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PRODUCTION OF BIOELECTRICITY FOR THE AQUEOUS EXTRACTS OF SOME PLANTS

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Abstract. Annual climate conferences draw public attention to the urgent need to ecologize CO_2-neutral fuel systems and recognize that global temperature increases must be limited to less than 2 °C to avoid dangerous climate change. Based on the projections of the International Panel on Climate Change, it is now widely accepted that in order to stay within this temperature range, CO_2 emissions need to be reduced by 80 % by 2050. Furthermore, developing countries most affected by climate change are pushing for a reduction (as opposed to stabilization) of atmospheric CO_2 equivalent levels from ~450 ppm to 350 ppm in order to stabilize at a 1.5 °C temperature rise.
Electricity plays an important role in our everyday life, and its consumption is constantly increasing. Its traditional production based on fossil fuels has huge environmental problems, such as pollution of the atmosphere with greenhouse gases with further global consequences – the greenhouse effect. To overcome these effects, technologies based on non-conventional energy sources such as solar energy, wind energy, biofuels, etc. are being implemented. While solar photovoltaic and thermal energy are attractive, the need for bioenergy is becoming inevitable to replace fossil fuels. Natural photosynthesis offers the means for this, primarily through the use of plants. Land plants have already been used as a source of bioenergy, and this use will increase in the future, despite a number of associated problems.
This study concerns a new technology of electricity production, namely, biotechnology, that is, the use of aqueous extracts of various plant resources. Some plants in nature have the ability to accumulate in their cells biologically active compounds capable of creating an electrolytic environment, in fact they are suitable for the production of electricity, which can be amplified.

Keywords: bioelectricity, vegetable raw materials, succulents, extract, biomass battery.

1. Introduction

Electricity is a basic need in all sectors of human life and includes industry, transport, agriculture and household economy. Without energy, the development of science and technology is impossible. (Datta, 2003). The lion's share of electricity comes from non-renewable sources, including burning coal, oil and natural gas. These sources, on the one hand, are depleted at a high rate, on the other hand, they are a powerful source of environmental pollution, of which greenhouse gases are the most dangerous (Sudhakar et al., 2013). Fossil fuels are a powerful factor in global warming and atmospheric pollution due diffusion of ALS into the intercellular space. Today, many factors are known that can intensify the process of diffusion through the cell membrane, but most of them lead to the loss of the optical activity of a complex molecule of organic origin and sometimes to the loss of the biological activity of the target compound. This is an unacceptable factor in the chemical and pharmaceutical industry because a therapeutic dose does not provide a therapeutic effect. In food technology, all the principles of nutrition science are violated. In chemical technologies, the quality of products obtained from such raw materials cannot withstand criticism (Diachok et al., 2016).

In order to prevent these disadvantages, environmentally friendly technologies that use renewable energy sources are being developed all over the

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world. Examples of such are solar energy, wind energy, biofuels, etc. Recently, there are more and more cases of the involvement of biotechnologies for the production of bioelectricity. Bioelectric cells are used to charge mobile batteries, wall clocks, gadgets, etc. Today, a promising direction for obtaining energy is the use of biomass. Conducted research using various types of plant extracts proves the perspective of this direction in engineering and biotechnology, as it is a potential source of energy for relatively cheap production of bioelectricity. The production of bioelectricity from water extracts of certain species and morphological organs of plant raw materials, as a model of galvanic cells using galvanic electrodes (zinc, copper, carbon and others) would reduce the use of non-renewable resources, in particular fossil fuels. This, in turn, would lead to a reduction in the threat of global warming (Carvalho et al., 2015).

The most important difference between bioelectric currents in living organisms and the type of electric current used to produce light, heat, or energy is that a bioelectric current is a flow of ions, organic and inorganic, that carry an electrical charge, while standard electricity is this is the movement of electrons. Bioelectricity can be generated when two electrodes with different potentials are immersed in biomass, thereby creating conditions for the movement of ions. Ions, as a rule, flow from a lower potential to a higher potential, that is, from the cathode to the anode. The main biochemical reaction that describes the process of bioelectricity production with the participation of organic substances (acetic acid) is as follows:

$$\text{Anode: } C_2H_4O_2 + 2H_2O \rightarrow 2CO_2 + 8e^- + 8H^+$$
$$\text{Cathode: } 8\,H^+ + 8e^- \rightarrow 4H_2$$

Different morphological organs of a plant, such as leaves, roots, flowers, fruits, etc., are a natural bioelectric system that contains ions of organic and inorganic origin. Controlled and regulated ionic movement in plants makes a specific biosystem that differs from the usual physical or electrolytic system. Thus, certain morphological organs of the plant can be called “bioelectrolytic systems” or “bioenergy-conducting systems”. Actually, ionic conductivity is the main factor in the emergence of bioelectricity. The specific electrolytic system found in living plants is of great importance as a low power energy source.

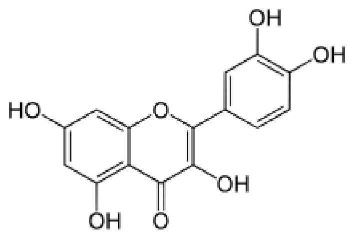
Therefore, the use of plant raw materials as a new non-traditional material for the development of bioenergy sources is an urgent task.

2. Experimental part

2.1. Description of the plant

All presented plants belong to medicinal plants and belong to succulents Succulents are plants that have special tissues for storing water. The epidermis of succulent plants usually has a very thickened cuticle, the stems and leaves are covered with a waxy layer and numerous hairs. They are characterized by the shape of the stem with a small evaporation area, a peculiar structure and arrangement of leaves. In addition, these plants have a special type of metabolism, which allows economical use of water accumulated during the wet period.

Another common feature of these plants is that the leaves contain flavonoids. Flavonoids are biologically active compounds based on a diphenylpropane fragment with the general formula:

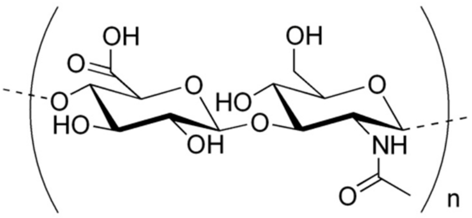


Flavonoids are found in almost all plants and are found in some types of microorganisms. They accumulate mostly in flowers, leaves, less - in stems, rhizomes, roots. Their content ranges from 0.1 to 20 % and varies depending on the plant's vegetation phase. The maximum number of flavonoids is observed during flowering, then they decrease (Chernykh, Avrvmenko, 2016).

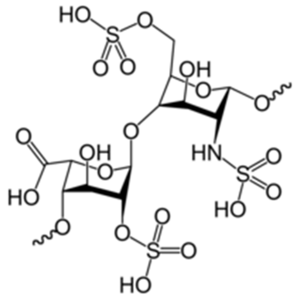
Egg-shaped crassula (*Crassula portulacea*), also known as money tree, jade tree, friendship tree. Her homeland is South Africa and Mozambique. A common indoor plant in our conditions.

An evergreen plant with thick branches and fleshy, smooth oval (egg-shaped) leaves. The leaves have a bright green color, sometimes – yellowish with a red rim, which is the result of exposure to bright sunlight. The stem is the same color as the leaves, but with age it becomes brown and woody. Sometimes the green color changes to yellow. The reason for this is the formation of carotenoid, which protects the plant from the scorching sun and ultraviolet radiation. The plant blooms in winter, in a cool, relatively dark and dry period.

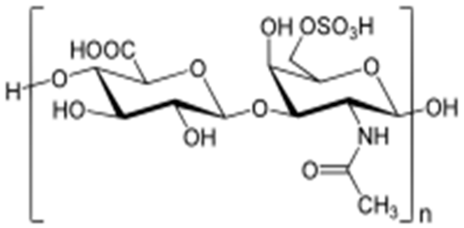
The plant contains arsenic in the leaves and at least 19 other elements. Among them, potassium up to 25.80 mg/g, silicon 11.20 mg/g, calcium – 10.0 mg/g were accumulated in significant quantities. The leaves of the fat plant contain water, fiber and mucus consisting of mucopolysaccharides. In addition, it includes the following types of chemical compounds:



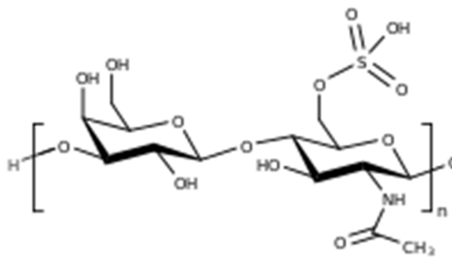
Hyaluronic acid



Heparan sulfate



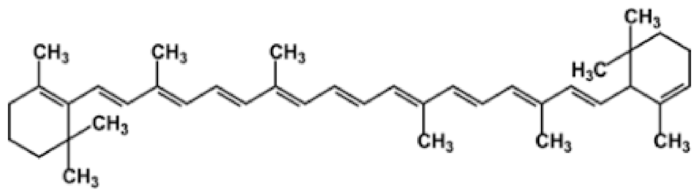
Chondroitin sulfate



Keratan sulfate

The presence of a large number of mineral salts and functional groups in organic compounds is the reason for the formation of ions (Chernykh V.P. et ol. 2016).

Aloe (*Aloe vera*) – comes from dry areas of Africa. In the modern world, aloe is spread all over the planet, it gets along well in any climate. There are hundreds of species of aloe, their hybrids and breeding varieties. This plant has a rich chemical composition, which explains the beneficial properties of aloe. Among the macronutrients in the composition of the leaves, calcium is the most – 79.1 mg g, – barium 14.90 μg/g, selenium – 11.90 μg/g and strontium 17.64 μg/g, especially a lot of lithium – 162.00 μg/g and boron 94.00 μg/g. In addition to mineral salts, Aloe contains organic compounds – carotenoids, amino acids, vitamin C, group B vitamins, vitamins E, etc. (Chernykh, Avrvmenko, 2016).



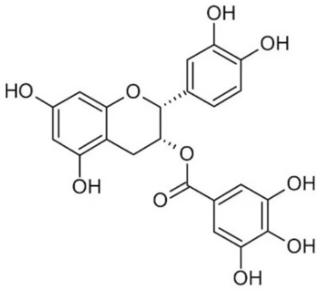
Carotenoids

$H_2N - CH - COOH$
/
R

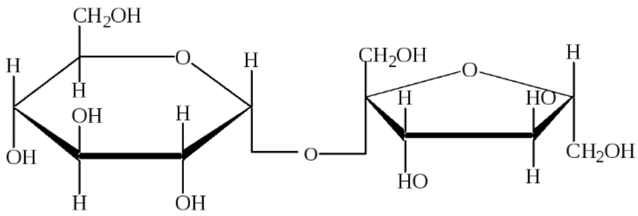
Amino acid

Kalanchoe pinnata (*Kalanchoe pinnata*) is an evergreen herbaceous perennial plant. When grown in room conditions, this plant blooms for a long time, its fruits are deciduous. *Kalanchoe pinnate* comes from the tropics. Its homeland is considered to be the Cape Verde Islands, the Comoros Islands, as well as the Reunion Islands and Madagascar. In Eastern Europe, Kalanchoe is grown indoors.

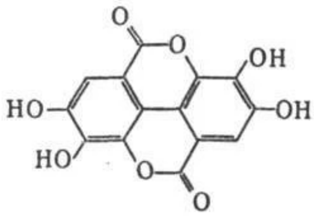
The chemical composition of *Kalanchoe pinnate* is rich in organic acids and other useful substances. The aerial part of the plant contains catechins, flavonoids, polysaccharides, tannins, enzymes (carboxylase of acetic and oxalic acids, dehydratase of malic acid), as well as citric, malic, oxalic, acetic and isolimic acids. In addition, the plant contains a significant amount of ascorbic acid and a number of micro- and macroelements such as iron, magnesium, aluminum, copper, calcium, manganese, silicon, etc. (Chernykh, Avrvmenko, 2016).



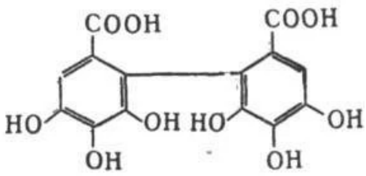
Catechin

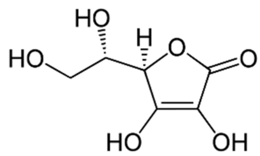


Polysaccharides

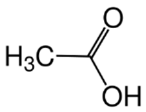


Tannins

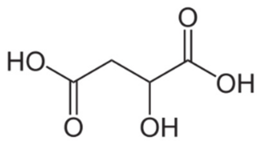




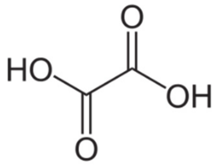
Ascorbic acid



Acetic acid



Malic acid



Oxalic acid

2.2. Preparation of aqueous extract

Fresh leaves, after washing with distilled water, were spread on filter paper to remove water droplets. Then the leaves were crushed with the help of a laboratory herb cutter and pestle into small fragments and weighed. The extraction was carried out in a glass container where the operation of the apparatus with a turbine stirrer was simulated. The extracts were filtered using filter paper and the volumes were adjusted to the final value by washing the precipitate with distilled water. The ratio of solid-liquid phases was 1–5.

2.3. Measurement of conductivity

Extracts of each sample were subjected to conductivity measurement (Fig. 1) using a measuring cell. A fixed volume of the extract, approximately 40 ml, was taken and the conductivity was determined by immersing the electrodes in the extracts.

2.4. Measurement of voltage and current

The extract of each sample was subjected to voltage and current measurement using a multimeter as shown in Fig. 1.

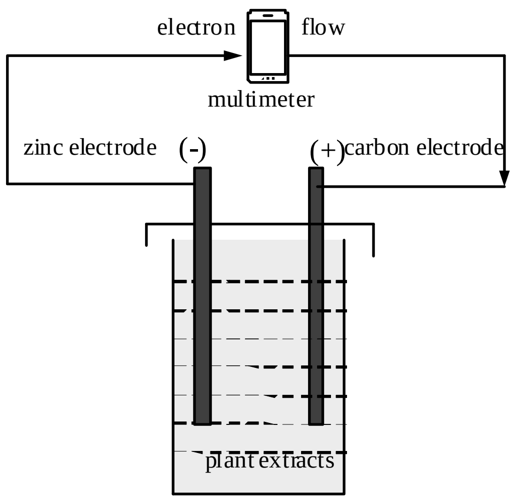


Fig. 1. Measurement of the conductivity of plant extracts

The electrodes connected to the multimeter were immersed in the extract solution. Multimeter readings were taken every five minutes. A graphical dependence of voltage on time was built.

2.5. Preparation of a bioelectric element

The bioelectric element included two types of electrodes, zinc and carbon, installed in a glass container - a cell. The volume of the cell was 50 ml. Such three galvanic elements were separately connected in series and parallel circuit for further study. Separate sets were prepared for different three types of plant extracts Fig. 2 and Fig. 3. Power was calculated as the product of current and voltage P=VI.

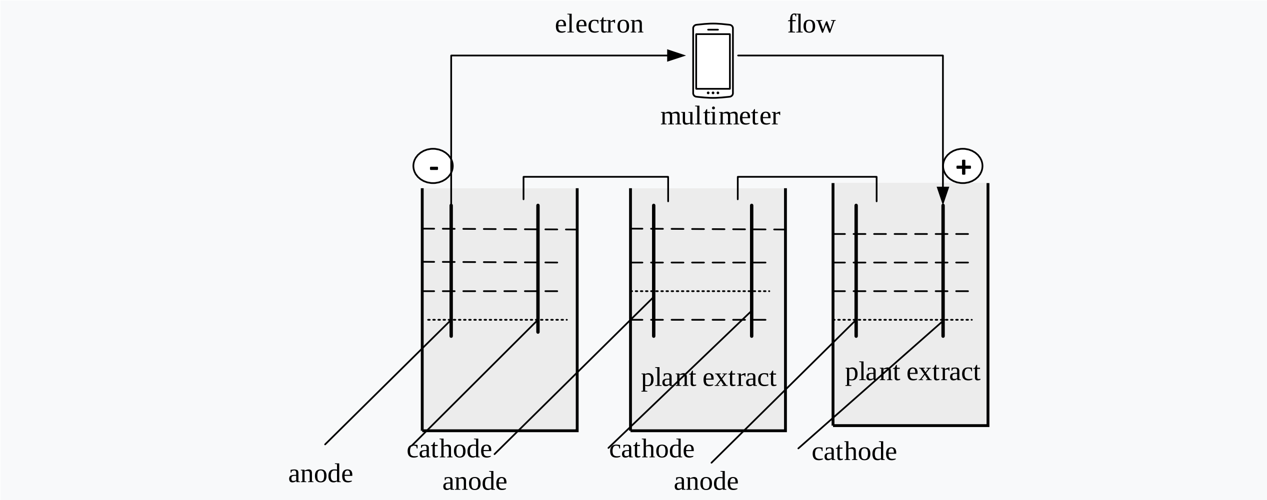


Fig. 2. Schematic diagram of galvanic elements connected in series
Measurement of voltage and current of plant extracts

3. Results and Discussion

Bioenergy as a clean and sustainable fuel obtained from the use of renewable energy sources such as biomass is gaining widespread development (Kaygusuz et al. 2009). Developing the concept of using water extracts of some types of plant material with juicy leaves to generate electricity is an important task. As a result of the traditional use of batteries in technology and everyday life, the most common electrolytes pose a threat to the environment. At the same time, aqueous extracts of certain plant species can be used as electrolytes because all plant materials contain different types of inorganic and organic electrolyte compounds that are easily absorbed by the root system of traditional plants and metabolized without harming the environment. In this study, aqueous extracts of Crassula portulacea, Aloe, and Kalanchoe pinnata were used to study the properties of electrical potential, including conductivity, current, and voltage. It was observed that the aqueous extract of Aloe leaves has the highest conductivity compared to other extracts. As shown in Table 1, Kalanchoe pinnata has a lower conductivity (2.65 mS/cm) compared to Aleo (3.9 mS/cm) and Crassula portulacea (2.84 mS/cm). This is explained by the chemical composition of the leaves, in particular, a significant amount of mineral salts and organic compounds. Aleo registered higher voltage compared to the other three plants as shown in Table 1 and Fig. 3. Crassula portulacea extracts showed lower voltage potential.

The results showed that the circuit voltage of the cells connected in series increased with the increase in the number of galvanic or fuel cells. Accordingly, the values of the output power also increase, and the current strength of the circuit remains practically constant.

With the parallel connection of the elements of the circuit, the voltage remains constant almost at the value obtained in one cell, but the current increases with an increase in the number of galvanic or fuel cells, in contrast to a series circuit, where the voltage increases with an increase in the number of galvanic or fuel cells, and the current in the circuit remains almost constant (Table 1). In addition, the comparison of power output showed that the Kalanchoe pinnata extract showed the highest power output values among the other tested extracts, in the parallel connection of the cells of the circuit, followed by the aloe then the crassula, respectively.

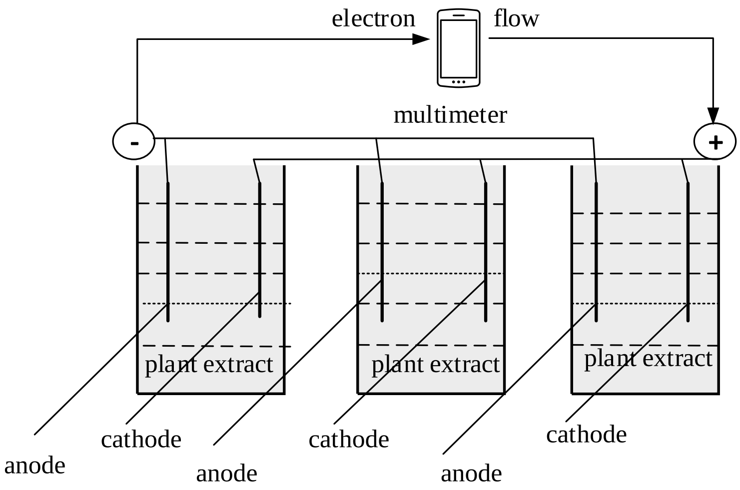


Fig. 3. Schematic diagram of galvanic elements connected in parallel
Measurement of voltage and current of plant extracts

Table 1

Obtained bioelectrical parameters of the studied extracts

Name of the raw material	Number of cells	σ; µS/cm conductivi ty	Serial connection			Parallel connection		
			U (V) voltage	I (mA) current	P (mWat) power	U (V) voltage	I (mA) current	P (mWat) power
Aloe vera	1 2 3	3.9	0.91 1.79 2.73	1.25 1.23 1.26	1.14 2.26 3.43	0.91 0.90 0.92	1.26 2.48 3.63	1.14 2.23 3.33
Kalanchoe pinnata	1 2 3	2.65	0.88 1.63 2.25	1.82 1.83 1.81	1.60 2.98 4.07	0.88 0.87 0.89	1.82 2.93 4.98	1.60 2.54 4.43
Crassula portulacea	1 2 3	2.84	0.81 1.51 2.39	0.80 0.83 0.79	0.64 1.25 1.88	0.81 0.80 0.82	0.81 1.52 2.27	0.65 1.21 1.86

The results of monitoring the achievement of the maximum value of the biopotential change under open circuit conditions over time are shown in Fig. 4. The figure shows that the maximum value of the biopotential is reached in 16 minutes in the one-cell model, for the two-cell model this time is six minutes, while in the three-cell model it is reached in four minutes, provided the cells are connected in series.

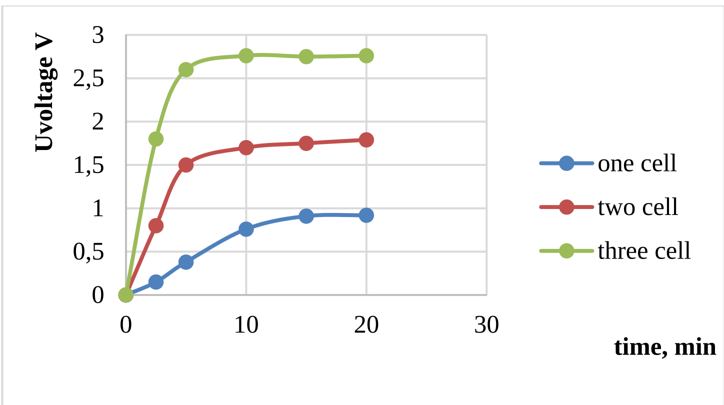


Fig. 4. Variation of voltage with time in one, two and three cell models

4. Conclusion

1. The disadvantages of non-renewable or conventional energy sources such as fossil fuels are exhaustive and pose a serious threat to global warming and environmental pollution.

2. Conducting a study of various plant extracts for the production of bioelectricity, the main parameters such as conductivity, voltage, current and calculated power of the studied biosystems were established.

3. It is shown that the plant extract has a significant potential for electricity generation due to the presence of mineral salts and biomolecules such as lipids, proteins, carbohydrates, polyphenolic compounds, and their metabolites cause the electrolytic properties of aqueous solutions that can serve as natural electrolytes.

4. Further research in this direction will allow us to find effective methods of renewable and environmentally friendly production of bioelectricity.

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