueden ser usados como precursores. En este trabajo se presenta una propuesta para la enseñanza de la biomasa en el laboratorio a nivel universitario. Esta propuesta experimental expone una práctica fácil y accesible para cumplir dicho objetivo. Esta metodología ha sido aplicada en dos diferentes universidades donde se enseñan carreras de corte ingenieril. Los materiales utilizados son accesibles y baratos. Una vez terminada la práctica se aplicó una encuesta a los estudiantes para verificar el grado de compresión acerca del tema, obteniendo resultados favorables. En conclusión, esta propuesta ofrece una metodología fácil y a bajo coste para la enseñanza del tema de Biomasa en el laboratorio a nivel universitario.

Biomasa, Metodología, Laboratorio, Nivel universitario

5.1 Introduction

5.1.1 What is Biomass?

We can define biomass as any organic solid product formed naturally or by human action and includes all those natural components originating from land cultivation (crops and trees) as well as aquatic vegetation (algae and marine plants), which are the result of photosynthesis or animal digestion (Vassilev et al., 2010).

This biomass is produced by converting energy from sunlight through photosynthesis into chemical energy and is stored in the chemical bonds of carbohydrates such as cellulose, hemicellulose and lignin whose proportions vary depending on the type of plant (Yan et al., 2022; Odoh et al., 2023).

Biomass can be classified as follows: woody plants, herbaceous plants, aquatic plants, a mixture of biomass, biomass and animal waste (manure) contaminated, and industrial waste, the first three being the types of greatest interest in energy production, especially plants with C4 types of photosynthesis (McKendry, 2002).

It is estimated that the average amount of Biomass on Earth is ≈550 Gt C of which ≈80% (≈450 Gt C) are produced by plants, mainly terrestrial ones (Barn-On et al., 2018).

5.1.2 Why is it important to study biomass?

One of the most important characteristics of biomass is that it has the capacity to convert the energy stored in its bonds into usable forms for humans, each one with its own specific requirements, advantages, and disadvantages.

At least three types of energy products derived from biomass can be obtained: transport fuels, electrical energy and precursors or chemical reagents (Gallezot, P., 2012 and Srivastava et al., 2021).

Recently, interest in the use of this energy source has been renewed, some of the reasons will be listed below:

- Technological advances have increased the efficiency of the conversion of biomass into fuel and have lowered the costs of this process.

- The use of non-food crops means that the production of energy from biomass does not put the population's food security at risk.

- Biomass is considered a renewable energy source, since when crops are produced sustainably, they do not contribute to increasing CO2 levels in the atmosphere, which helps against climate change.

- In the same way, biomass can be used by Indigenous peoples since it is widely available and easily accessible, and these communities have used it for a long time, which makes them familiar with its use (McKendry, 2002).

- The use of biomass known as "waste", which is part of industrial processes or from other anthropogenic activities such as livestock that produce tons of waste, contributes to reducing the amount of "garbage" residues derived from these activities (Sánchez et al., 2019).

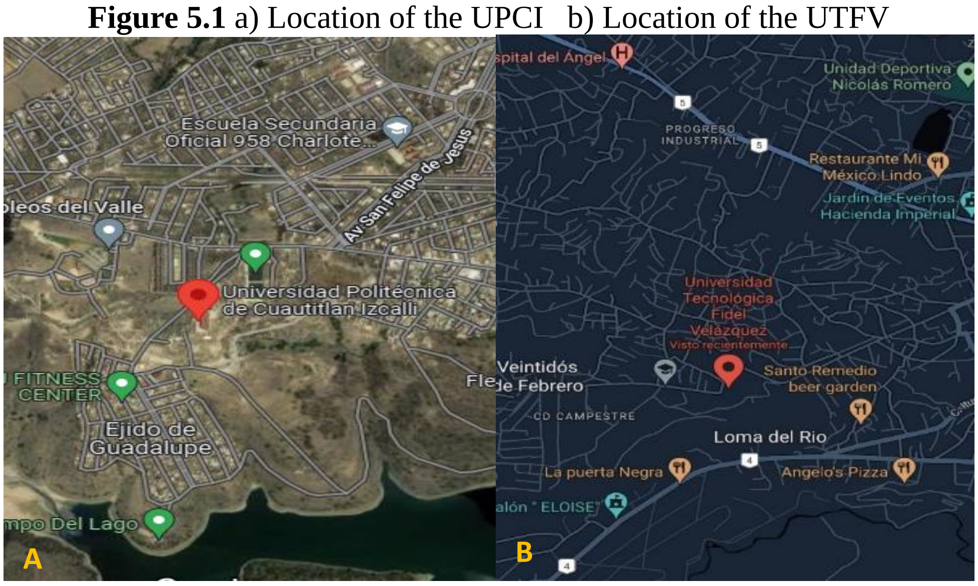
5.2 Methodology

In this paper, it is explained a methodology that helps the teaching of biomass in the laboratory at the university level, mainly in engineering courses such as Biotechnology Engineering (IBT), Energy Engineering (IE), Environmental Engineering (IA) and Nanotechnology Engineering (INT), to name a few.

This practice has been conducted both at the Universidad Politécnica de Cuautitlán Izcalli (UPCI) located in the municipality of Cuautitlán Izcalli and at the Universidad Tecnológica Fidel Velázquez (UTFV) (UTFV) located in the municipality of Nicolás Romero both belonging to the Estado de México State (Figure 5.1).

This methodology has been assessed on young students between the ages of 18 and 22 belonging to IBT and IE careers in the case of UPCI, as well as IA and INT in the case of UFTV.

Figure 5.1 a) Location of the UPCI b) Location of the UTFV



Source: (Taken from Google Maps, 2023)

Obtaining polylactic acid (pla)

5.2.1.1 Objective

Extract starch from the potato, to be able to synthesize lactic acid to obtain polylactic acid (PLA).

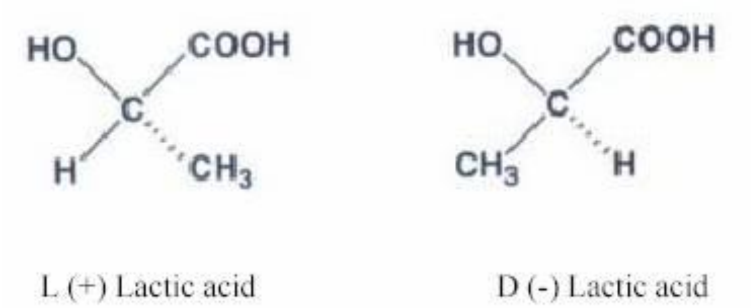
5.2.1.2 Introduction

Conventional plastics are a product with a great impact on the environment since they are used daily in our lives and are derived from oil. Currently, other alternatives are being sought to help us reduce this problem of plastics; an alternative is bioplastics, which are a type of plastic that characterizes by being made from organic materials and therefore can be compatible with the environment.

The advantages of bioplastics are that they reduce the carbon footprint, they save energy in production, they do not consume non-renewable raw materials and they reduce non-biodegradable waste that pollutes the environment.

Among the biodegradable materials, polylactic acid (PLA) stands out, which is a derivative of lactic acid that has characteristics similar to polyethylene terephthalate (PET) and polyethylene; it is an organic acid with three carbons, in one terminal the carbon atom is part of the carboxylic group; the other terminal carbon atom is part of a methyl; and the central carbon atom is attached to an alcohol group. There are two stereoisomers of lactic acid:

Figure 5.2 Isomers of lactic acid



Source: (Taken from: Molina et al., 2018)

It is obtained by fermentation of a vegetable raw material with certain strains of bacteria. It presents a wide range of properties since there are different grades, with different molecular weights, stereochemistry, and morphology, ranging from the amorphous state to the semi-crystalline state. Lactic acid polymerization can be controlled to obtain different molecular weights and different degrees of crystallinity by catalyst selection.

PLA is a versatile polymer that has various applications, including in the textile industry, in the medical industry and especially in the packaging industry. Its tensile strength and modulus of elasticity is comparable to polyethylene; it is more hydrophilic than polyethylene, it has a lower density, it is stable to UV light and its flammability is too low (Serna and Albán, 2003).

5.2.1.3 Obtaining potato starch

Materials

- Three large potatoes
- 200ml of water
- Blender
- Sieve
- Muffle
- Knife

Procedure

1. Peel the three potatoes and cut them into small cubes, to have the maximum amount of starch.

2. Blend with only 200ml of water for only three seconds (this is to avoid modifying its polymer chain).

3. Filter; use the sieve and a cloth.

4. Keep the liquid obtained at rest so that they separate.

5. Decant (remaining only with the lower part).

6. Dry for 24 hours.

5.2.1.4 Synthesis of the PLA

Materials

• 500ml beakers
• Glass stirrer
• Granary scale
• Spatula
• Magnetic grill
• Magnetic stirrer
• Thermometer
• 250ml beakers
• Watch glass
• Molds

Reagents

Starch
Acetic acid
Vegetable dye
Glycerin
Lactobacilli (Yakult)

Procedure

1. Weigh 250g of starch on the granary scale.
2. Gradually add 250ml of water.
3. Mix and then add 30ml or 40ml of Lactobacilli.
4. Let ferment for 24 h.
5. Decant the water, leaving only the white mixture.
6. Shake on the grill, gradually adding 50ml of glycerin.
7. Leave stirring for 10 min.
8. Add 50ml of acetic acid little by little while stirring (add dye).
9. Heat the mixture until it boils, checking the viscosity with the glass stirrer.
10. Pour into the molds and put them on the stove until they have polymerized.

5.2.1.5. Survey Application

Once the practice was finished, the students were asked to answer an electronic form with a check box grid with options from 1 to 5 where number 1 corresponded to the option "I don't contribute anything" and number 5 corresponded to the option "I learned something new and reaffirm the knowledge that I already had”. The form consisted of five questions related to the acquisition and reaffirmation of knowledge related to biomass.

5.3 Results

5.3.1 Obtaining potato starch

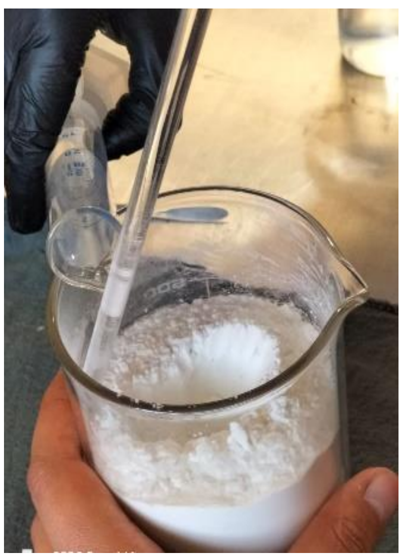
For this section, the students could easily follow the instructions for obtaining potato starch, the potatoes were blended, and the mixture obtained was sifted (figure 3).

Figure 5.3 Mixture obtained from potatoes.

Source: Own source

The mixture was left to rest and was decanted, discarding the supernatant, and drying the precipitate for 24h, thus obtaining a fine, whitish powder (figure 4) that was used for the next section of the practice.

Figure 5.4 Obtaining potato starch.

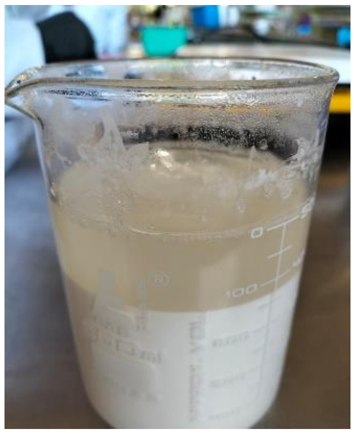


Source: Own source

5.3.2 Synthesis of PLA

Once the starch was obtained, PLA was synthesized: Figure 5 shows the result of mixing hydrated starch with lactobacilli, leaving it to ferment for 24 h. Note the separation into two phases, the transparent supernatant, and the whitish precipitate.

Figure 5.5 Result of fermentation of potato starch by lactobacilli.



Source: Own source

In figure 5.6 it can be seen how the PLA is added dye, at this stage the PLA has a high viscosity so that it allows the formation of small balls that do not stick to the hands when they are kneaded, once obtained this viscosity, the mixture was poured into the respective molds.

Figure 5.6 Obtaining PLA.

Source: Own source

5.3.3 Verification survey

Once the practice was finished, the students were asked to answer a verification survey, the results obtained from this survey show that 80% of the students consider that "I learned something new and reaffirm the knowledge I already had", regarding their prior knowledge around biomass.

5.4 Conclusions

This paper presents a methodology that shows a laboratory practice where it is exposed that using simple and low-cost materials, basic knowledge about biomass can be taught in the laboratory.
The results obtained in the survey indicate that the application of this type of methodologies helps students, not only, to better understand or reaffirm the theoretical knowledge that is explained in the specialty subjects, but also to appropriate said knowledge and realize the technological applications that such knowledge implies.

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