USE OF BIOENERGY CONVERSION TECHNOLOGIES IN ORGANIC AGRICULTURE

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There is no doubt that every measure proposed for implementation in agroecosystems should not only provide soil fertility, but favour the expanded fertility renewal. Therefore, the important task is to determine the amount of plant biomass, which can be used in heating without any harm to soil fertility recovery. It should also be taken into account that the use of technological processes with high mechanization level does not always lead to higher economic production indices because of increased deductions in production costs for technical servicing and repair of technical equipment, as well as deductions for depreciation, which are not compensated by additional production profits.

Oil-bearing crop production takes one of the leading positions in the structure of plant growing and in the whole system of agricultural production in Ukraine. In the structure of total agricultural output, 35% of total production volumes in all farm categories are due to these crops. The main producers of these products manufacture 60% of oilseed products *(Agricultural Ukraine, 2015)*. In terms of food security, the volumes of domestic production fully satisfy domestic demands in these products, leaving some bulk for export and raw materials for biofuels.

The experience of using biogas plants was completely analysed by the Agency for renewable resources in Germany *(Guide to biogas, 2012)*. The authors of the analysis indicate that in the absence of biomass mixing in the reactor, after a while there is a separation of biomass with layer forming due to the difference in density of certain mineral and organic components, as well as to flotation of particles while yielding gas. Thus, the biggest part of the anaerobic bacteria biomass is situated at the bottom of the reactor and the organic part of the biomass substrate accumulates at the top of the reactor. As a result, the contact zone of anaerobic bacteria with biomass substrate is limited by a boundary layer of mentioned parts of the reactor. Floating crust of solid organic substances also blocks biogas yield. Facilitation of anaerobic bacteria contact with substrate biomass is provided by mixing the substrate, but intensive mixing should be avoided because it can cause stopping of anaerobic fermentation at the expense of disturbance of acetogenic and methanogenic bacteria symbiosis. In practice, a compromise is achieved by slow rotation of agitators or by their work within a short period of time. Part of the solid mineral inclusions contained in substrates based on manure is released in the process of biological decomposition inside the reactor. Mineral sediment reduces the useful volume of the reactor (*Gouxa X. et al, 2016; Satjaritanuna P. et al, 2016; Golub G. et al, 2017).*

With due regard to well-known regularities and research results it is developed the structural diagram and simulation model of diversified manufacturing of products with biological energy conversion of organic raw materials for 6-field crop rotation with a total area of 300 hectares (fig. 1).

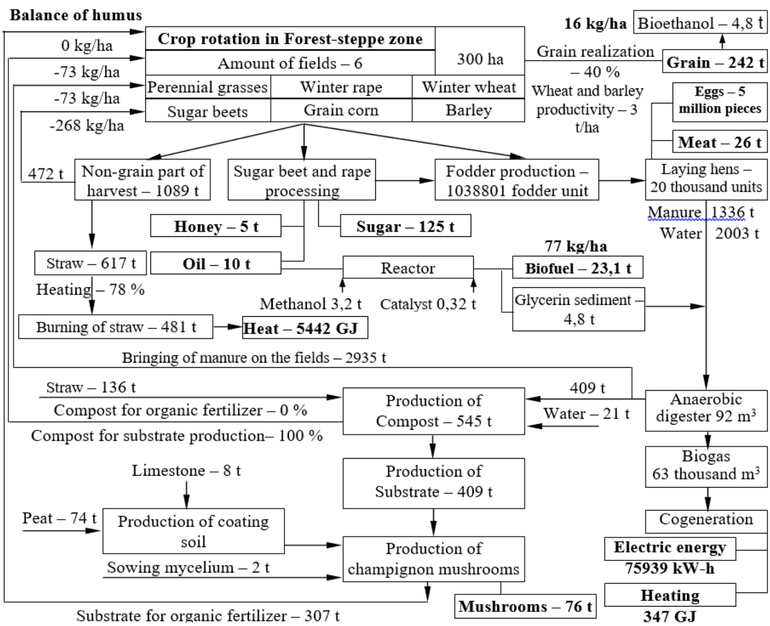

Fig. 1. Structural diagram for the manufacturing of production and energy on the basis of biofuels

Structural diagram of diversified manufacturing of agricultural products and energy envisages: growing of rotation field crops with production of grain and sugar beets; harvesting of crop straw and rape stalks; leaving of shredded corn stalks in the field as mulch; feed production for poultry; manufacturing of poultry products; methane (anaerobic) fermentation of poultry manure with production of heat and electric power from biogas; the preparation and use of grain crop straw and rape stalks for heating needs in the form of briquettes, rolls or chaff; usage of grain crop straw, rape stalks and fermented manure for compost production; production of substrate for champignon growing in compost and champignon production; production of biodiesel from rape seeds; use of glycerine residue for heating needs or its anaerobic fermentation.

On the basis of the introduced scheme it was defined the balance of humus in crop rotation using the well-known equation:

$$B = \frac{1}{\sum_{i=1}^{n} S_i} \left[-\sum_{i=1}^{n} S_i M_i + \sum_{i=1}^{n} S_i U_i k_{DWi} k_{Hi} + \sum_{j}^{m} OB_j \left(1 - \frac{W_j}{100} \right) k_{Hj} \right], \qquad (1)$$

where: B – the annual balance of humus in crop rotation, kg/ha; S_i – the area under the i rotation crop, ha; M_i – mineralization of humus by the i rotation crop, kg/ha; U_i – the productivity of the i rotation crop, kg/ha; k_{DWi}, k_{Hi} – output coefficients of dry weight of residues and their humification for the i rotation crop, rel. units.; OB_j – annual organic biomass volume of the j species (non-seed biomass of agricultural crops remaining in the fields, manure, compost, substrate and biomass of weeds, green manure, etc.), which enters the field during a year, kg; W_j – relative humidity of organic biomass of the j species, %; k_{Hj} – humification coefficient of dry organic biomass of the j species, rel. units.; n, m – the number of rotation fields and the number of organic biomass species respectively, units.

Computer simulation model allows determining the quotient of straw, which can be used for heating needs individually for separate farm. Thus, under the conditions shown in the figure, it can be reserved 78 % of straw for heating needs, and the part of the gathered straw in amount of 136 tons should be used for humus deficiency compensation in order to compensate humus losses completely. This can be done by two methods – either to leave some chopped straw in the fields or to develop on its basis compost or substrate for growing champignons.

On the basis of existing indicators, which characterize agricultural production in Ukraine during recent years in general, there were also made the calculations on defining the straw volume limits used for heating needs. This dependence defined as a percentage of the total amount of straw is as follows:

$$C\% = -0{,}57D + 48{,}66 \qquad (2)$$

where: $C^{\%}$ is the straw amount limit from the total amount which can be used for heating needs, %; D – annual humus deficiency, kg/ha.

It should be mentioned, that in the case of the total humus deficiency in the range of 80 to 90 kg/ha, the use of straw for heating needs is impossible because of soil fertility preserving terms. The maximum amount of straw which can be used for heating needs with zero humus balance is about 50%.

To ensure use of corn and sunflower tops for heating needs, as well as of rape stems, there remain unsolved technical issues of this plant biomass storage, that's why nowadays it is usually crushed and left in the fields.

When summarizing the data of chemical composition of straw it was assumed that the nitrogen-sulphur ratio in cereal straw is 5 units (in legume straw – 10 units), and the hydrogen-sulphur ratio is 56 units, which correspond to the averaged data according to (*Barotfy I., Rapan P., 1988*). The carbon-nitrogen ratio was taken as medium in volume, according to the data in (*Shkarada M., 1985*).

While calculations performed to prove the use of plant biomass for specific region or whole country, the heat of straw combustion should be determined by the equation which takes into account the importance of the volumes of a particular straw type. For example, it is known that the main volumes of grain crop straw in Ukraine are presented by wheat straw (from 40 to 60%), barley straw (from 20 to 30%), rye straw (from 3 to 6%) and legume straw (from 2 to 8%). In recent years, it began to increase specific weight of rape straw, which reached values from 4 to 6%.

It is well-known that grain crops, vegetative mass major producers, traditionally occupy from 40 to 55% in the structure of sowed crops. It should also be mentioned that with livestock decrease straw consumption for feeding and litter decreased as well, and the surplus straw is usually burned in fields. Using straw in existing volumes would allow natural gas saving in the range from 4.5 to 14.3 billion m^3.

It is necessary to mention the appropriateness and availability of rolled straw storage, because this technology allows quick removal of straw from fields and is realized by means of simple and reliable technical equipment.

According to our estimations, while annual volume of straw combustion at the rate of 30 million tons, the total amount of natural gas yielded will be 10.9 billion m^3. In these conditions, additional investments for preparation and combustion of straw will be 14.6 billion UAH, and their payback period will be from 1.2 to 1.3 years.

The effectiveness of straw combustion on the basis of comparison to heat generation by natural gas burning dependence from the heat production efficiency of straw when compared to gas heating and changing of straw cost.

In Ukraine there are many cases of usage by agricultural producers of rapeseed oil in mixture with diesel for diesel tractors which have exceeded their service life.

We found that rapeseed oil production for usage as biodiesel can be economically reasonable in terms of agricultural production, when compared to rapeseed selling if the total cost of production is high and close to the average selling price of rapeseeds, or if the price of realization is low and similar to the total cost of rapeseeds.

Using biodiesel to replace diesel, it is necessary to heat biodiesel in the fuel lines of low pressure up to the temperature which provides the determined level of biodiesel filtration (*Man X. et al, 2015; Corsini A. et al, 2015)*. To increase efficiency and temperature range of biodiesel use, we have designed and made a two-stage heating system, which allows using biodiesel under any values of environment temperature and provides an increase in completeness of fuel combustion. The second stage of fuel heating is made in the fuel pump-injector section for its better spraying and increase of speed and combustion completeness.

On the basis of statistical data about consumption of diesel in agriculture and rape gross harvest, we have evaluated the capacity of replacing diesel to biodiesel while processing of whole rape harvest.

The largest consumption of diesel in agriculture for the observed period was noticed in 2001, 2002, 2000, and the lowest – in 2006, 2007, 2008; in 2011 it was observed the tendency of diesel use increase when compared to 2010 from 1201.4 thousand tons to 1349.7 thousand tons. Rape gross yield increase is being observed since 2004, and in 2009 was noticed production decline. The volume of biodiesel production while processing the whole rape harvest was to be the highest for the investigated period in 2008 – 900.6 thousand tons of biodiesel, in 2009 – 587.3 thousand tons, in 2010 – 460.8 thousand tons, in 2011 – 387.9 thousand tons, and the lowest – in 2003 – 15.8 thousand tons, as well as in 2002 – 19.1 thousand tons. The quotient of diesel which can be substituted to biodiesel while processing whole rape harvest was the largest in 2008 – 64.7%. At the same time, as it is predicted, production and use of biofuel in 2020 will not exceed 100 thousand tons per year (*Geletukha G.G., Zheleznaya T.A., 2012*).

Farms can produce biodiesel after harvesting oilseeds, i.e. in autumn. In autumn-winter period diesel is limitedly used in agricultural production – in animal husbandry only (*Ivanova B., Stoyanov S., 2016; Baskar G., Aiswarya R., 2016*). The produced biodiesel is stored in warehouses for oil products till the beginning of spring field work. When stored in sealed containers, biodiesel does not lose its properties during the year, unlike rapeseeds and rape oil. Prices for fossil diesel are constantly increasing, especially at the beginning of spring, but the cost of produced biofuels in the previous year remained unchanged, that is one of the cost saving provisions in agriculture.

Experience of using biogas reactors showed that there are reactors already half-filled with mineral sediment, which can be removed only with an excavator after total stopping of fermentation process. Floating layers, especially based on fibrous substrates, often form a crust and if it is not mixed, the reactor must also be stopped to remove it.

Thus, the improvement of biogas reactor work to ensure the mixing of biomass substrate layers requires new technical solutions, one of which is mixing by rotation of the suspended reactor submerged into water. We have developed and patented several designs of modular anaerobic digesters of rotational type (*Patent Ukraine №110077, 2015*).

Our calculations showed that the microbiological decomposition while anaerobic fermentation of 1 kg of organic matter is accompanied by about 0.4 kg of methane yield and by 0.7 kg of carbon dioxide yield.

Assuming that the volume of produced biogas is determined by the intensity of organic matter decomposing during organic biomass fermentation, biogas yield while fermentation in terms of normal conditions can be defined as follows:

$$V_{BG} = \rho_{BM}\left(1 - \frac{W_{BM}}{100}\right)k_{OM}\,k_{OM}^{D}\,\frac{m_{BG}}{\rho_{BG}^{N}}, \quad (3)$$

where: V_{BG} – is a specific biogas yield from the reactor under normal conditions, m^3_{BG}/m^3_{BM} per day; ρ_{BM} – biomass density, kg_{BM}/m^3_{BM}; W_{BM} – biomass humidity, %; (1-W_{BM}/100) – dry matter content in relation to the total biomass, kg_{DM}/kg_{BM}; k_{OM} – organic matter content in relation to the volume of the total dry weight in fermenting biomass, kg_{OM}/kg_{DM}; k^D_{OM} – the number of decomposed organic matter per day in relation to the total organic mass, kg_{DOM}/kg_{OM} per day; M_{BG} – biogas yield per unit of decomposed organic matter, kg_{BG}/kg_{DOM} ; ρ^N_{BG} – biogas density under normal conditions, kg_{BG}/m^3_{BG}.

Biogas and biomethane yields increase proportionally with increasing the level of organic biomass decomposing in the reactor, and the fermentation time decreases exponentially until it reaches 38% fermentation level.

Conclusions. Biological and energetic conversion of organic agrocenosis raw materials with energy production can ensure energy autonomy of agroecosystems in total energy balance. Though, it is impossible to do it according to the types of fuels and energy, since there is a limit on the possibility of autonomous production of electric power and gasoline. However, production of biodiesel and heat energy can be redundant. The source of raw materials that would meet the needs of agricultural production under centralized bioethanol production is sufficient. At the same time, to implement such systems, first of all, it is necessary to change the basic principles of society existence, regarding manufacturing of environmentally friendly production and biological diversity preserving.

The heat of straw combustion reduces down to 0.18 to 0.21 MJ/kg for each percent of its humidity increase. Energy efficiency is increased while burning straw in the compressed form (briquettes, pellets). Baled straw should be burned in boilers equipped with cameras for post-combustion of volatile compounds. Non-pressed straw should be burned in crushed form by using eddy chambers.

The main direction in manure fermentation process intensification is the increase of organic matter decomposition at the cost of creation of appropriate conditions for the development of anaerobic microflora. This can be achieved by creating stable fermentation temperature conditions and, what is more important, by providing quality biomass mixing, which, on the one hand, must not disturb the symbiosis of acetogenic and methanogenic bacteria, and, on the other hand, prevent the exfoliation of biomass in the reactor to mineral sediment and floating organic layer.

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