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IN ANAEROBIC TREATMENT OF CHEESE WHEY MODELLING OF LACTOSE CONVERSION IN PRE-TREATMENT TANK

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ABSTRACT

The high lactose content of cheese whey adversly affects the activities of the methane archaea due to the rapid pH drop during directly treatment in the UASB reactor and cheese whey pH must be controlled first in pre-treatment tank and it would be fed to the UASB reactor at stable pH. In this study, the effects of temperature, pH and dilution ratios on lactose conversion were modeled in the pretreatment tank depending on the data obtained in the experimental conditions determined by the statistical experimental design method. In this study, lactose conversions determined by measuring lactose concentrations with DNS method at the conditions determined by the Box-Wilson experimental design method, and they were studied in 20 reactors. The obtained data was evaluated by Design Expert 7.0.0 Trial "package program. Using the obtained data in the "Design Expert 7.0.0 Trial" package program, the following model equation was obtained in the pre-treatment tank:

$Y_1 = 44,70 + 14,11*X_1 + 1,35*X_2 + 2,85*X_3 - 0,29*X_1*X_2 + 0,80*X_1X_3 - 0,13*X_2X_3 + 6,81*X_1^2 + 3,24*X_2^2 + 1,75*X_3^2$

(Y_1 = % Lactose Conversion, X_1 = Temperature, X_2 = pH, X_3 = Dilution Ratio)

In the pretreatment reactor, a model equation that gives the changes of the lactose conversion with temperature, pH and dilution ratio was developed and controlled feed conditions for the UASB reactor were determined.

Key words: Cheese whey, lactose conversion, pre-treatment reactor, UASB reactor, model equation.

INTRODUCTION

The environmental pollution and especially the water pollution are among the biggest problems of our today's world with the increasing world population, accordingly many necessities and increasing consumption rate. Necessities and rate of consumption require industrialization, industrialization increases the energy demand, and all this leads to the disposal of many wastes which are dangerous to human beings and natural life.

There is an increase in the pollution load in the food sector as well as in many other industries such as chemistry, healthcare, and textile. Milk and dairy product plants within the food sector in our country take an important place in terms of pollution load. For this reason, before discharging the generated wastes of these kind of plants to the receiving environment (water and soil) it is necessary to treat these wastes with most suitable treatment methods not to deteriorate ecological balance. 9 kg cheese whey is obtained from 1 kg cheese production. Cheese comes first among the most consumed dairy products in Turkey. Total cheese production in our country in 2014 is 638,648 tons (1). In this case, the amount of CW (cheese whey) produced is 5,747,000 tons.

Although there are many options for the evaluation of cheese whey, approximately half of the world produced cheese whey is discharged to receiving environment without any treatment. In addition to the environmental risk of any untreated raw cheese whey, even the treatment effluent of such high organic content wastewater is often fails to meet the discharge standarts. Increase in annual production of cheese whey and increasing the quality of the effluent water requirements in the legislation necessitated appropriate solutions for the treatment of these wastewaters (2).

Anaerobic digestion of cheese whey is preferred because of the more efficient and superior to other treatment methods (3). In addition, the final product obtained from the anaerobic treatment can be assessed in favor of anaerobic treatment systems. For this purpose, biogas plants are built and the final product is intended to be used economically for electricity generation and heating.

The aim of this research is to determine the optimum temperature, pH and dilution rates in the pre-treatment reactor according to the changing conditions to ensure continuity of upflow anaerobic sludge blanket reactors (UASBR) during the production of biogas from cheese whey. Due to the high lactose content of cheese whey (CW), sudden pH drops occur during anaerobic treatment. The reason for this is that acid-producing bacteria multiply faster than methane-producing archaea, and acid production reduces or even stops the activity of methane-producing archaea. Unlike known CW treatment systems, in this study; bacterial groups, called fermentative and hydrolytic bacterial strains existing in CW structure will first convert lactose and proteins in CW to lactic acid and a large part of it into soluble organic substances to give a more stable CW which will feed to Upflow Anaerobic Sludge Blanket Reactor (UASBR). Because of this, hydrolysis and acidogenic phase take place prior to the entry of the UASBR, microorganisms acclimatize to substrate more quickly in the YAÇYH (UASBR) reactor, resulting in higher effluent quality, higher COD (Chemical Oxygen Demand) removal and a good rate to methane conversion.

MATERIALS AND METHODS

As raw material, cheese whey produced as a result of cultured white cheese production obtained from AOÇ (Atatürk Orman Çiftliği) Cheese Production Facilities was used. In this study, the effects of different temperature, pH and dilution ratios on the lactose conversion in the Pre-Treatment Reactor for the Biogas Production from cheese whey in the Upflow Anaerobic Sludge Blanket Reactor (UASBR) have been determined and a statistical model for the lactose conversion to lactic acid by the whey microorganisms has been established. The Box-Wilson Experimental Design Method was applied to determine the most suitable operating conditions in the experiments (4) (Table.1). With this experimental design method, the most accurate results are obtained by reducing the number of experiments to the minimum (Table 2). In order to control the lactose removal in the cheese whey in the pretreatment tank, an experimental matrix was prepared (twenty experiments) with different pH, temperature and dilution ratios determined from preliminary studies and a model equation was obtained from these data.

The DNS method was used for lactose analysis (5). Twenty experiment results were calculated by measuring the lactose conversion in each experimental condition by the DNS method and the modeling work was completed by entering the data into the "Design Expert 7.0.0 Trial" package program. As a result, a model was developed to control the lactose removal in different conditions in the modeling study.

Table 1. Experimental design variables, levels and ranges

Independent variables	**Levels and ranges of coded and real values**				
Coded values	- 1.682	- 1	0	+1	+ 1.682
Temperature, °C	21.59	25	30	35	38.40
pH	5.79	6.2	6.8	7.4	7.81
Dilution Ratio	2.32	3	4	5	5.68

Table 2. Percent lactose conversion

Exp. No.	**Temperature (°C)**	**pH**	**Dilution Ratio**	**% Lactose Conversion**
1	35	7.4	5	76.3
2	35	7.4	3	70.6
3	35	6.2	5	73.0
4	35	6.2	3	69.0
5	25	7.4	5	47.5
6	25	7.4	3	47.2
7	25	6.2	5	45.3
8	25	6.2	3	42.2
9	38.41	6.8	4	86.1
10	21.59	6.8	4	35.02
11	30	7.81	4	52.34
12	30	5.79	4	48.6
13	30	6.8	5.68	53.9
14	30	6.8	2.32	38.6
15	30	6.8	4	48.8
16	30	6.8	4	50.52
17	30	6.8	4	42.5
18	30	6.8	4	35.3
19	30	6.8	4	46.35
20	30	6.8	4	45.9

RESULTS

The model equation for the obtained data to control the lactose conversion is given below:

$$Y_1 = 44,70 + 14,11*X_1 + 1,35*X_2 + 2,85*X_3 - 0,29*X_1*X_2 + 0,80*X_1X_3 - 0,13*X_2X_3 + 6,81*X_1^2 + 3,24*X_2^2 + 1,75*X_3^2$$

(Y_1 = % Lactose Conversion, X_1 = Temperature, X_2 = pH, X_3 = Dilution Ratio)

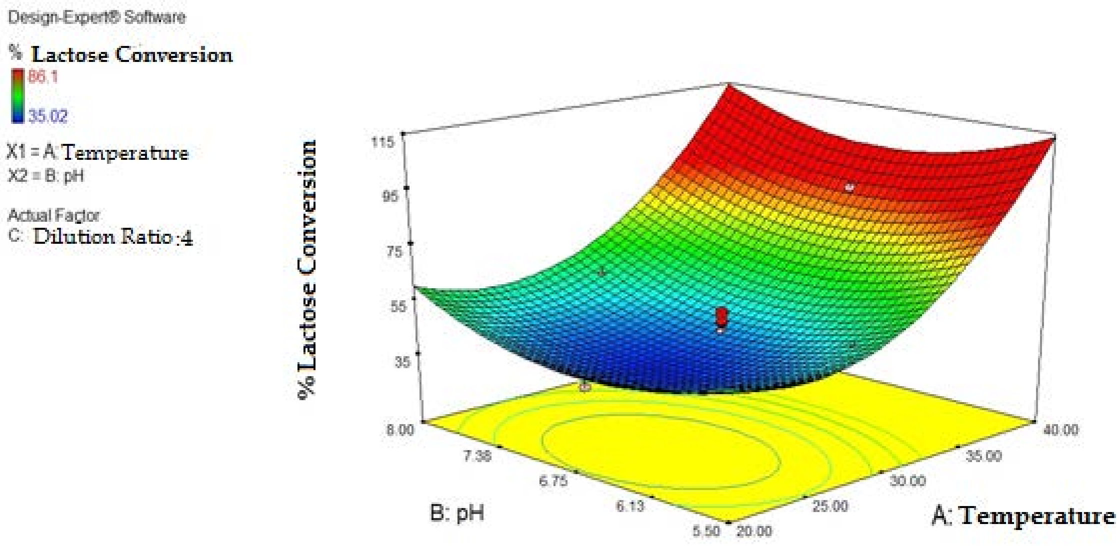

Figure.1 Effect of pH and temperature to conversion of lactose

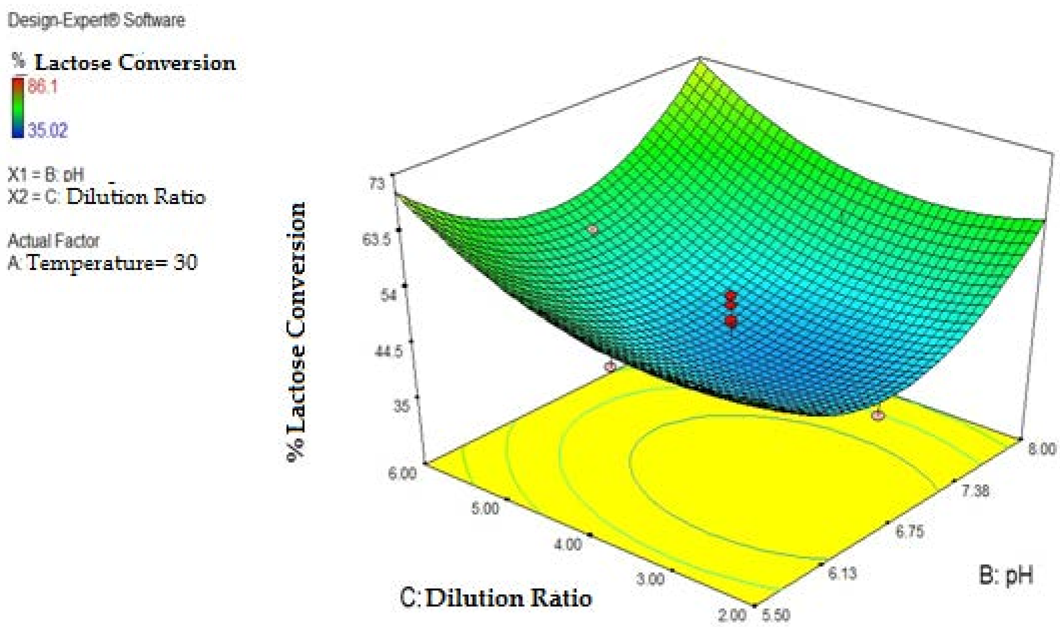

Figure.2 Effect of dilution ratio and pH on lactose conversion

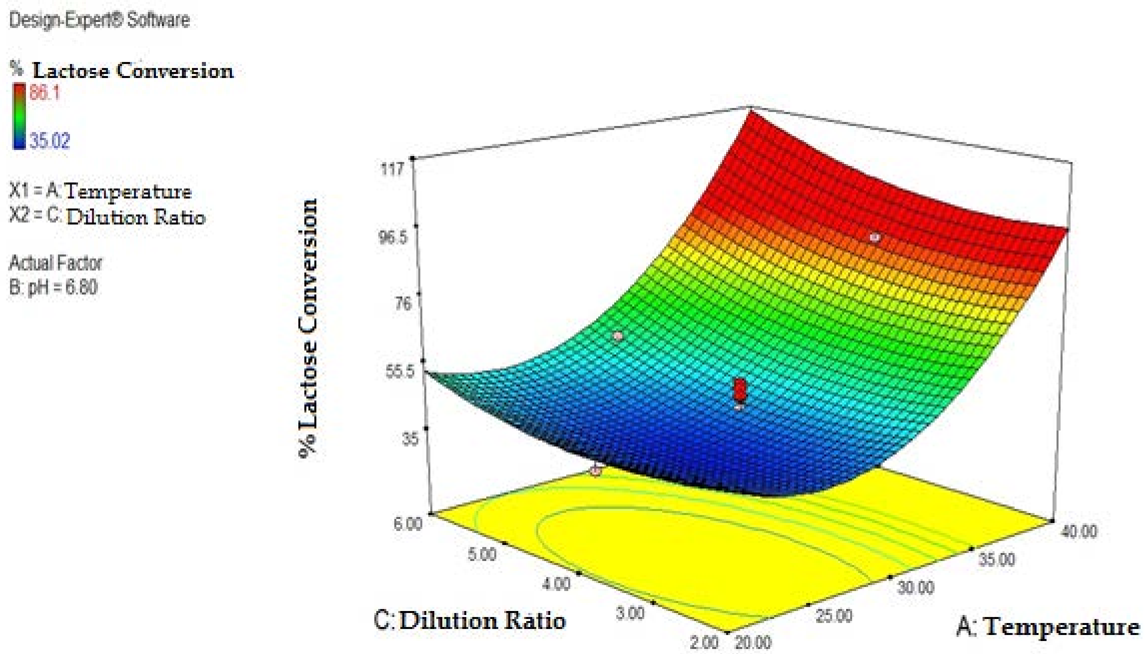

Figure.3 Effect of dilution ratio and temperature on lactose conversion

Temperature, pH and dilution ratio effects on lactose conversion can be interpreted from the obtained graphs and appropriate changes can be made to the reactor conditions. Using the model equation, the UASB reactor feed rate will be controlled and the continuity of the treatment will be ensured.

Since the study was conducted in accordance with anaerobic environment conditions; when the pH value falls below 6.5, the methane archaea is adversely affected in terms of living conditions, and the pH value exceeds 8.2, the risk of ammonia formation is negatively influence the methane archaea in the formed granules (6). Here, the conversion rate can be controlled to prevent the increasing or decreasing of the pH value.

Discussion

When we look at three-dimensional graphics, the temperature, dilution rate and pH value appear to be effective in the lactose conversion. In order to control the working conditions in the UASB reactor and to avoid the adverse conditions that may occur (Rapid lactose conversion, low level of whey or completely cut off in some periods, climatic factors, pH balance, change of organic load etc.), it is important to change the conditions in the pre-treatment tank. The effects of independent variables (temperature, pH, dilution ratio) in lactose conversion were determined and with using obtained data modelling study was completed. By changing the values of the variables in the model equation established for the pre-treatment reactor, negative changes occurring in the UASB reactor can be compensated.

CONCLUSIONS

In anaerobic treatment of cheese whey the Box-Wilson experimental design method was seen to be applicable in modeling the lactose conversion in the pre-treatment reactor which are controlled the UASB reactor feed. By the use of the model developed and the response surfaces, variation of the lactose conversion rate depending on the changes in system variables, temperature, pH and dilution ratio can be investigated and controlled.

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