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OPTIMIZATION OF OPERATIONAL PARAMETERS FOR MICROWAVE PRE-TREATING SYSTEM

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Abstract
In this study the influence of magnetron power (PM), flow rate (FR) and number of treating (NT) on biogas production was investigated using 2^3 factorial design. Pre-treating of wastewater was carried ot in a continuous flow microwave treating system. Minimum and maximum values for PM (300-700W), FR (6-25Lh^{-1}) and NT (1-5) were adopted as the base of the operation of the magnetron and the irradiation power consumption for wastewater treatment (1.5 Wg^{-1} and 2.5 Wg^{-1}) [2]. NT was observed to have the largest effect on specific energy demand (SED)

Keywords: *pre-treatment, biogas, microwave, anaerobic digestion.*

1. INTRODUCTION

Growing pressure due to growing population and increasing in general demand for water means that more wastewater treatment plants are to be expected and the ones that already exist should be increased in wastewater volume to be treated. Waste water dispensed directly into the environment without proper treatment is an impact on community well-being and the livelihood of the population. Accordingly wastewater treatment is an imperative in human ecosystems that intend to maintain a satisfactory balance between resource consumption and resource renewal. Instead of disposing and discharging waste water to the environment, it is useful to return it to the economic cycle after proper treatment. We can not only decrease water consumption, but also get other useful energy sources, in form of biogas. Anaerobic digestion is a technology can be used to treat wastewater as it reduces the pathogen content, stabilizes it requiring no oxygen or other chemicals. In addition methane is generated by the degradation of organic matter, such that in certain cases an energy surplus can be obtained.

Anaerobic degradation seems to be an obvious solution as the wastewater generated by food industry contains very high levels of organic matter. But most of the organic matter is located within the semi-rigid structured microbial cell membrane contains glycan fibres cross linked with peptide chains. It is capable to protect the cell from osmotic lyses but because of this reason cell wall is resistant to biodegradation. The increase in biodegradability is very important improvement in waste water treatment, because it results in more methane produced per mass.

Several pre-treatment techniques have been studied to improve the biodegradability, mainly by disintegrating or solubilising cell walls prior to digestion, such as mechanical disintegration by various means (ball milling, special thickening, high pressure homogenizer), thermal disintegration (heating or freezing and thawing of biomass) or chemical disintegration (acids, bases, oxidants) [1]. In some cases, a combination of more than one of the techniques was used. These studies revealed that the breakup of cell walls increases the biodegradability of the substrate and causes an increase in the rate of biodegradation.

The application of microwaves (MW) is one of the pre-treatment techniques. Additionally, it was reported that biogas production increased with the application of microwaves and that it was higher than the gas production obtained in tests subjected to the same temperature but with conventional heating, suggesting that other effects besides the thermal effect would occur when using this technique. This effect is usually called the athermal effect; however, it is not clear if this effect really exists. [4]

Materials and Methods

Meat industrial wastewater was collected in a Hungarian medium-sized meat processing company; the sampling point was after the grease tap. Sewage originates from meat processing technology, mainly from the flushing and rinsing process of equipment (slicing and packaging machines, smoking chambers). To remove grit, particles and other large-sized solids a cloth filter was used.

Table 1 Characteristics of wastewater

Parameter	**Value**
Total solid (TS) (mgL^{-1})	3210±296
Total organic carbon (TOC) (mgL^{-1})	834,1±35,3
Lipid(mgL^{-1})	115,1±21,7
Protein (mgL^{-1})	379,4±21,2

Microwave pre-treating system

Microwave pre-treating system (Fig. 1) contains a water-cooled, variable-power magnetron (M) operating at 2450 MHz. High-voltage power supply (NF power supply) feeding the magnetron consists of two transformers, one of them produces cathode heating voltage and heating current, the other produces the anode voltage which can be controlled by the primary circuit of an external auto-transformer. With this device (PM scaled TTR) the power of the magnetron can be set as well. Electromagnetic energy of the magnetron spread over a resonant slot. Getting through this slot the energy gets in the toroidal resonator. [5]. During the operation of toroid resonator energy is given to the treated material. As a result of energy transmission the temperature of the material rises and the dielectric properties change continuously. The effect of the microwave energy intake, variable power, impedance and dielectric relationships are formed in the microwave resonator. Some of these can be measured (eg. power dissipation, reflected power), some of them can only be determined by calculation, knowledge of the other parameters [6]. Material is transferred in the continues-flow microwave treating system by a peristaltic pump (PP) with variable flow.

Fermentation process, biogas measurement

Anaerobic digestion (AD) tests were carried out under controlled mesophilic temperature range (35±0,2 °C). in 12 mini continuously stirred laboratory scale reactors with 250 mL total volume, equipped with Oxitop C.

Experimental

The influence of PM, FR and NT on biogas production was investigated at maximum and minimum level, yielding a 2^3 factorial design as shown in Table 2. Minimum and maximum values for PM (300-700W), FR ($6\text{-}25Lh^{-1}$) and NT (1-5) were adopted as the base of the operation of the magnetron and the irradiation power consumption for wastewater treatment (1.5 Wg^{-1} and 2.5 Wg^{-1}) [2].

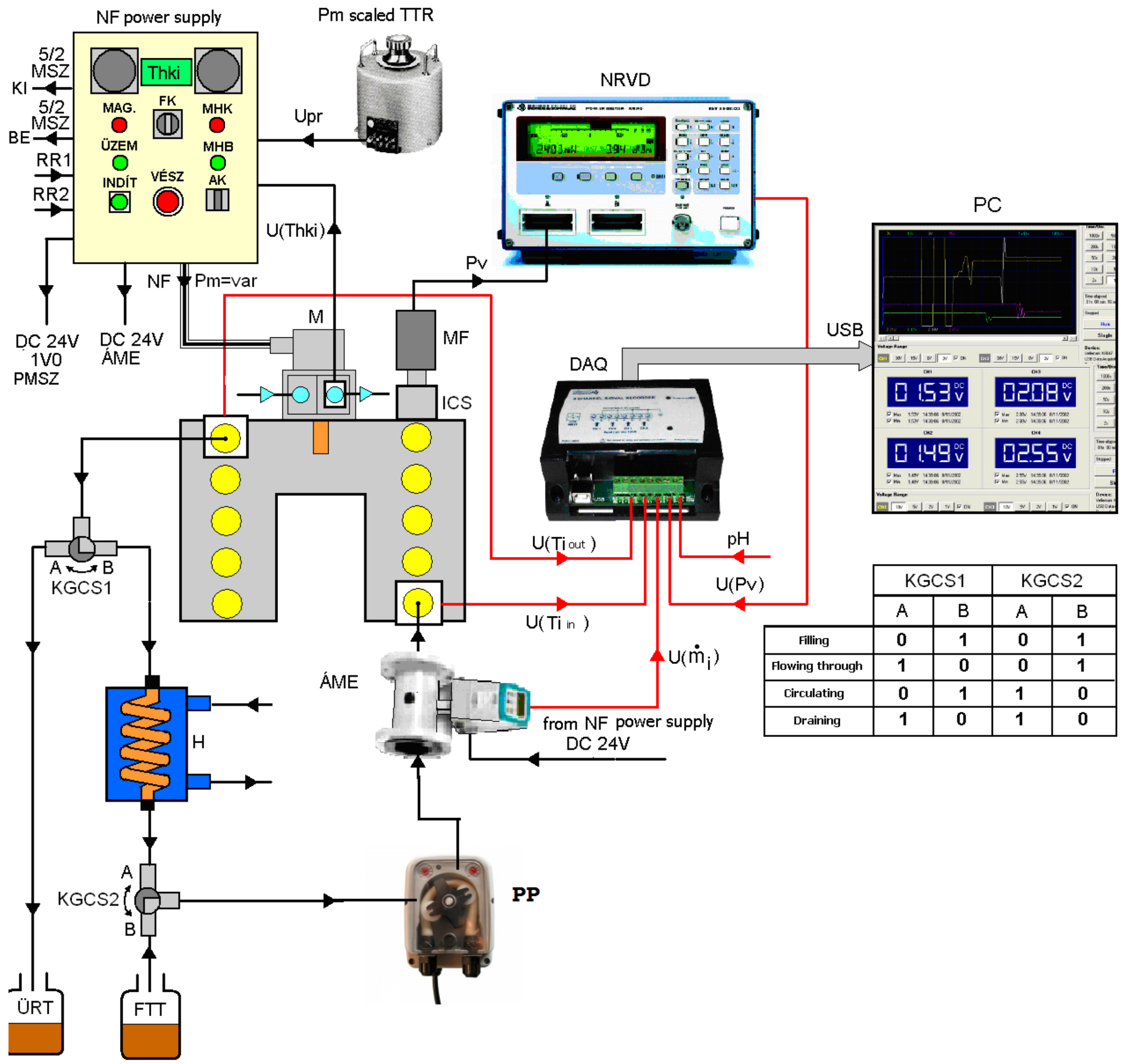

Figure 1 Microwave pre-treating system

Table 2 Assignment of operational parameters in the 2^3 factorial design

Run	**Power of the magnetron [W]**	**Flow rate [Lh^{-1}]**	**Number of treatings [db]**
1	+	+	+
2	+	+	-
3	+	-	-
4	-	+	+
5	-	-	+
6	-	+	-
7	+	-	+
8	-	-	-

3. RESULTS AND DISCUSSION

Specific energy demand

Pre-treatment conditions and accordingly energy demand were very different, therefore specific energy demand was determined. Due to the nature of the parameter, the lowest value is the best in terms of energetic.

$$SED = \frac{E}{BP} \tag{1}$$

where BP is biogas production, E is the energy demand of pre-treatments was calculated from the power of the magnetron (P_M) and the time of irradiation (t).

$$E = P_M \cdot t \tag{2}$$

In Table 3, *SED*-values for each run within the experimental design are given. Runs 5 and 6 exhibit highest and lowest SED. To define precisely the relative effect of each operating parameter, the main effects as well as the two and three factor interactions were calculated [3].

Table 2 PM, FR, NT used in the composite design and response associated

No.	PM [W]	FR [Lh^{-1}]	NT [-]	t [s]	E [J]	SED [$\frac{J}{ml}$]
1	700	25	5	360	252000	845
2	700	25	1	72	50400	183
3	700	6	1	300	210000	646
4	300	25	5	360	108000	420
5	300	6	5	1500	450000	1510
6	300	25	1	72	21600	87
7	700	6	5	1500	1050000	3125
8	300	6	1	300	90000	310

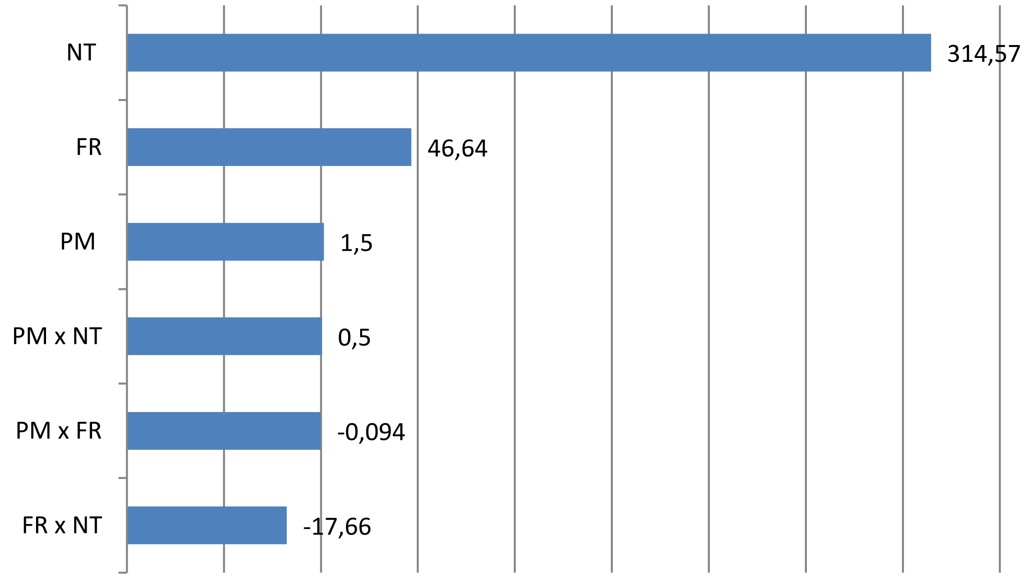

Figure 2 Main effects of the operational parameters on SED and interactions

As shown in Fig. 2, NT was observed to have the largest effect on SED.

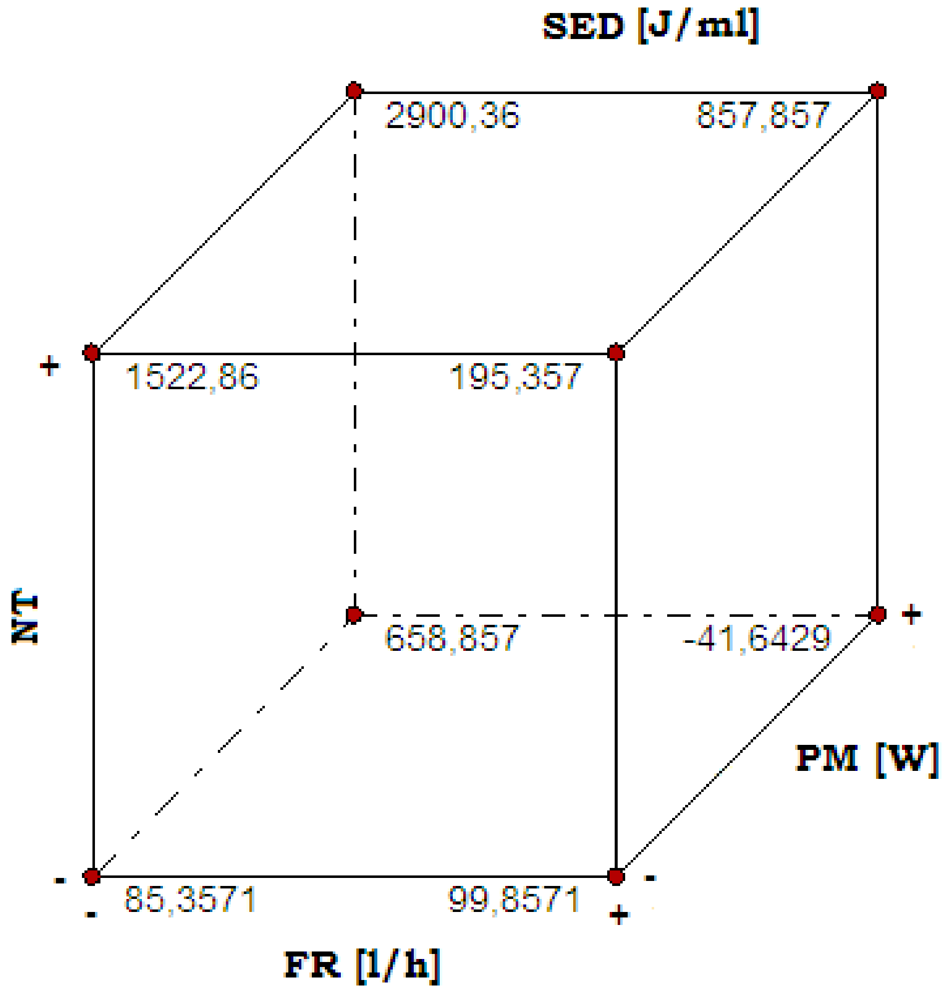

Figure 3 Main effects of the operational parameters on SED and interactions

As shown in Fig. 3, FR/PM by NT interactions evidently arise from a difference in sensitivity to NT for both operational parameters. With NT at (−), a change in FR and PM affected SED increase by 573,5 and 14,5, respectively. At high NT (+), an increase of FR or PM affected fouling decidedly stronger as a decrease in SED of 1377,5 and 700,5 , respectively has been observed.

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