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Managing environmental innovation: Case study on biorefinery concept

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Abstract

A brief report on the long path from fundamental studies to applied research, prototype development, samples testing and the construction of the commercial scale biorefinery is provided. Condensed technical and financial assessments are presented. Processing parameters were robustly analyzed in order to increase the surface area of the pyrolysis residue from different biowaste for its better subsequent utilization in the building industry. Finally, it is noted that research and innovation are the key moments to improve the overall competitiveness of firms and countries too.

Keywords: technology transfer; innovation economy; clean technologies; building engineering

Las innovaciones en el campo de la protección del medio ambiente: Un estudio de caso del concepto de las biorrefinerías

Resumen

Se presenta un breve informe que describe un largo camino desde la investigación básica, desarrollo de prototipos, análisis de muestras para construir biorrefinerías en dimensiones comerciales. Sobre la base del breve análisis tecnológico y financiero se ha llegado a las siguientes conclusiones. El entorno local para la innovación en el campo del medio ambiente es muy problemático, porque no existe suficiente calidad de la investigación aplicada, falta el capital de riesgo y la aplicación de la ley. El concepto de biorrefinería se finalmente logró poner en práctica, pero se declaró una advirtencia: si no se realiza un cambio radical, será cada vez más vulnerable la calidad de la ciencia y la competitividad.

Palabras clave: transferencia de tecnología; economía de la innovación; tecnologías limpias; ingeniería de edificación

Introduction

Competitiveness is a pillar of building industry. However, competitiveness and environmental performance have traditionally been viewed in terms of tradeoffs. The logic was that environmental improvements (internalizing the externalities of production) could be achieved only at a cost to competitiveness [1]. The nature of economic value and wealth creation has become fundamentally different not only for enterprises but also for countries. This requires not only new mindsets, but also new management and tools [2]. Technological innovation and finding of new building materials is, without doubt, the major force for change in modern society – a force of knowledge [3]. There are two basic issues about the knowledge: creating knowledge and applying knowledge. Rapid product research and development in building engineering creates significant advantages, including access to early cash flows, external visibility, legitimacy, and early market share. The higher a firm's rate of new product development, the more likely the firm is to achieve and maintain these first – mover advantages [4]. To achieve this requires groundbreaking discoveries [5]. Additionally, a functioning and agile venture capital system coupled with liquid equity markets is crucial in order to properly invest in these new technologies. Given time and financial resources, a firm can internally develop the complementary technological, manufacturing, and marketing assets needed to transform new knowledge into a commercially viable product [4]. However, by the time this has been achieved, the firm may have lost the ability to capture any first – mover advantages due to quicker competitors. Alternatively, the firm may be able to quickly gain access to complementary assets, including financing, through strategic alliances. Perspective firms should invest into manufacturing know – how, as well as financial resources. This reduces the time required to develop new products and bring them to market, thereby increasing their probability of survival and/or capturing first – mover advantages. Managing innovation is not easy or automatic [6]. It requires skills and knowledge, which are significantly different to the standard management toolkit and experience, because most management training and advice is aimed to maintain stability. As a result, most organizations either simply do not formally manage the innovation process, or manage it in an ad hoc way. From an economic perspective, science and technology can be viewed as a form of societal investment in possibilities of future technologies [3 - 11].

Hypothesis was stated whether it is possible to start a new economically feasible biorefinery concept that will turn the biowaste (represented by oats straw, wheat husks and waste from public greenery) into a solid pyrolysis residue with its with potential use in the building industry. However, the building products they need from their nature cheap materials with high surface area. To achieve economical viability of such an enterprise a robust analysis of process parameters in order to improve these parameters was carried out in a commercial scale.

Technology and Methods

The principle of the biorefinery was raised on a long – term basic research. The initial findings revealed some new properties and mechanisms of biowaste biochemical behavior in relation to different qualitative indicators of the present plant organic matter [12, 13], which was previously subjected to anaerobic fermentation. Different parts of the technology were developed gradually in recent years (see Fig. 1).

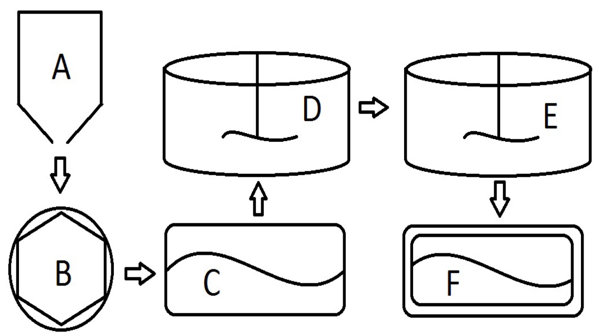

Figure 1: Technological schema of the biorefinery for production of building material from biowaste, where: A = hopper, B = under – hot – water macerator, C = high pressure steam – explosion reactor, D = reactors for enzymatic hydrolysis, E = reactor for anaerobic fermentation, F = pyrolysis chaber

The overall concept of the biorefinery is based on a different way of economically – driven utilization for each stage of plant organic matter stability [14]. The biorefinery focuses on processing of various phytomass residues: oats straw, wheat husks and waste from public greenery (for analysis see table 1).

Table 1

Biochemical analysis on the biomass input

material	volatile solids (%)	acid detergent fiber (%)	labile pool 1 of C (%)	labile pool 2 of C (%)
oats straw	88.6	26.7	24.0	19.3
wheat husks	74.3	18.9	13.6	15.7
public greenery	21.5	4.8	9.5	10.4

Such sources of lignocellulose allow reducing the cost of inputs and at the same time eliminate any ethical criticism regarding the possible threats to food sources (in comparison to purpose – grown phytomass). The philosophy of clean technology goes even further. Not only the waste materials are used, but also only the waste heat (flue gases generated in the biogas combustion engine) is used. As per usual, any process in the biorefinery does not use any hazardous reagents or rare catalysts [15]. The biotechnological partition of the lignocellulose residues in a commercial scale goes as following. The incoming material passes through the OdK-07 stone separator (PHARMIX s.r.o., Czech Republic) to be subsequently subjected to the under – hot – water maceration (15% volatile solids, 85°C, 5 minutes), which takes place in the M2 macerator (AIVOTEC s.r.o., Czech Republic), which is developed on synergy of knowledge obtained by [14-17]. The M2 macerator not only mixes the phytomas with water into pumpable mash causing fractional biological partition of the phytomass, but the material is also significantly preheated and deaerated. The deaeration, and especially the preheating results in elimination of possible pressure fluctuations in the subsequent continuous steam – explosion technology [16] where the mash is subsequently pumped by the high pressure screw pump. In brief, the continuous steam – explosion technology can be described as a strengthened metallic reactor. The reactor is equipped with a helix (which controls the hydraulic retention time, 8 minutes) and the live steam inlet (which pressurizes the lignocellulose mash by steam at 1.2 MPa). Subsequently, the lignocellulose is extruded by a rapid pressure drop (1L 0.2 s^{-1}) in the expansion tourniquet. This results in cavitation powers, which breaks the cell walls (liberating more cellulose to be subjected to further biochemical utilization). The extruded material is being pumped into the battery of continuous reactors (Fig. 2), where the enzymatic hydrolysis (operates under 55°C, 10% volatile solids, 24h hydraulic retention time with mixtures of xylanases, cellulases and β–glucosidases) takes place [17].

Figure 2: Battery of hydrolyzing reactors whose composition and activity is being precisely tailored according to the biochemical composition and level of disintegration of the substrate.

Using the custom – made funnel – shaped flocculation reactor, the (AIVOTEC s.r.o., Czech Republic) single screw drainer separated the hydrolyzed mash into the liquid and solid fraction. The liquid fraction so far undergoes rapid anaerobic fermentation in the upflow anaerobic sludge blanket reactor (45°C, 10% volatile solids). The solid fraction is pyrolysed (90% volatile solids, 410°C, 4 minutes) according to [17]. Because it is considered that the pyrolysis residue is a promising additive to building materials, the manifestations of process parameters on the specific surface area were the subject of robust analyzes (see Tab. 2).

Table 2 a (oats straw):

	A	B	C	D	E	F
I.	0.1 ± 0.0	0.3 ± 0.1	42.7 ± 9.8	45.6 ± 6.6	51.2 ± 5.0	70.3 ± 13.8
II.	0.2 ± 0.2	0.2 ± 0.1	72.0 ± 8.2	75.0 ± 9.0	79.5 ± 7.7	81.7 ± 9.5
III.	0.3 ± 0.1	0.4 ± 0.1	36.5 ± 5.0	40.1 ± 3.1	45.1 ± 10.1	51.0 ± 15.9
IV.	0.3 ± 0.0	0.3 ± 0.2	35.4 ± 3.2	72.3 ± 4.5	77.4 ± 6.4	79.1 ± 9.0
V.	0.1 ± 0.0	0.2 ± 0.1	33.0 ± 4.6	36.4 ± 7.1	39.6 ± 8.3	41.5 ± 18.3

Table 2b (wheat husks):

	A	B	C	D	E	F
I.	0.5 ± 0.4	0.7 ± 0.5	28.4 ± 4.5	35.2 ± 5.8	39.5 ± 6.4	51.3 ± 6.7
II.	0.7 ± 0.5	0.8 ± 0.4	30.2 ± 6.1	35.2 ± 3.7	39.6 ± 4.3	44.3 ± 11.6
III.	0.3 ± 0.2	0.4 ± 0.2	31.4 ± 3.3	32.1 ± 4.4	35.9 ± 7.1	42.6 ± 8.4
IV.	0.2 ± 0.1	0.5 ± 0.1	25.7 ± 4.0	31.5 ± 5.0	33.0 ± 5.1	34.0 ± 5.5
V.	0.3 ± 0.2	0.4 ± 0.2	21.1 ± 6.9	23.4 ± 5.3	29.3 ± 4.3	31.6 ± 7.9

Table 2c (public greenery):

	A	B	C	D	E	F
I.	0.2 ± 0.1	0.4 ± 0.3	17.5 ± 3.1	29.9 ± 11.0	47.6 ± 5.0	62.9 ± 9.2
II.	0.1 ± 0.0	0.3 ± 0.1	19.6 ± 5.2	31.5 ± 4.9	49.3 ± 7.7	53.0 ± 10.1
III.	0.1 ± 0.1	0.5 ± 0.1	23.0 ± 3.6	29.1 ± 7.0	30.9 ± 9.1	36.5 ± 7.3
IV.	0.2 ± 0.1	0.3 ± 0.1	16.4 ± 7.2	30.1 ± 8.1	35.7 ± 8.1	39.7 ± 8.0
V.	0.2 ± 0.1	0.2 ± 0.2	22.6 ± 8.8	26.6 ± 7.6	39.8 ± 8.0	57.1 ± 7.6

Where: I. = single point surface area at $P/P_0 = 0.2$, II. = Brauner–Emmett–Teller surface area, III. = Langmuir surface area, IV. = micropore area, V. = external surface area (all I. – IV: $m^2\ g^{-1}$), A= before processing, B = after maceration, C = after steam – explosion, D = after hydrolysis, E = after anaerobic fermentation, F = after pyrolysis (all: n = 6, α = 0.05).

Results and Discussion

As stated in the technology chapter, the given case study focuses on sustainable production of building materials. Regarding the conclusions of [11], such an area of interest is highly promising. In particular, the production of the pyrolysis residue is considered one of the most promising technologies in the field of building engineering (Lehmann and Joseph, 2009). It was also pointed out that the novelty lies in the negligible price of the building material obtained because it is made from biowaste and recuperated energy. The trials carried in a commercial scale indicate that high surface area is achievable (Tab. 2). The results indicates that the under – hot water maceration does not represent any significant increase on the surface area. However, it was proved that this pretreatment preheated and deaerated the biowaste that resulted in elimination of the pressure fluctuations in the subsequent steam – explosion high – pressure reactor. According to the expectations, the steam – explosion caused higher increase on the surface area itself (2 up to 7 tens of %). This indicates that this pretreatment was mandatory for the following enzymatic hydrolysis. The increase on the surface area carried by the enzymatic hydrolysis was not significant (usually no more than 10%), however, this pretreatment showed up to be mandatory for the subsequent anaerobic fermentation. Without the hydrolysis the biogas yields would be significantly lower (usually by one half, data not stated). The pyrolysis step increased the surface area very selectively according to the original of the biowaste material. It shows out that the acid detergent fiber and pools of labile carbon correlates with the overall surface area. It may be indicated that the rest of the biochemical parameters are less important (all: n = 6, α = 0.05).

Conclusion

The described biorefinery represents a technologically and economically interesting achievement. It was shown in a nearly – commercial scale that it is possible to turn the biowaste and into an interesting building material with negligible price. A prerequisite, however, is to remove the labile pools of carbon from the biowaste. This coule be achieved by repeated biotechnological pretreatment consisting of: 1) under – hot – water maceration, 2) steam – explosion, 3) enzymatic hydrolysis, 4) anaerobic fermentation and pyrolysis. Economical and environmental advantages are that it does not use any additional electricity, fuels, hazardous reagents or rare catalysts. Creating better conditions for the biorefineries development could positively affect the entire industrial sector, and hence the national economy.

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