RESEARCHING BIOFUELS IN PRIMARY SCHOOL LABORATORY

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Abstract: *The aim of the article is to show how to encourage students to deepen their knowledge, creativity and their enthusiasm for research. In this way we can also promote the popularization of science and technology as well as the identification of students talented in specific research areas. This article presents an example of writing a research assignment undertaken by students in the final year of primary school (class 9, i.e. age 14-15).We live in the age of diminishing supplies of fossil fuels and consequently a growing interest in the renewable energy sources, including biofuels. Through research assignment, we wanted our students to learn more about the characteristics of biofuels which we haven't discussed in detail in class. Biofuel is a solid, liquid or gaseous fuel, obtained from a relatively recently deceased biological substance. For the production of biofuels, we use various plants and substances of plant origin, which are known under the term "biomass". In addition to looking for information in literature and electronic resources, we conducted experiments in which we measured how many degrees a particular quantity of water heats up by the burning of various fuels, and the amount of residue left after burning. The biofuels we used were: pellets, briquettes, olive pulp, cherry stones, biodiesel, ethanol and sawdust.*

We established that different types of fuel emit, when burnt, different amounts of heat. Water heated up the most when burning ethanol, while it heated up the least when using biodiesel. Experiments showed that different fuels burn for different amounts of time, leaving a residue which depends on the type of fuel

Keywords: RESEARCH ASSIGNEMENT, BIOFUELS, EXPERIMENTAL WORK

1. Introduction

1. 1 Alternative energy sources

Renewable energy sources are sources of energy we obtain from constant natural processes such as the wind, solar radiation (solar power stations), water current in rivers or streams (hydroenergy), Earth's heat fluxes (geothermal energy), the tides and waves of the seas and oceans (tidal energy and wave energy), photosynthesis by which plants build biomass (wood, vegetable oils that we convert into bioethanol, biodiesel, biogas).

The majority of renewable energy sources, with the exception of geothermal energy and tidal energy, come from regular solar radiation. The Sun is constantly sending into space a heat flux which we call solar radiation. Solar radiation is heating up our planet and changing into other forms of energy. A few tenths of 1 percent of solar radiation are used for photosynthesis, and this is how organic material, biomass is made. We turn solar radiation into heat and electricity using various technologies. [1]

The main characteristics of renewable energy sources include the fact that their use reduces the emissions of greenhouse gases; these energy sources are also free, they are durable and have a great potential.

Renewable energy sources cannot be stored in nature except in the form of biomass and the heat of oceans. Thus we have to use various devices for storing the energy of renewable resources, which lessens their efficiency and makes their exploitation more expensive. [2]

This decade of the 21st century is a favourable time for further development of technologies linked to renewable energy sources. The European Union decided to pursue the objective of reducing greenhouse gases emissions by 40 percent by the year 2030. Using the existing technologies, this can be achieved through greater use of the energy from nuclear power plants or by expanding the use of renewable sources of energy in all forms: direct solar radiation and the energy of water, wind and biomass. In recent years, wood, other solid biofuels and renewable waste have presented the crucial part of renewable energy sources.[3,4]

1. 2 Biomass

According to the Directive on renewable energy resources, biomass derives from different kinds of organic materials: energy crops (oil plants; plants containing sugar), wood, forest waste and agricultural waste, and biodegradable waste from households, fishery and industry [5].

Biomass can be used for heating, for generating electricity and producing biofuels. Both plant biomass and substances formed in the process of its decomposition contain elements that burn in presence of oxygen and at high temperature.

We distinguish between four procedures used to convert biomass into fuels:
- combustion in which combustible substances in biomass burn into carbon dioxide and water, emitting heat;
- biological transformation such as anaerobic fermentation, fermentation and composting;
- heat and chemical transformation such as pyrolysis;
- liquefaction or gasification.

Fuels produced from biomass with the described procedures can be classified into three groups:
- solid biomass (wood biomass, agricultural crops);
- liquid biofuels (bioethanol, biodiesel) ;
- gases from biomass (biogas, wood gas, landfill gas).[1]

1. 3 Advantages and disadvantages of using biomass

It is a renewable energy resource – its quantity is not infinite, but with the right use it is relatively quickly renewed (in contradistinction to fossil fuels). This is one of the greatest strengths of biomass, beside reducing pollution, contributing to the cleaning of forests and a positive effect on the development of agriculture. However, there are also disadvantages to it: the high price of the developing technology and the low level of people's awareness about its use, there is also a possibility of harmful ecological effects (excessive deforestation, degradation and contamination of fertile soil, reduced biodiversity ...). Total replacement of fossil fuels with biofuels is at the moment therefore unattainable. Energy is needed to produce biofuels, too. [1]

Interestingly, many scientists believe that the best natural source of biomass are algae, single cell water organisms, since they grow in waste water, including the sea, and only need light and carbon monoxide to flourish. [6,7]

1. 4 Types of biomass and biofuels

Bioethanol is an alcohol which is nowadays produced by sugar fermentation, especially from corn and sugar cane, but also from corn stalks, prairie grasses, fast-growing trees, sawdust and algae.

By using bioethanol we can reduce emissions of greenhouse gases by 22-56 percent (and even by 91 percent, by using cellulose ethanol – a fuel barely known to date). However, production of corn ethanol leads to a great consumption of fossil fuels and releases a lot of CO_2, so many scientists are currently in double mind as regards the processing of corn into fuel. For the time being it is mostly used as a complement to petrol.

Biodiesel is a methyl ester produced from biomass. It is formed through the esterification of vegetable oils and animal fats (usually canola, soya and oilseed rape). High quality biodiesel can be used in normal diesel engines, independently or in mixtures with diesel. Its use can reduce carbon dioxide emissions by 68 percent.

Olive pomace (pulp) is one of the more interesting biofuels, which can be completely dried and compressed into blocks that can be then used for heating. While olive pomace remains nearly unknown as a fuel in Slovenia, it is already being used as an energy resource in the Near and Middle East and some other parts of the world (Spain, Turkey).

Wood biomass is an ancient, but at the same time modern, environmentally friendly and familiar source of energy. If we want to keep waste gas emission below the permissible level, wood biomass needs to be treated in a suitable way and the heating devices (stoves) should be in working order.

The source of wood biomass are forests. Slovenia is rich with forests, considering that 56 percent of its surface is covered in them. The wood industry in Slovenia uses almost all wood waste for the production of heat and steam, and only to a small extent also for electricity. Briquettes or pellets made of compressed wood are used as modern solid fuels produced from forest biomass or agricultural yields. Pellets are made of sawdust and are of a cylindrical shape, with a diameter of 5-15 mm and up to 30 mm in length. Wood briquettes are produced in a similar manner as wood pellets, but they are larger, with a diameter of 20-120 mm and a length of up to 400 mm. Only high pressure and steam are needed in the manufacturing process. Briquettes are made of bark, sawdust and dry wood dust. [1,8]

2. Experimental part

This article presents an example of writing a research assignment undertaken by students in the final year of primary school (age 14-15).

During school lessons, we did not discuss biomass as a fuel in detail, but we found the topic very interesting, which is why we decided that we would focus on it in our research paper. We decided to use olive pomace because we live in a region which is known for the production of olive oil and the locals use the leftovers of the process of pressing olives also at home as a fuel in central heating appliances. Cherry stones can also be used as a fuel. In the applied part we tried to answer the following questions:

- how many °C do various fuels heat up a particular amount of water,
- what amount of residue is left after the burning of solid fuels.

2. 1 Hypotheses

Before the experimental work we have set the following hypotheses:
First hypothesis: Different fuels emit different amounts of heat.
Second hypothesis: Burning time varies depending on the type of fuel.
Third hypothesis: There is no residue left after the burning of liquid fuels, while there is some after the burning of solid fuels.
Fourth hypothesis: Solid fuels emit more heat during burning than do liquid ones.
Fifth hypothesis: The quantity of residue left after the burning of various solid fuels varies.

2. 2 Fuels that were used

The fuels we used during our experimental work were the following:

- pellets,
- briquettes,
- sawdust,
- olive pomace (undried and dried for one hour at 105°C),
- cherry stones (undried and dried for one hour at 105°C),
- biodiesel,
- ethanol,
- fuel oil.

Figure 1 shows olive pomace and cherry stones we used as biofuels.

Fig. 1 *Olive pomace (left) and cherry stones (right) (Photo: Marzi)*

2. 3 Laboratory equipment

For our experiments we needed: an empty spirit burner, a laboratory balance, a stand and a gauze, a beaker, a holed aluminium container, a thermometer, a measuring cylinder and a stopwatch.

2. 4 The work procedure

We investigated the amount of heat emitted during the burning of various fuels. We observed this indirectly, through measuring the temperature of water heated by the release of heat during the burning of a specific fuel.

On a piece of paper we weighed 20 g of solid fuel; we measured out 20 ml of liquid fuel with the help of a measuring cylinder. We put some old newspaper (0,9 g) and a combustion tablet (3 g) into the aluminium container, while the liquid fuel was poured into the empty spirit burner. On the lower stand we put a container with a solid fuel, or the burner with a liquid fuel, while we put a gauze and a beaker containing 50 ml of water on the upper stand. (see fig. 2)

Fig. 2 *Burning of biodiesel (Photo: Marzi)*

With the thermometer we measured the initial water temperature and noted it down. Then we ignited the combustion tablet and watched the burning process and the changes in water temperature. Temperature was read every 5 minutes. After all of the fuel burnt out, we noted the final water temperature and the total burning time. We also weighed the mass of the residue.

2. 5 Results of experiments

2. 5. 1 Final temperature of water after the burning of various fuels

The experiments done gave us the following results:

Table 1: *The final water temperature*

Fuel	Initial water T [°C]	Final water T [°C]
Biodiesel	21	42
Ethanol	22	92
Fuel oil	22	70
Pellets	22	71
Briquettes	15	90
Sawdust	17	72
Undried cherry stones	21	90
Dried cherry stones	22	65
Undried olive pomace	17	80
Dried olive pomace	21	90

Ethanol gave off the most heat during burning (the final water temperature being 92°C), while biodiesel produced the least heat (the final water temperature being 42°C). (Table 1)

During the burning of ethanol temperature rises until the end (see fig. 3), while the temperature of biodiesel reaches 45°C and then starts to drop.

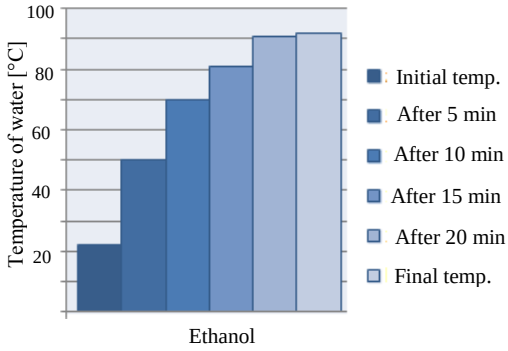

Fig. 3 *Water temperature when burning ethanol*

2. 5. 2 Residue left after the burning of solid fuels

After weighing the residue left after burning, we arrived at the following findings. (see Table 2)

Table 2: *The residue after the burning of solid fuels*

Fuel	Residue after the burning of solid fuels [g]
Pellets	8
Briquettes	1,2
Sawdust	4
Undried cherry stones	6,3
Dried cherry stones	6,5
Undried olive pomace	6,4
Dried olive pomace	11,6

We found that briquettes burnt down almost completely - the amount of residue left after burning this fuel is the smallest. The greatest amount of residue is left after burning dry olive pomace.

2. 5. 3 Burning time

The burning time of a particular fuel can be seen in the following diagram:

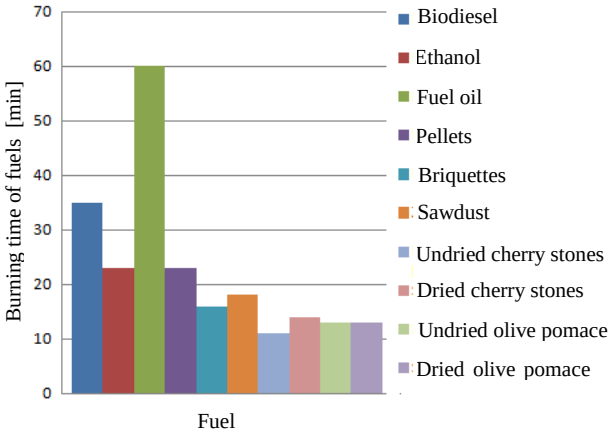

Fig. 4: *Burning time of different fuels*

Fuel oil burnt the longest (60 min and more), while undried cherry stones burnt for the shortest time (11 min). (see fig. 4)

3. Discussion and conclusion

The experiments done showed us the following:

- Different kinds of biofuel emit different amounts of heat during burning (for example, the final temperature with biodiesel is 42°C, while the final temperature with ethanol is 92°C), and thus we proved the first hypothesis (*Different fuels emit different amounts of heat*).

- Some substances take more time to burn, some less (for example, fuel oil burns for more than an hour, while undried cherry stones burn for eleven minutes). We thus also confirmed the second hypothesis (*Burning time varies depending on the type of fuel*).

- After the burning of all kinds of fuels we noticed a residue, even if only in the form of soot. Therefore we dropped the third hypothesis (*There is no residue left after the burning of liquid fuels, while there is some after the burning of solid ones).*

- Amongst all the samples, ethanol gave off the most heat, which is why we refuted the fourth hypothesis (*Solid fuels emit more heat during their burning than liquid ones*).

- Each of the fuels used left a residue after burning, namely different amounts of soot and ash (for example, the burning of briquettes gave us 1,2 g of residue, while dry olive pomace left 11,6 g of residue). This is how we confirmed the fifth hypothesis (*The quantity of residue left after the burning of various solid fuels varies*).

The article presents an example of making a research paper in elementary school, which is not the same as proper research work. This is especially true when it comes to the originality of hypotheses that form the basis of research and the precision with which these are tested. Students upgrade their existing knowledge with a different, research-oriented approach which includes doing experiments and forming conclusions independently. In their work, students can deploy their creativity and critical thinking skills, especially in connection to trending topics and everyday subjects of their interest.

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