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EARTH AND ITS RESOURCES
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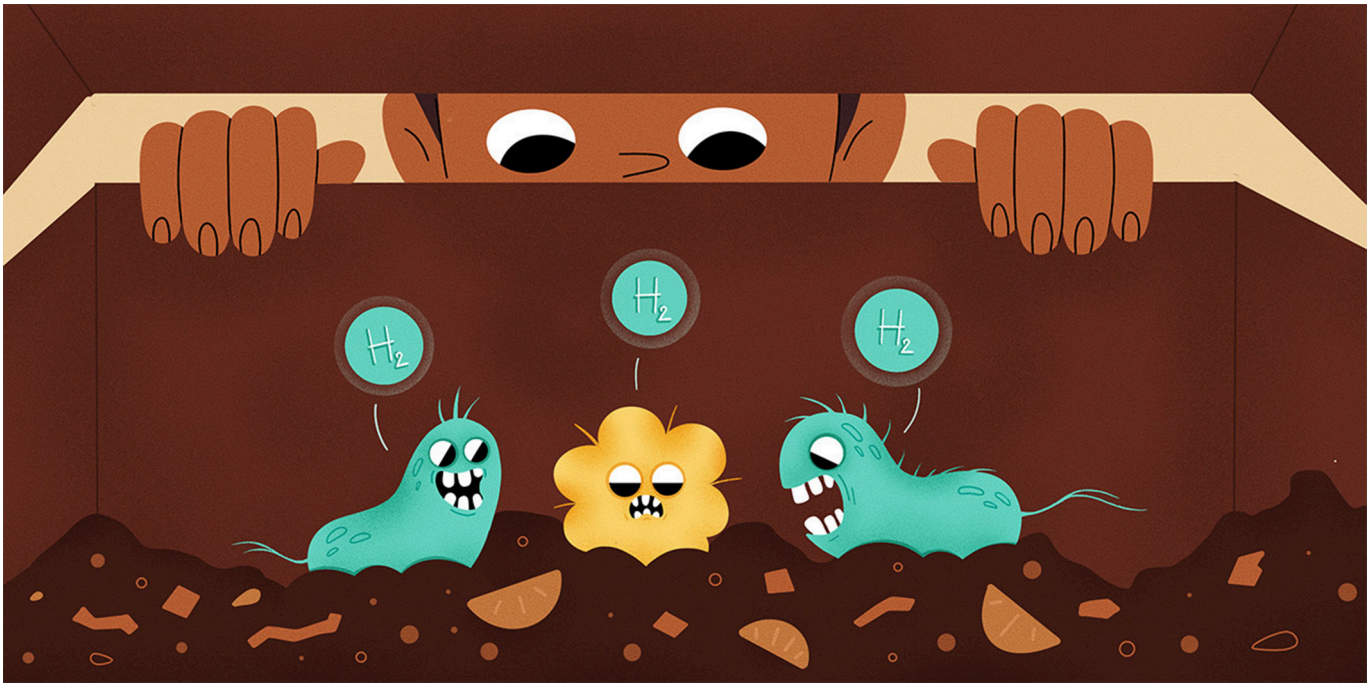

USING MICROBES TO PRODUCE HYDROGEN FROM GARBAGE

José de Jesús Montoya-Rosales * ***and Elías Razo-Flores***

División de Ciencias Ambientales, Instituto Potosino de Investigación Científica y Tecnológica A.C., San Luis Potosí, Mexico

YOUNG REVIEWERS:


DAVID
AGE: 11


ELILL
AGE: 15


YUHENDRA
AGE: 12

What if it was mentioned that there are good microbes that can eat garbage? There may be reports stating that microbes are bad and cause diseases. However, there are also good microbes that can eat the organic garbage (like banana peels and old vegetables) generated in houses or restaurants. These microbes can use garbage to produce energy, in the form of hydrogen, which can be used to fuel our cars. The process of turning organic garbage into energy is called dark fermentation. During dark fermentation, other helpful compounds are also generated, which can be used to make foods, medicines, beverages, and other useful things. This article discusses the dark fermentation process and the products obtained along the way.

MICROBES THAT EAT GARBAGE

Microbes are one of the smallest living things and they can only be seen using a microscope. Although we cannot see them with

DECOMPOSITION

The breakdown (by microbes) of a compound made of chains of blocks of organic matter.

ORGANIC GARBAGE

Any materials that come from a plant or an animal and can be decompound by microbes.

HYDROGEN

The slightest gas with the highest energy content. It is also the most abundant element in the universe.

DARK FERMENTATION

This is a natural process in which some microbes consume carbohydrates to grow, reproduce, and create compounds like organic acids and hydrogen gas.

the naked eye, microbes are present everywhere: on our hands, in our stomachs, on the surfaces of toys and other objects, and of course, all over the Earth—in the air, soil, and water. Although they are small, microbes are diverse and extremely abundant. Microbes play important roles in many natural processes. For example, they can help with the **decomposition** and recycling of **organic garbage**.

Organic garbage is made by living organisms, including all fruits and vegetables. Have you ever wondered what happens to the fruit and vegetable wastes that are thrown into the trash in your home or in restaurants? Usually, a garbage truck picks up the trash and takes it to a landfill (Figure 1). In landfills, organic garbage accumulates and disappears very slowly over time. As it breaks down, organic garbage produces dangerous compounds that can contaminate the air, soil, and water. For example, during the breakdown of organic garbage, a black liquid is produced (called leachate). If this liquid is released into nature, it will contaminate the water used for drinking and will affect the quality of soil used for cultivation.

What can we do to prevent organic garbage from affecting nature? Well, there is another way to deal with this garbage—a way that is clean and friendly to our planet! We can combine organic garbage with certain microbes that transform organic garbage into valuable products. These products can be used to make food, beverages, and medicines. Even better, these microbes produce **hydrogen** as they break down organic garbage. Hydrogen is an amazing gas that can be used to produce energy to fuel cars. This process is called **dark fermentation** [1].

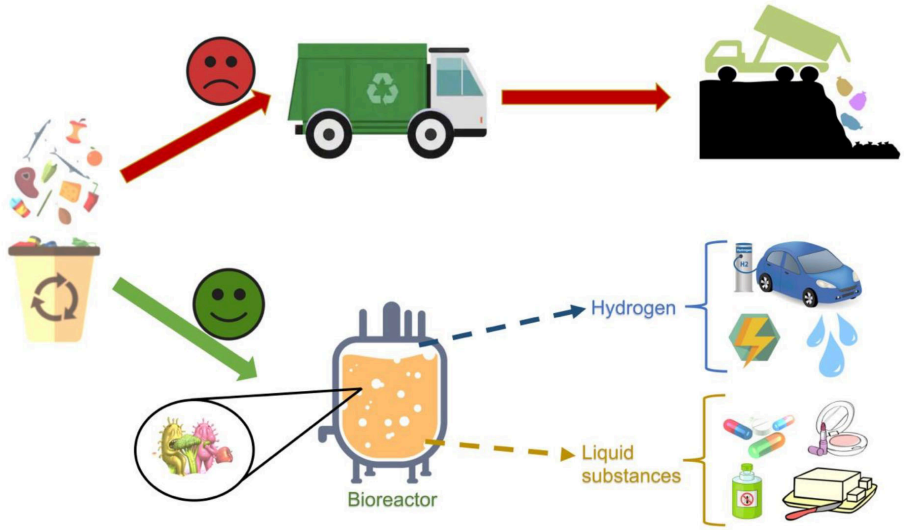

Figure 1

The organic garbage generated in homes usually goes to landfills, where it accumulates and disappears very slowly over time. As an alternative, this garbage can be broken down in bioreactors, which produce valuable products that can be used to make medicines, food, cosmetics, and hydrogen, which can be used to produce energy.

FROM ORGANIC GARBAGE TO ENERGY AND VALUABLE COMPOUNDS

CARBOHYDRATES

Composed of building blocks made of sugars, this is the principal source of energy for living beings.

ORGANIC ACIDS

These are substances made of carbon, hydrogen, and oxygen and naturally are present in some fruits and vegetables.

BIOREACTOR

A vessel that allows microbes to live, grow, and perform their activities, such as decomposition.

All organic garbage is made up of tiny building blocks called **carbohydrates**. In dark fermentation, some fantastic microbes can separate and eat these blocks. The carbohydrates allow the microbes to grow, make more microbes, and create compounds called **organic acids** and hydrogen gas.

To visualize dark fermentation, let us imagine making a cake. What do you need to make a cake? Well, we need the ingredients (milk, flour, sugar, etc.), a cook, and an oven. Dark fermentation needs similar things. We need organic garbage as the ingredients and the microbes as the cook. We put these things in a special oven called a **bioreactor** (Figure 1). In the bioreactor, the microbes cause dark fermentation to happen, producing a "cake" with "slices" of various flavors. Each slice corresponds to a different product; for example, hydrogen, acetic acid, butyric acid, and others. We call this process *dark fermentation* because the microbes do not need light or oxygen to produce these products in the bioreactor.

HOW ARE THE PRODUCTS OF DARK FERMENTATION USEFUL?

So, what can be done with the compounds produced by dark fermentation? As mentioned earlier, hydrogen is a gas that can be used to produce energy to power our cars [2]. Most cars use gasoline as fuel. However, when gasoline is burned in car engines, air pollutants are produced. Incredibly, hydrogen gas does not produce pollutants and compared to gasoline, we need much less hydrogen gas to travel long distances.

What about the acids? Acetic acid is used in the production of medicines and paints. Butyric acid can be used to prepare some foods and beverages, like butter and fermented drinks [2]. Other acids help to keep foods fresh for a long time. Usually, these acids are produced in factories that release lots of pollutants that can damage the planet. In dark fermentation, these acids are produced in a clean way using the garbage from our homes without generating pollution.

NO MORE LANDFILLS?

Although this sounds great, so why do we continue sending our garbage to landfills? It turns out that the technology needed to make dark fermentation efficient on a large scale is still being developed. To understand why, let us revisit the example of the cake. Figure 2 shows the various flavor slices produced from "cooking" organic garbage in a bioreactor. You can see that the biggest slice corresponds to the

microbes (which reproduce in the bioreactor) and a gas called CO_2. The next largest slices are acetic and butyric acids. Finally, the slice of hydrogen is the smallest [2]. More research on dark fermentation is needed to increase the size of hydrogen for it to be useful and to reduce the size of the microbes and CO_2 slice. The role that CO_2 plays in global warming is common knowledge. Since dark fermentation is a planet-friendly alternative, we need to avoid the release of the CO_2 produced in the "oven" into the air. Thus, the CO_2 produced in dark fermentation can be stored and used for many planet-friendly options. For example, for the growing of specific algae.

How can we get these microbes to be more efficient and enhance dark fermentation? The answer is to stimulate them to work harder. To get microbes to work harder, they need food and other conditions in the bioreactor to be perfect. Our research group has been studying other ways to improve dark fermentation. For example, we stimulate the microbes in the bioreactor by putting in more microbes to make the process faster and more efficient. By doing so, we can double the size of the hydrogen "slice" [3].

CONCLUSION

This article explains that there are microbes that can eat and break down the organic garbage from our homes and restaurants through a process called dark fermentation. These microbes produce valuable compounds, including acetic acid and butyric acid, which can be used for the fabrication of medicines and foods, among other daily products, and hydrogen, which can be used for energy to power our cars. Dark fermentation has fewer negative effects on the planet than throwing organic garbage into a landfill, but there is still work to be done before we can use this process on a large scale. Across the globe,

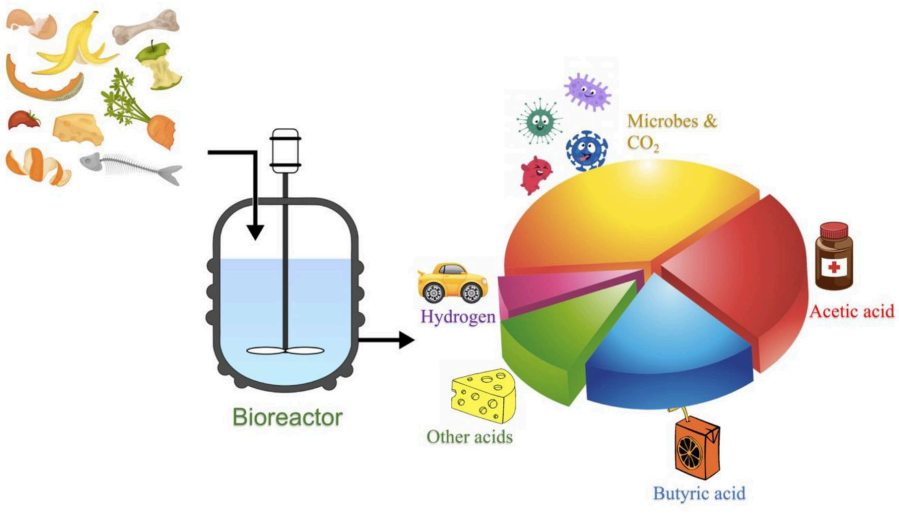

Figure 2

In a bioreactor, a process called dark fermentation occurs. Dark fermentation produces "slices" of various compounds. The largest slice is for microbes and CO_2, following the slices of some acids, and, finally, the slice for hydrogen.

many scientists studying ways to transform organic garbage into useful substances by improving dark fermentation.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

DAVID, AGE: 11
I like fishing and being outdoors. My favorite food is fried catfish with tarter sauce. My favorite color is deep metallic green. My favorite movie is Harry Potter and the Prisoner of Azkaban.

ELILL, AGE: 15
Hi! My name is Elill and I am 15 years old. I like reading non-fiction books, studying and spending time with family. I also enjoy Star Wars movies. My favorite subjects in school are Science, History, and Maths.

YUHENDRA, AGE: 12
Hi! It is great to be a Young Reviewer. I am 12 years old and I like Science and Maths, they are my favorite subjects at school. In my free time I do lego, read books, and spend time with my family. I also like to play video games.

AUTHORS

JOSÉ DE JESÚS MONTOYA-ROSALES
I am an environmental engineer from the Instituto Politécnico Nacional—Campus Zacatecas, México. Currently, I obtained my Ph.D. degree in the Instituto Potosino de Investigación Científica y Tecnológica A.C., México, in the area of environmental sciences. My research interests include environmental biotechnologies and the role of microorganisms in such processes. *jose.montoya@ipicyt.edu.mx

ELÍAS RAZO-FLORES
Elías is a chemical engineer with a master's degree in biotechnology and a Ph.D. in environmental technology. He works on several topics related to environmental biotechnology, in particular, on bioenergy production (hydrogen and methane), biodegradation/biotransformation of toxic compounds, and wastewater treatment.