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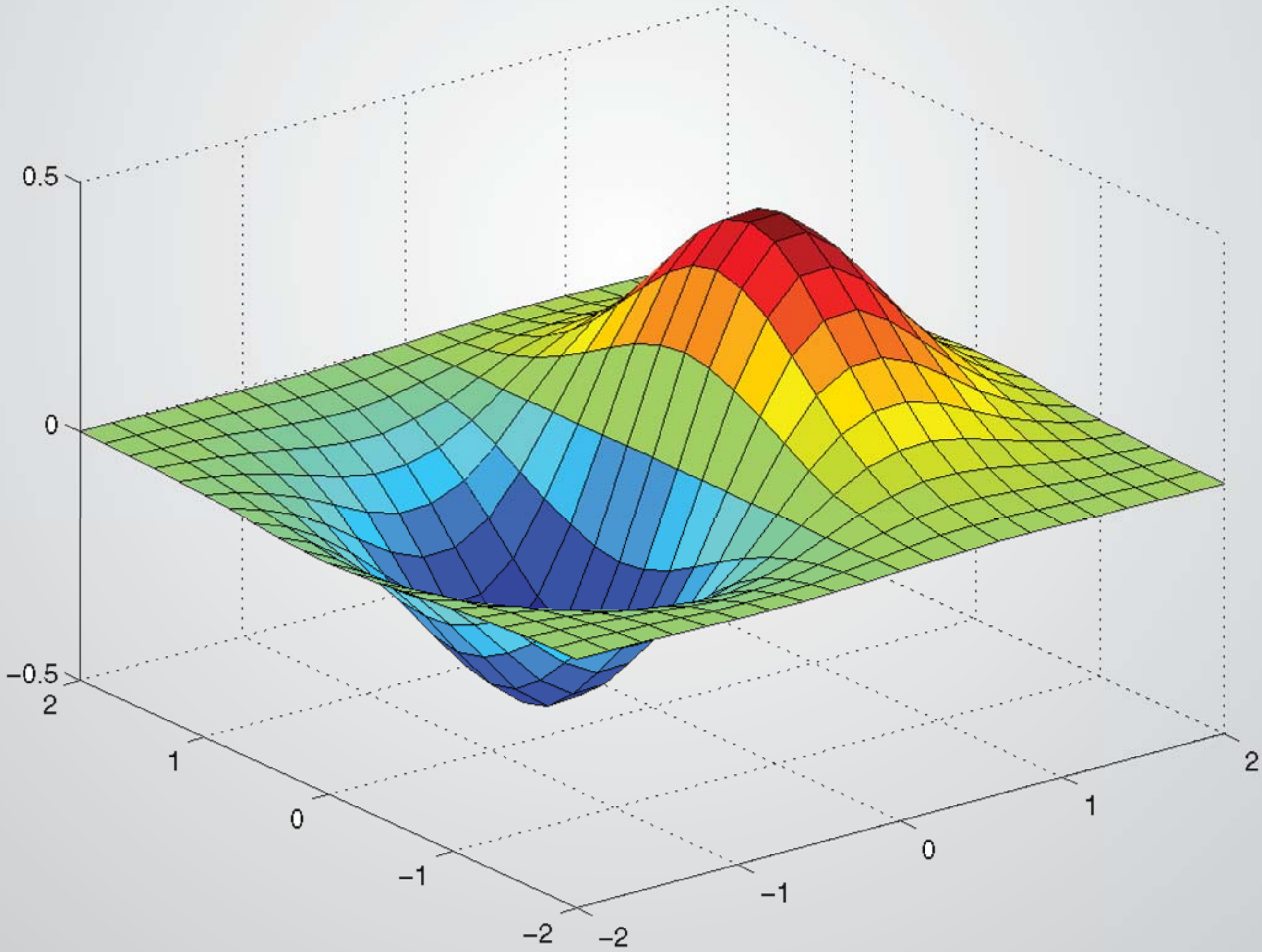

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ANALYSIS OF VARIANTS OF SOLID FUEL PRODUCTION FROM SUGAR INDUSTRY WASTE AND CONDITIONS NEEDED FOR ITS BURNING

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Abstract: *The use of alternative fuel and energy resources should be considered as the strategic approach to solving energy issues of Ukraine's economy. Currently the potential capabilities of growing sugar beet in Ukraine are twice as good as the need for sugar production support.*

On a total mass basis the major part of solid waste of sugar industry (up to 75…83 % in relation to the mass of processed sugar beet) accrues to pulp. Currently the most of pulp is not used and has to be taken to stockpiles or fields before the start of the new sugar campaign. Potentially, the amount of pulp which can be used for energy needs takes up 4,5…5 million tons per year, or in conversion to dry basis - 330…370 thousand tons. There are two possible ways of its use: use of dried pulp as secondary fuel and direct firing of pressed pulp.

Key words: sugar industry, pulp, biofuel, burning

I. Introduction

The problems of overcoming shortage of energy carriers, as well as timely energy supply have become the issues of utmost importance for the economy of Ukraine; therefore, their solving requires the search of alternative ways of energy supply. The use of alternative fuel and energy resources should be considered as the strategic approach to solving energy issues.

In Ukraine sugar beet is the only national raw material used for production of sugar, which is strategically important foodstuff for the state.

Currently, planting acreage and amount of sugar beet storage ensure sugar production volume, which is sufficient only for home market needs. It is proven by experts, that the potential capabilities of growing sugar beet in Ukraine are twice as good as the need for sugar production support.

Apart from that, sugar industry possesses excess capacity, which can be used in case of increase in sugar beet processing. That is why we believe that it would be advisable to combine sugar production from beetroots, receiving sugar-containing semi-products of bioethanol and energy production for technological needs from excess pulp [2, 7].

While working sugar beets into bioethanol several problems may arise, which are connected with comparatively short beetroot processing period (1…3 months), as sugar beets must not be subjected to long-term storage, they quickly rot and lose sugar. Thus, it becomes necessary to search for the ways of organization of bioethanol production using such semi-products of sugar production, which may be stored for a long time, as well as are economically attractive, that is provide an opportunity to receive the maximum amount of bioethanol.

II. Research materials and methods

The subject of research is the sugar-containing semi-product, its production technology and potential use for bioethanol production. Use of industrial waste for solid fuel generation.

The task of the paper is research of manufacturing schemes of receiving bioethanol from semi-products of sugar industry, solid fuel from industrial waste and expedience of their use as sources of alternative energy.

In the paper we used systems analysis method and informational approach.

III. Results and discussion

Balance of solid organic waste of sugar refinery.

On a total mass basis the major part of solid waste of sugar industry (up to 75…83 % in relation to the mass of processed sugar beet) accrues to pulp. Part of pulp is given to feed cattle in the form of fresh, sour or dried pulp. Dried granular pulp is for the most part exported, at that its price, depending on season and financial conditions, runs up to 100…150 € per ton.

Currently, the most of pulp is not used and has to be taken to stockpiles or fields before the start of the new sugar campaign. This leads to environmental pollution and worsens land fertility.

Potentially, the amount of pulp which can be used for energy needs takes up 4,5…5 million tons per year, or in conversion to dry basis - 330…370 thousand tons.

Solid organic waste of sugar industry also includes trapped beet tops and beetroot waste products (beetroot ends, small slices of beetroots), which amount to 5…8 % of beetroot mass. All this biomass is transported to dump pit. Its amount in sugar refineries of Ukraine amounts in total weight up to 600…900 thousands of tons, or in terms of dry matter – 50…75 thousands of tons per year.

The amount of filtration deposit amounts to 3…3,5% of beetroot mass. Dry matter of filtration deposit consists of noncombustible part – $CaCO_3$, which comprises more than ¾ of the deposit; the rest of dry matter of filtration deposit is organic substance. Organic substances in filtration deposit amount to 50…60 thousands of tons. But in the most sugar refineries of Ukraine filtration deposit is pumped out in the form of aqueous suspension to the filter fields. Nowadays only about 8…10 % of deposit is received from the press-filter, and it can be removed in dry form (it contains 60…70 % of dry matter).

There are also up to 10…15 thousands of tons of coal screenings in sugar refineries, which form during preparation of fuel for limestone annealing in shaft furnaces.

The total theoretical balance of secondary fuel in sugar refineries of Ukraine (on condition that seasonal production volume amounts to 13 million of tons of beetroots) is presented in table 1.

Table 1. *The balance of secondary fuel in sugar refineries of Ukraine*

The kind of source of fuel and energy resource	Wet weight, thou of tons	Content of dry matter, thou of tons	Thermal value for RM, kcal/kg	Theoretical amount of eq. fuel, thou of tons
Pulp	9600–10400	730–1050	3000	156–169
Beet tops	600–1040	48–83	2900	20–22
Filtration deposit	300–330	300–330	2500	2,7–2,9
Coal screenings	13,4–14,6	13,4–14,6	5800	11,1–12,1
TOTAL	10513–11780	1090–1210	—	190–206

On the basis of the balance, given in the table 1, the use of potential theoretical reserves of solid fuel from waste of sugar industry for conditions of Ukrainian sugar refineries may reduce the contemporary level of fuel consumption for sugar production by quarter.

But at the same time all these kinds of secondary solid fuel, apart from screenings of coal, contain considerable amount of moisture, which makes it harder to use them as solid fuel. In their initial state, they are more suitable for processing using biochemical methods.

Filtration deposit in respect to its potential as fuel is not very promising, but with further introduction of press-filters it would be more expedient to use it in agrotechnology in order to increase alkalinity and fertility of land.

Pulp pressing is widely used in the process of improvement of technology and heating engineering of sugar production. Lately in the sugar refineries of Ukraine has begun the introduction of presses with profound degree of compaction of pulp – up to 24…30 % of dry matter.

Introduction of such presses is caused by the opportunity to dramatically increase the amount of pump-down of diffusion juice (to the level of 100…110 % with respect to the mass of sugar beets) with the same normative amount of sugar loss in pulp. This arrangement makes it possible to decrease fuel consumption for technological needs of sugar production to 8…20 %. At the same time, profound compaction of pulp makes specific fuel consumption for pulp drying 1,5…2,5 times less.

Obviously, in the near future, profound degree of compaction of pulp will be introduced in the vast majority of working sugar refineries of Ukraine. It can also positively influence the opportunity of using pulp as the secondary kind of solid fuel for sugar production. There are two possible ways of its use.

On the basis of the information, given above, we are going to define and analyze both ways of use of pressed pulp.

The ways of receiving energy from biomass.

The process of burning of fuels is rather complicated, and in order to describe it one should be expert in the field of physical chemistry and chemical kinetics in particular, fluid mechanics and applied mathematics, especially possess some knowledge about heat and mass transfer.

Complexity of quantitative description of the process of biomass burning depends mostly on its heterogeneity. One should pay attention to the fact, that in normal state potentially combustible components of biomass are solid, organic substances, which decompose during burning. Consequently, forms a mixture of combustible volatile substances and coaly mass. Volatile substances burn in gas stream, and coaly mass, as a rule, burns on grates. Thus, these two ways of burning have different chemical mechanism and kinetics [3, 4].

In general, burning of biofuel is in principle described by chemical equation:

$$C_xH_yO_z + \left[x + \frac{y}{4} - \frac{z}{2}\right]O_2 \rightarrow xCO_2 + \frac{y}{2} \cdot H_2O. \quad (1)$$

In it, after complete combustion of organic substances form carbon dioxide and water, which are not dangerous for environment, whereas after partial combustion form carbonaceous and cindery volatile particles, smoke, resinous aerosol, as well as foul and noxious gases with carbonyl compounds and carbon monoxide.

Phytogenic biomass, which includes also beetroot pulp, usually contains absorbed and condensed moisture, different types of organic and some inorganic compounds. The content of biomass depends on its origin [1].

For plant tissue presence of cellulose and big hollows (vacuoles) in the walls is typical. Protoplasm of living cells, for instance, green leaves, contains some proteins and considerable amount of water. Wood or xylem of higher plants consists of vascular elements of tracheid, grains of strengthening tissue (libriform) and parenchymal cells.

Moisture content.

Cells of strengthening tissue may contain considerable amount of moisture – both condensed and absorbed, the amount of which depends on humidity of environment.

100 kg of dry matter of fresh pulp contain about 20 kg of cellulose, 30…35 kg of hemicellulose, approximately the same amount of pectin, 8…10 kg of proteins, 2…3 kg of sugar and up to 2 kg of mineral substances.

Thus, the main combustible part of pulp is cellulose (hemicellulose); it contains also other combustible organic substances, i. e. sugar. Theoretical heating value of cellulose amounts to 3465 kcal/kg of dry matter. Heating value for dry matter of sugar amounts to 3607 kcal/kg.

In general, heating value for dry pulp has to be between 3300 – 3500 kcal/kg, which is practically the same as the heating value of dry peat or low-quality brown coal. But while burning pulp in real-life environment, one should take into account the influence of humidity, which may considerably decrease its heating value, probably, make it several times less.

Pyrolysis and combustion value of biomass.

During the burning of biomass, it decomposes, and this process is accompanied by further oxidizing of disintegration products. As a rule, this process proceeds the same way as pyrolysis of biomass components does [1, 6].

Progressively as biomass gets warmer in combustion chamber or another type of furnace, it decomposes: volatile substances escape and remains coaly substance which contains a large amount of mineral substances. Volatile substances contain CO, CO_2, some hydrocarbons and H_2. The parts of volatile substances, that condense, contain water and such low-molecular compounds as aldehydes, acids, ketones and alcohols. Resinous fraction contains high-molecular sugars, furan derivatives and phenol compounds.

Amount of forming volatile substances and condensing residual, as well as their evaporation efficiency are measured using thermogravimetric method; change of enthalpy ΔI – with the help of the method of thermal differential analysis or scanning calorimetry (thermal analysis). These methods can be used to measure energy needed for drainage, distillation, pyrolysis and heating of biomass before burning (heat, which is used before burning). Energy, generated as a result of complete combustion of disintegration products, is measured using calorimetric method. Discharged energy can be also measured during the process of pyrolysis and burning as function of time or temperature.

Combustion value of plant biomass of different types and its component is given in the table 2, combustion value of pyrolysis products of biomass – in table 3 [1].

Table 2 *Combustion value of plant biomass*

Substance	$Q^p_в$, kcal/g	Coaly substance		Combustible volatile substances	
		Efficiency, %	$Q^p_в$. kcal/g	Efficiency, %	$Q^p_в$. kcal/g
Cellulose	4143	14,9	7052	85,1	3634
Lignin	6371	59,0	7416	41,0	4867
Wood (poplar)	4618	21,7	7124	78,3	3923
Pine-trees	5120	41,8	7044	58,2	3738
Asp (dry leaves)	5034	37,8	6344	62,2	4238

Table 3 *Combustion value of pyrolysis products of biomass*

Substance	Coaly substance, kcal/g	Combustible volatile substances, kcal/g	Total, kcal/g
Cellulose	1050	3093	4143
Lignin	4375	1995	6370
Wood (poplar)	1546	3072	4618
Pine-trees	2438	2708	5146
Asp (dry leaves)	2398	2636	5034

Combustion values of different types of biomass fuels are closely connected with amount of oxygen, needed for their burning. Approximately per every gram of oxygen during burning discharge about 3,349 kcal of heat energy [5]. Thus, combustion value is determined by the level of fuel oxidation. Combustion value of raw materials and pyrolysis products for biomass fuels of the same type is determined by the carbon content.

Relation between combustion value of different types of biomass fuels, products of biomass pyrolysis (coaly and volatile substances) and carbon content in them can be described with the help of equation:

$$Q_{в}^{р}\ (\text{kcal/g}) = 94{,}19\ (C\%) + 55{,}01, \qquad (2)$$

which is absolutely acceptable, since oxygen is used mainly to oxidize carbon.

Thermal decomposition of cellulose and hemicellulose involve complicated reactions, which result in forming intermediate products. These reactions may proceed either at the same time, or sequentially, and they can be classified in the following way [1, 7]:

– at temperatures lower than 300°C cellulose pyrolysis in the air or inert atmosphere is followed by such processes, as forming of free radicals, removal of water, depolymerization, forming of compounds with carbonyl and carboxyl groups, CO and CO_2, which results in precipitation of carbonized sediment;

– at temperatures 300…450°C glycosidic linkage of polysaccharides disintegrates, which is followed by forming of one free hydroxyl group in a mixture of levoglucosan and other cellulose derivatives and oligosaccharides. This mixture is usually called resinous fraction;

– at temperature 300–450°C or higher as a result of dehydration, rearrangement and disintegration of sugars form different carbonyl compounds, such as acetaldehyde, glyoxal and acrolein, which easily evaporate.

At high temperatures and little seize of particles of raw material proceeds the process of gasification and at low temperatures and large seize of particles as well as presence of moisture and inorganic substances in raw material forms coaly substance, water and CO_2.

As it was already mentioned above, in order to use pulp biomass in heat electropower station of sugar refinery, the process of its burning should be conducted with maximum possible efficiency of fuel gas [2]. In another words, it is necessary to ensure the maximum possible level of temperature (more than 500…600 C^0). To ensure the forming of synthetic gas, the part of steam which forms during the drying of pulp should be put into combustion chamber.

IV. Conclusion

Analysis of balance of solid organic waste as a source of alternative fuel for sugar refinery has shown, that the biggest source of fuel is represented by pulp. Two ways of its use is possible – as secondary fuel from dried pulp and direct burning of pressed pulp.

In order to use pulp biomass in heat electropower station of sugar refinery, the process of its burning should be conducted with maximum possible efficiency of fuel gas at level of temperature above 500 °C.

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