Production of Volatile Fatty Acids and Kinetic Study of the Anaerobic Digestion of Cheese whey

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INTRODUCTION

Cheese whey (CW) contains lactose, fat and proteins, being a source of carbon and nitrogen. The current uses for CW include animal feeding, methane production and production of whey powder, lactose powder or protein concentrate. Anaerobic digestion (AD) has been traditionally focused on methane production. However, and due to the value of the intermediate compounds, this technology is shifting to the production of volatile fatty acids (VFA) in the frame of a circular economy approach. VFA are value added molecules with a high price in the market and they are mostly produced by transformation of petrochemicals.

The aim of this research was to evaluate the influence of pH in the production and composition of VFA using CW as substrate and to apply two kinetic models to describe the kinetics and mechanisms of VFA production.

MATERIAL AND METHODS

CW was used as a substrate and anaerobic sludge was used as inoculum. CSTRs of 1 liter with a mixture of substrate/inoculum (1:1, in volatile solids (VS) proportions) were used. Batch performance at pH 5.5 (acidic) and at pH 10 (basic), both at 38ºC. The pH was adjusting every day by using 1M NaOH and 1M HCl. The assays were carried out for 14 days.

Two types of kinetic model (First Order (**Eq. 1**) and Gompertz (**Eq. 2**)) were used to predict the maximum production of VFA.

Eq. 1) First Order Kinetic model: $$\text{VFA} = VFA_{max} \times \lfloor 1 - exp(-kt) \rfloor$$

Eq. 2) Modified Gompertz model: $$M = VFA_{max} \times exp\left\{-exp\left[\frac{VFA_p . e}{VFA_{max}}(\lambda - t) + 1\right]\right\}$$

where VFA is yield with time, VFA_{max} is the maximum VFA, k is the hydrolysis rate constant, t is time, VFA_p is maximum VFA production rate, λ is the lag phase time (days) and "e" is Euler's function equal to 2.7183. The Bayesian information criterion (BIC) test was used to compare the models and to determine the model that is more appropriate.

RESULTS AND DISCUSSION

VFA production was higher under acidic conditions than basic conditions, with a concentration of 9.11 g COD L^{-1} and 7.01 g COD L^{-1}, for pH 5.5 and 10 respectively (**Figure 1**). The highest variety of VFA was in pH 5.5, with higher concentration of propionic (2.79 g COD L^{-1}), acetic (2.58 g COD L^{-1}) and butyric acid (1.40 g COD L^{-1}).

Figure 1. VFA production and composition at pH 5.5 and pH 10 at different temperatures and pH

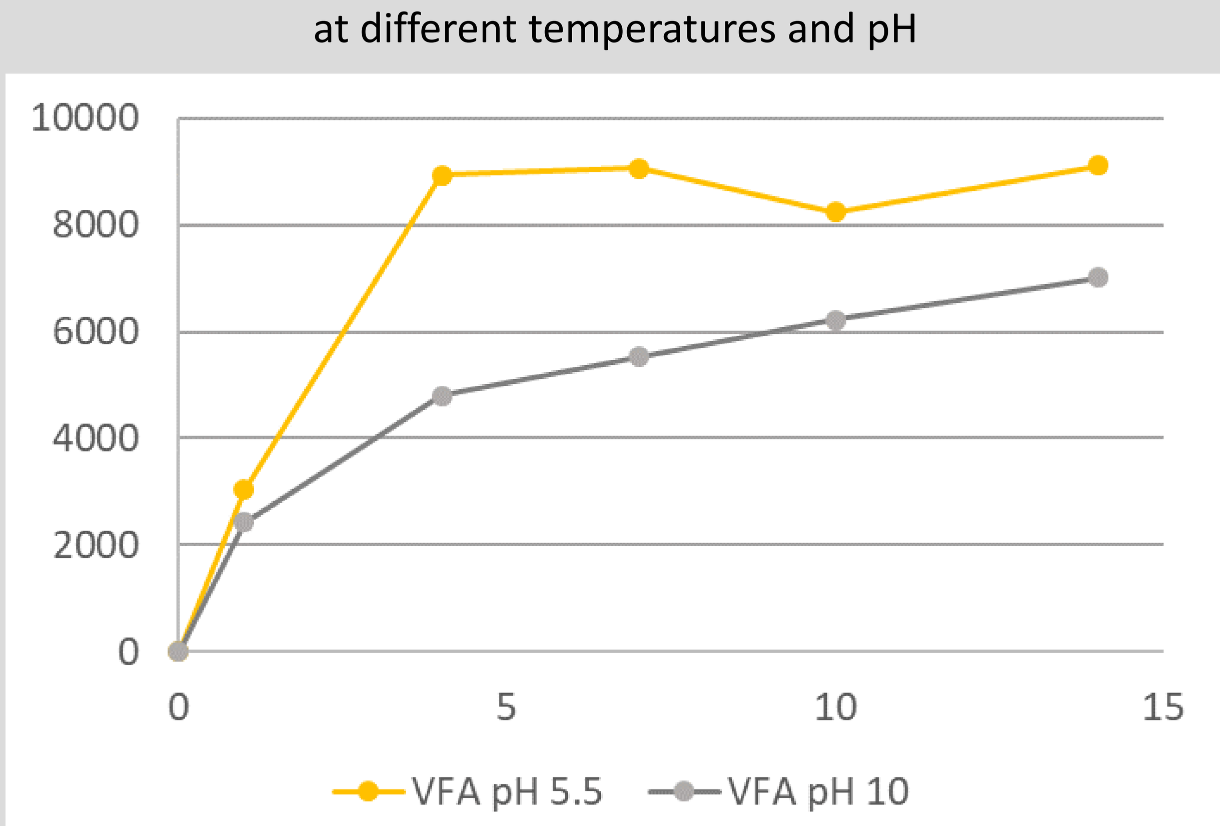
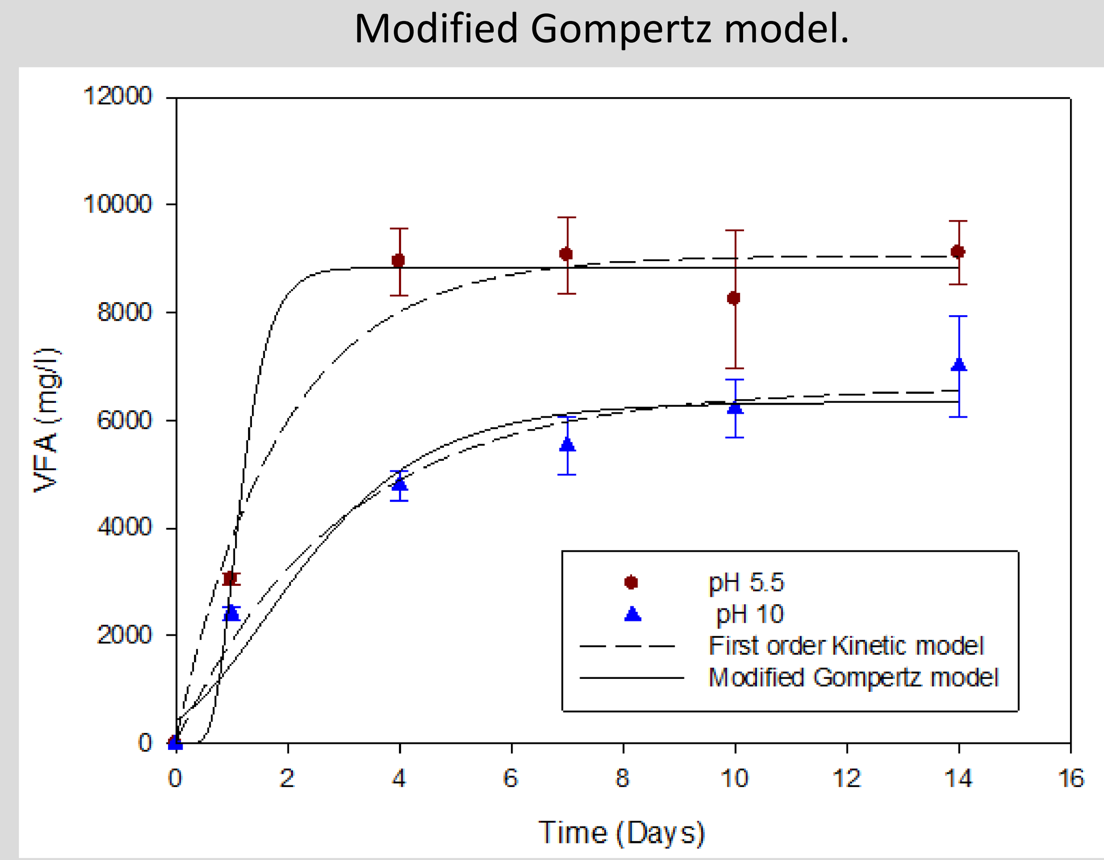


Figure 2. VFA yield from the First Order Kinetic model and Modified Gompertz model.



VFA_p is higher for pH 5.5 than pH 10, indicating that the production of VFA is faster at acidic conditions than at basic conditions. The adaptation of microorganisms and the digestion response time is expressed by the lag phase (λ). The value of λ was lower for pH 10 than for pH 5.5 indicating that there is a higher adaptability of microorganisms to produce VFA at basic conditions. High r^2 values confirm that both models fit the experimental data. According to BIC data, for pH 10 the best fit is for the First Order model and for pH 5.5 the Gompertz model.

CONCLUSIONS

- VFA production through anaerobic digestion is a sustainable way of valorization of cheese whey.
- Anaerobic digestion of whey produces up to of 9 g VFA-COD L^{-1} and 7 g VFA-COD L^{-1}, for acidic and basic pH conditions, respectively.
- First order and Gompertz kinetic models can be used to indicate the best conditions and predict the maximum production of VFA.
- The Modified Gompertz model fits better for pH 5.5 while the First Order model fits better for pH 10.

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