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Utilization of CO_2 from Biogas Installation in Greenhouses

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Abstract

The paper is deals with new approach for use of carbon dioxide gas which is generated in biogas installations. A new method for utilization of the carbon dioxide for the needs of the greenhouses is proposed. The use of the described installation will contribute to better growth of different crops cultivated in the greenhouses. The normal CO_2 concentration in the ambient air is 400 ppm, using such an installation CO_2 concentration in the greenhouse air can be raised to 1000-1200 ppm, which will increase the growth of greenhouse crops

Keywords: carbon dioxide, biogas installations, greenhouses.

1. Introduction

Carbon dioxide naturally occurs in the atmosphere. It is an essential factor in the photosynthesis of plants, the process by which they produce food and energy. Atmospheric carbon dioxide levels have increased since the Industrial Revolution. The main causes are deforestation and burning of fossil fuels such as coal, fuel oil, natural gas and more. As carbon dioxide levels increase, as a consequence it contributes to the air pollution. In the atmospheric gases the carbon dioxide content is less than 1 percent. However, there is a delicate balance between carbon dioxide and other gases. Within the last decade the concern for carbon dioxide is a significant change in a relatively short period of time.

Carbon dioxide put up to air pollution in its role in the greenhouse effect. Carbon dioxide captures radiation at ground level, producing ground-level ozone. This atmospheric layer prevents the earth from cooling down at night. One result is the warming of the ocean waters. The oceans absorb carbon dioxide from the atmosphere. Higher water temperatures, however compromise the ability of the oceans to absorb carbon dioxide. Over time, the effects of carbon dioxide have increased.

Climate change is another environmental effect of carbon dioxide on air pollution. According to studies from the National Oceanic and Atmospheric Administration (NOAA) within the last one hundred years the temperature of the Earth's surface have increased. According to the latest scientific reports that carbon dioxide pollution is the main culprit. The effects are very complex. Evidence, however, shows that ocean water levels have increased, led by the loss of coastal and coastal wetlands.

Acid rains are also environmental consequence of the carbon dioxide. Fossil fuel power plant emissions combine with moisture in the air. The result is highly acid precipitations. The documented evidence shows physical damage to trees and other plants. The acidic precipitations also cause water and soil pollution. Emissions mobility is a complicating factor. The effects of carbon dioxide can be seen and felt far from their sources, making their impact on air pollution more serious.

Carbon dioxide have adverse effects on human health. Higher carbon dioxide concentrations may lead to difficulties in breathing. Moreover, high levels of carbon dioxide indoors give rise to health complaints such as headaches. Carbon dioxide levels can indicate high levels of other harmful air pollutants, such as volatile organic compounds that contribute to indoor air pollution.

Biogas and methane which are renewable gases are considered key carriers of energy when society replaces fossil fuels with alternative energy [1-3].

Global climate change caused by CO_2 emissions is currently under discussion around the world. Therefore, greener energy sources are needed as an alternative for fossil fuel replacement. So far, various biogas improvement technologies have been developed and some of them are already commercially available. Some of them for upgrading biogas today are adsorption of rocking, high pressure washing, organic solvent cleaning, amine cleaning, membrane separation and cryogenic separation, which are briefly described in the following section. Choosing the right technology, taking into account the efficiency and economy of a particular application, is important [4].

The use of biogas and biomass as an energy source is considered to be CO_2 neutral, since the CO_2 released during biogas burning is the same CO_2 that plants in biomass utilizes during photosynthesis to create organic matter. Thus biogas combustion is simply recycling of CO_2 into the biosphere. In addition, energy production itself also helps to

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reduce greenhouse gas emissions, depending on the fuel being replaced. If biogas is used instead of straw, there will be no reduction in CO_2 emissions since the use of straw is already carbon dioxide neutral. However, if biogas replaces oil, less oil will be used and this will lead to global reduction of the emissions. There will also be a different set of figures to reduce if biogas is used for transport purposes and replacing diesel or gasoline [1, 2, 3, 5].

Table 1 Content of biogas

Component	**Formula**	**Concentration**
Methane	CH_4	50-75%
Carbon dioxide	CO_2	25-45%
Water steam	H_2O	2-7%
Hydrosulfide	H_2S	0.02-2%
Nitrogen	N_2	>2%
Ammonia	NH_3	>1%
Hydrogen	H_2	>1%
Other gases		>2%

The aim of the work is to present a review of exisiting way to remove CO_2 from biogass installationc and how this CO_2 can be used for the needs of greenhouses.

2. Extraction of carbon dioxide from biogas installation

In practice are used some different technologies for removal of carbon dioxide from installation. Such a technologies are given in Table 2.

Table 2. Removal of CO_2 from biogas installation

Techniques	Function
Pressure Swing Adsorption (PSA)	Adsorption of carbon dioxide on e.g. activated carbon.
Water scrubber	Absorption of carbon dioxide in water
Chemical absorption	Chemical reaction between carbon dioxide and amine – based solvents.
Membrane	Separation through a membrane that is permeable for carbon dioxide
Cryogenic separation	Cooling until condensation or sublimation of the carbon dioxide

3. CO_2 in greenhouse

Plants consist of 70 to 90% water and only 10 to 30% dry substance. The carbon content (C) is 45% of this dry substance. Plants take over carbon predominantly in the form of carbon dioxide (CO_2) from the air. For growth, they form biomass using water and CO_2 from the air and in the presence of light (photosynthesis). For optimal growth, the factors are temperature, nutrients, water, light and carbon dioxide.

When enriching the greenhouse atmosphere from 0.06 to 0.12% CO_2, photosynthesis is facilitated and more plant substance is formed. So in the year periods of reduced light when using additional lighting are possible higher yields.

The life and growth of plants depend on assimilation processes. As there is a regular relationship between light, heat and CO_2, assimilation is possible when the three components are in the correct ratio. CO_2 diffuses through the pores of the leaves. The green leaves absorb CO_2 from the air and, using light energy and water, converts them into energy-rich carbon-containing compounds such as sugar, starch and other carbohydrates.

According to equation:

$$6CO_2 + 12H_2O + light \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

the necessary carbon atoms (C) are captured by the absorption of carbon dioxide (CO_2), whereby oxygen is released. Photosynthesis is carried out in chloroplasts of plants and runs in two phases – on light and dark. If one of the factors light heat, nutrients, air (CO_2), and water is below its optimal value, then that factor limits the amount of assimilation and plants growth. (fig.1)

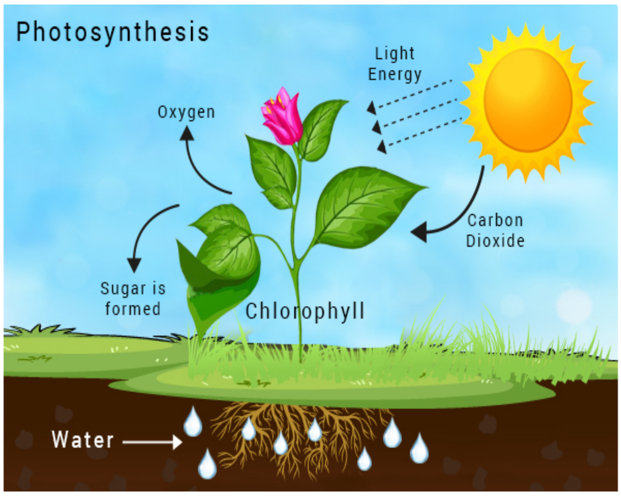

Fig. 1 Scheme of the photosynthesis

One of the main aims of planting in greenhouses is to maximize yield and improve competitiveness. One option is "carbon dioxide fertilization". The CO_2 content of our atmosphere is 0.04% by volume. Even at the optimum concentration of CO_2 in the air, it is insufficient compared to other growth factors. To avoid heat loss, greenhouses are compacted as much as possible. Thus, the concentration of CO_2 from the atmosphere in the greenhouse decreases during the day. Growth may slow down or stop altogether. This disadvantage can only be compensated by the artificial addition of CO_2 in the presence of light. If other growth factors are optimized for heat, moisture and light, then increasing the concentration of CO_2 in the atmosphere greenhouse plants improve photosynthesis approximately by 2.5 times and hence the production of carbohydrates. The most appropriate concentration of CO_2 is different for different crops of vegetables or flowers. Experience has shown that 0.06 - 0.12 % rise of the concentration is optimal. [6, 7, 8, 9]. Many manufacturers use carbon dioxide to enrich the atmosphere and achieve:

- up to 300% higher yields in the first four weeks of receiving crops in long-growth plants;
- up to 35% higher yields throughout the growing season;
- faster growth of leafy vegetables caused by plants better light capture;
- Better quality of the crops such as thicker, longer stems and better shaped, well-colored colors;
- More effective protection of plants against direct sunlight and better surface quality;

- Increased yields and / or shorter crop growth periods.

Photosynthesis uses CO_2 in the production of sugar, which breaks down during respiration and promotes plant growth. Although atmospheric and environmental factors such as light, water, nutrition, humidity and temperature can affect the rate of use of CO_2, the amount of CO_2 in the atmosphere has a greater impact. The difference in CO_2 concentration depends on the time of day, the season, the number of industries producing CO_2, composting, combustion, and the number of sources that absorb CO_2, such as plants and water bodies nearby. An environmental CO_2 concentration (naturally occurring CO_2 level) of 400 parts per million can occur in a properly ventilated greenhouse. However, the concentration is much lower than the daytime environment and much higher at night in sealed greenhouses. Carbon dioxide levels are higher at night due to plant breathing and microbial activities. Carbon dioxide levels can drop to 150 to 200 parts per million a day in a sealed greenhouse due to CO_2 use by plants for photosynthesis during the day. Exposure to plants at l Lower CO_2 levels exposure of the plants, even for a short period, may cause reduction of the photosynthesis rate and plant growth. In general, doubling the level of CO_2 in the environment (i.e 700 to 800 parts per million) can lead to a significant and visible difference in plant yield. Plants with the C_3 photosynthetic pathway (geranium, petunia, fungus, aster lily and most wild species) have a 3-carbon compound as the first product in their photosynthetic pathway, which is why they are called C_3 plants and are more responsive to higher CO_2 concentration of plants having the C_4 pathway (most grass species have a 4-carbon compound as the first product in their photosynthetic pathway, which is why they are called C_4 plants). Increasing ambient CO_2 to 800-1000 ppm can increase the yield of C_3 plants by 40 to 100 percent and C_4 plants by 10 to 25 percent, while maintaining other inputs at optimum levels. Plants show a positive response of up to CO_2 concentration of 700 at 1800 ppm, but higher levels can cause damage to the plants (Figure 2).

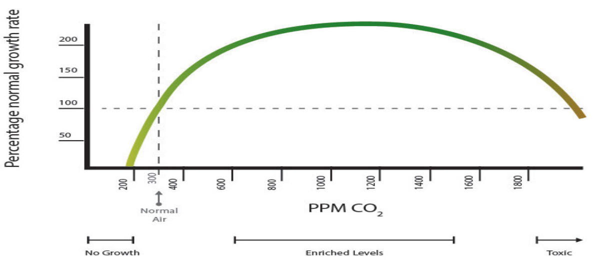

Fig. 2 Relation between CO_2 concentration and rate of plant growth [10]

Increasing the CO_2 content in the air by 300 ppm usually increases the productivity of most herbaceous (non-woody) plants by about one-third; and this positive response occurs in plants that use all three of the major biochemical pathways (C_3, C_4, CAM) of photosynthesis. Thus, with more CO_2 in the air, the productivity of almost all crops increases as they yield more branches , more and thicker leaves, more developed root system and at the end more flowers and fruits.

An average increase in CO_2 concentrations in the atmosphere of 300 ppm results in a 15% increase in yield for CAM crops, 49% for C_3 cereals, 20% for C_4 cereals, 24% for fruits and melons, 44% for legumes, 48 % for roots and tubers and 37% for vegetables [6,7,8, 9,10].

Table 3. Summarizes the mean percentage yield increase production by 300 ppm increase of the CO_2 [11].

Crop	%	Crop	%
C_3 Cereals		Legumes	
Barley	66	Beans	32
Rapeseed	62	Broad bean	39
Rice	37	Cow peas	86
Sunflower seed	36	Okra	32
Wheat	43	Peas	31
Average	48,8	Soybeans	46
Roots and tubers		Average	44,3
Carrots	60	Vegetable	
Cassava	87	Cabbages	27
Onions	28	Cauliflower	34
Potatoes	35	Green Chillies&peppers	25
Sugar beets	33	Cucumbers and gherkins	39
Sweet potatoes	46	Eggplants	54
Average	48,2	Lettuce	40
C_4 Cereals		Tomatoes	20
Maize	22	Other Vegetables	53
Sorghum	18	Average	36,5
Average	20	Woody plants	
Fruits and melons		Average	51
Other fresh fruit	30	Cam plants	
Pumpkins, squash, gourds	18	Average	15
Average	24		

4. Test-rig for utilization of CO_2 from biogas installation for need of greenhouse

In this work are presented two chains for utilization of CO_2 from biogas installation for the needs of greenhouses.

Chain 1. The CO_2 is captured from the biogas with some of the methods mentioned in part II above and after that is supplied in the greenhouse. The principle sheme is given on fig. 3.

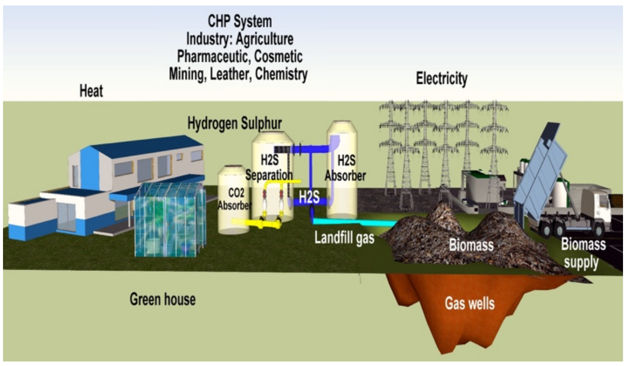

Fig.3 Principle scheme of the test-rig

Figure 4 represents schematically the proposed greenhouse CO_2 supply chain system.

Chain 2. Biogas is used as a fuel for co-generation of electricity and heat by a spark ignition internal combustion engine. The flue gases, after purification from NO_x and CO, are mixed with the atmospheric air to reach a mixture with 1400 ppm volume fraction of CO_2 and supplied to the greenhouse volume.

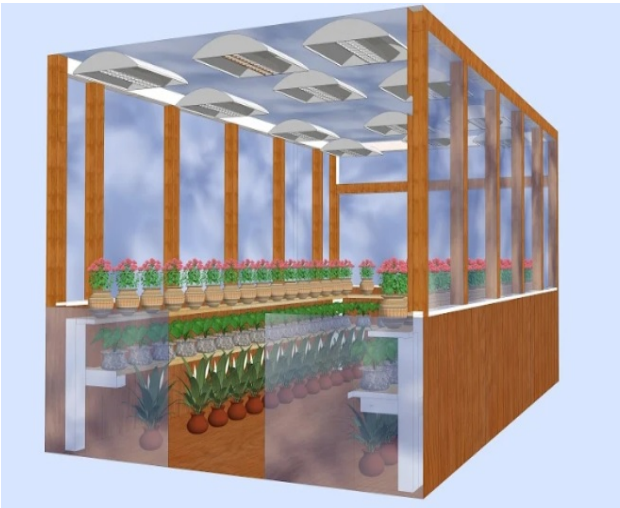

Fig. 4 Supplement of CO_2 in greenhouse

Each of those scheems have advantages and dissadvantages.

Chain1. The addition of clean CO_2 from a biogas instalation to the atmosphere in the greenhouse does not add extra moisture. CO_2 can be supplied to the greenhouse even when there is no need of heating. Unlike CO_2 from flue gases, biogas instalation CO_2 does not contain substances that harm the plants. Of course all processes for CO_2 separation from the biogas use energy.

Chain 2. Since biogas is used for co-generation of heat/cold (by installations applying absorption cycle) and electricity it may be used all over the year for space heathing/cooling and supllying the greenhouse with required CO_2. Based on the particular situation hot flue gases may be mixed with outdoor air and supplied directly to the greenhouse, or they may be cooled down by a heat exchanger and then mixed with the greenhouse air.

5. Conclusion

As conclusions of the presented work can be mentioned:

- A new suggestion for CO_2 utilization from biogas installations is proposed;
- An increase in the photosynthesis and increased crop growth rates is expected;
- In production, supplemental CO_2 increases the number and size of the products, which increase the sales value because of higher product quality;
- Supplemental CO_2 provides additional heat (depending upon the method of supplementation) through burners, which will reduce heating costs in winter.

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