

REVIEW OF DOCTORAL DISSERTATION

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- Doctoral study program:** Mechanical Engineering
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- Reviewer:** prof. Ing. Roman Fekete, PhD.
- Title:** Technology and equipment for lignocellulosic waste conversion to biofuels and bioproducts with high added value

Fulfilment of the objectives of the dissertation

The work begins with an overview of existing biorefineries. The goals of the work are based on this. These are listed in chapter 4. *Objectives*. They are divided into two basic groups. *General objectives* focus on the creation of a general parametric model for biogas refineries which should be based on the principles of energy and mass balance and economy assessment. Furthermore the attention is paid to the innovative biorefinery concept with the aim of reaching investment attractions. *Specific objectives* specify these goals. They are focused on the design of brand – new biogas biorefinery with the aim to reach maximum waste conversion efficiency, creation of methodology to perform techno – economic analysis of designed paths, creation of parametric simulation and verification of design suitability for industrial application.

Some questions about the goals and their fulfilment are listed in the *Questions* section.

It is possible to state that the goals were met to the required extent.

Level of the analysis of the current status of solved problem

The analysis of the current state, within the possibilities and scope of the dissertation, is presented in chapter 2. *Critical Review* and in chapter 3. *Need for Action*. The analysis of the current state is based on 110 publications. The main principles and key operations of biorefineries and main technologies are described, as well as the influence and importance of process parameters. An overview of some patents is also presented.

Based on this information, the author continues to work with those process parameters that are important for the technical and economic assessment of individual configurations of biorefineries. For individual parameters, he made an overview of important and new knowledge, published in the literature, to the extent necessary to manage the issue.

The scope of the analysis of the current state of the biogas refinery issue corresponds to the topic of the dissertation to the necessary extent.

Theoretical contribution of the dissertation

A model study of the operation of various modifications of biorefineries and their mutual comparison was carried out, while some parameters, e.g. the prices of electricity or materials are based on market prices in the given period. It should be emphasized that the procedures used in the design of calculations are based on material and energy balances, at the parameters that are not influenced by the market. Therefore, it is possible to consider them as parameters that can be modified only by modifying the technology. However, then the implementation itself is connected to the current prices on the market in terms of investment and operating costs for technological equipment.

The theoretical contribution of the work is in the development of a methodology that will allow to compare different configurations of processes taking into account product and by-products and NPV at the end of plant lifetime through an overview table.

Practical contribution of the dissertation

The benefit of the work for practice is precisely a comprehensive view of the issue of the operation of bioplants, which is based on a theoretical analysis. Its results are applied to various, even modified, biogas plant technologies through the most important devices, which are assessed from the point of view of investment and operating costs. These are built on the expected production capacity.

It is possible to state that the procedures presented in the work will allow assessing new biogas plant concepts and comparing economic costs taking into account the current prices of raw materials, energy and technological equipment.

Suitability of the used methods of solution and the way in which they were applied

The work is based on three basic areas. The author first describes the design of technology and process set-up parameters through process flow diagrams. The next area deals with the parametric model of individual operations, such as mechanical size reduction, hydrothermal pretreatment, anaerobic fermentation, etc... The last area is focused on the economic evaluation technique.

At first the author analyzes individual areas separately and then uses them, as needed, in individual parts of the work. Their connection and the results obtained from them are evaluated in the chapter *Discussion*.

Demonstration of relevant knowledge in the field

The content, form and results of the work allow us to state that the doctoral student has demonstrated mastery of the issue. He is able to study the issue. Based on them he can formulate conclusions and provide analysis of the results and propose other procedures for solving the problem.

The doctoral student demonstrated the knowledge necessary for the preparation of a doctoral thesis in the addressed issue.

Formal level of work

The ideas are clearly formulated. It is supplemented by a number of tables and images that facilitate an overview of the given issue.

It is possible to state that the objectives of the work are met to the required extent.

The formal and graphic editing of the work is at a high level. The work is written in English.

Questions and comments

Page 2 On what basis did you modify some of the original configurations of biogas production technologies? Based on experimental experience or from the available literature?

Fig. 12 Why is the mass balance of C, N, H, S compared at the output via biogas and digestate, when the input is always a different ratio of corn silage/pig slurry and with hydrogen there is also water at the input? Is it objective?

Page 45 The „Hypothesis“ - is it your idea?

Page 45 By the term "parametric model" do you mean the mathematical relations mentioned in chapter 5.2?

Page 47 Table 7. Why is it considered only with straw? Do you have information on its availability for these purposes in terms of return on investment in technology? I mean, will there be enough of it? If not, is it possible to replace it, at least in the short time, e.g. by the wood?

Page 54 How was the energy demand model (10) created? Is it from literature? Parameter D_i are D_{out} and D_{in} ?

Page 60 The equation (35) - why is the Air surplus (+ 25%)?

Page 74 Fig.27 and the accompanying text to it – is that taken from the literature? Also *page 79* in the *Table 12*, the *Power* column is from the literature for the given technology?

Page 78 I assume that the price for concrete for a fermenter volume of 6600 m³ is recalculated through the volume to a certain thickness of the fermenter wall?

Page 116 Instead of 6.1 in the title should be 8.1?

Page 118 *SWOT Opportunities – Reduction CO₂ ...* I think that in terms of the ratio of the kinetics of CO₂ production and CO₂ reduction, it is questionable what the benefit will be.

Why did you choose such input data for your work, e.g. *Figure 27* wheat straw input = 0,152 kg/s?

In the work you state that wheat straw wastes are free from owned farm. Can it become a commodity? Do you have information about its price now?

Also the assumption that electricity from biogas will be sold, but purchased electricity will be used to power the equipment is interesting. Why this way?

The conclusion from the study is that actually all combinations, except for one, are irreversible in the given time interval. What about that?

What is your opinion on the use of biomass for fuel production? Do you assume that the mass after extracting substances with a higher added value would be used as biofuel?

Do you think that the use of biofuels would help significantly reduce the rate of growth of CO₂ in the atmosphere, if the mass balance and kinetics of CO₂ production by human activity and its consumption through photosynthesis are compared?

In conclusion, it must be stated that the dissertation contains a large amount of the quality work by the doctoral student. The mentioned comments are rather a topic than a critical evaluation of the work.

The content and form of the work meet the requirements for dissertations.

I recommend the dissertation for the defence. I propose to award the academic degree.

philosophiae doctor (Ph.D.)

V Bratislave 8.9.2023

prof. Ing. Roman Fekete, PhD.