Optimization of food waste fermentation for the maximum production of volatile fatty acids: effect of anaerobic sludge, temperature, pH, and total solids content

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Introduction

This study focused on the maximum production of volatile fatty acids (VFAs) from food waste fermentation based on process parameter control. VFAs are a group of carboxylic acids, valuable for various applications, such as the production of eco-friendly bioplastics (Stavroula et al., 2020), and the generation of bioenergy (Tampio et al., 2019). They commonly derive from fossil fuel sources via chemical routes (Zacharof & Lovitt, 2013), but the fermentation of rich organic wastes, such as food waste (FW), is a promising process for their production, too.

FW is a well-studied organic substrate for biogas production, but there is not enough literature on the production of VFAs from it. It is the most generated type of bio-waste in the EU (Eurostat, 2020), and its disposal causes environmental pollution (Print, 2015). However, due to its abundance and great variety, it is ideal as a low-cost raw material for producing valuable substances, such VFAs (Tropea, 2022).

In this study, the sludge presence, the temperature, the pH value, and the total solids content of the fermentation reactor, were examined for the feasibility of maximum VFA production from food waste fermentation.

Materials and methods

Effect of anaerobic sludge: In mesophilic conditions (T=35^{O}C), two groups of reactors were used. The 1st group comprised four (4) batch reactors, each with a working volume of 200 ml, filled in only with food waste solution to a final TS content of 5%. No sludge was added. The pH value was adjusted to a different value per reactor: 4,6,8, and 10. The fermentation was conducted inside an incubator with integrated stirring at 100 rpm. The 2nd group comprised four (4) batch reactors, each with a working volume of 200 ml, filled in both with food waste as substrate and with anaerobic sludge as inoculum, with VS ratio of food waste to sludge equal to 1:1. In each reactor the final TS content was equal to 5%, and the pH value was adjusted to 4,6,8, and 10, respectively. The fermentation was conducted inside an incubator with integrated stirring at 100 rpm. The same experiment was also conducted in thermophilic conditions (T=55^{O}C).

Effect of pH: To evaluate the pH effect for VFA production optimization, three (3) batch reactors with a working volume of 200 ml were filled only with food waste to a final TS content equal to 5%. No sludge was added. The pH value was adjusted to a different value per reactor: 5,7, and 9. The fermentation was conducted in T=35^{O}C inside an incubator with integrated stirring at 100 rpm. The experiment was also conducted in thermophilic conditions (T=55^{O}C).

Effect of Total Solids Content: Four (4) batch reactors, each with a working volume of 200 ml, were filled in with different quantities of food waste to a final TS content of 2.5%, 5%, 7.5%, and 10%, respectively. The pH value in all the reactors was adjusted to 9 since this was proven to be the most favorable pH value for VFA production. No sludge was added to the reactors. The incubation was conducted at 35^{O}C in an incubator with stirring at 100 rpm. The experiment was also conducted in thermophilic conditions (T=55^{O}C).

Results and discussion

The maximum VFA production yield is specified as the maximum concentration of VFAs produced divided by the initial TS concentration in each reactor. From the experiments, which focused on the evaluation of the anaerobic sludge addition, it was demonstrated that the addition of anaerobic sludge improved VFA production in thermophilic conditions, but it was not proven to be beneficial at the mesophilic temperature. However, the maximum VFA production yield (g $VFAs_{max}$/g TS initial) was achieved for no sludge addition and for basic pH value. The effect of pH is quite notable in both

temperatures (35^{O}C and 55^{O}C), with the alkaline values being more favorable for VFA production. The highest yield of VFA production was achieved for pH=9, and it was equal to 25% for 35^{O}C. Anaerobic digestion is highly affected by the moisture inside the reactor (*Basic Information about Anaerobic Digestion (AD) | US EPA*, n.d.). Therefore, the total solids content is an important parameter for the process. The highest VFA production yield for a pH value equal to 9, was achieved in mesophilic conditions for TS=5%, and it was 25%. The next highest yields were achieved for TS=2.5% both in mesophilic and thermophilic conditions. Figures 1 and 2 present the maximum VFA production yields achieved for every system of pH, TS, and inoculum both in mesophilic and thermophilic conditions.

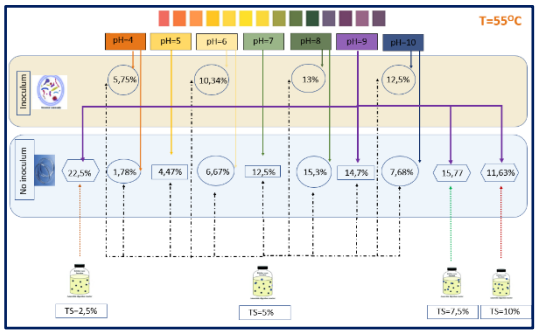


Figure 1: Maximum VFA production yields for every system of pH, TS content, and inoculum addition in mesophilic conditions

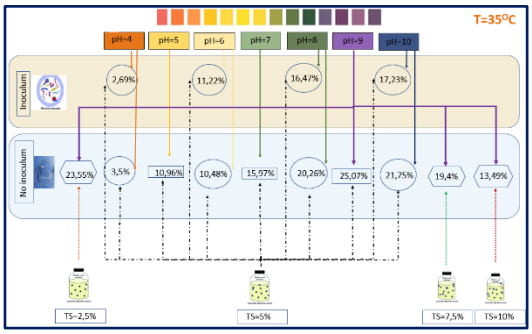
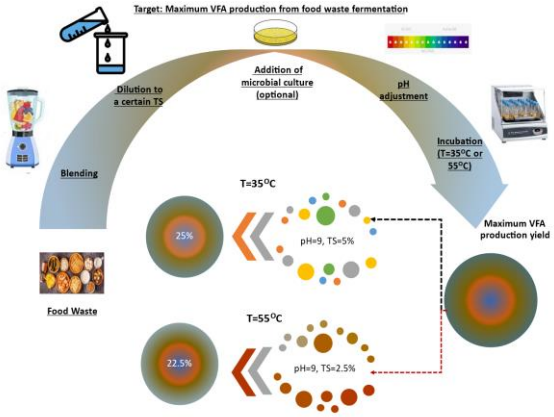


Figure 2: Maximum VFA production yields for every system of pH, TS content, and inoculum addition in thermophilic conditions

Conclusion

The temperature, the pH value, the total solids content, and the presence of anaerobic sludge as inoculum were examined for maximum VFA production in food waste fermentation. The optimum system of parameters was proven to be the following: T=35^{O}C, pH=9, TS=5%, and no addition of anaerobic sludge. For these parameters, the maximum VFA production yield was equal to 25% and was detected on the 10th day of the fermentation process. The pH condition inside the reactor is a more important factor than the rest parameters examined since any change in the pH value was associated with a large change in the VFA concentration values. The alkaline pH provided maximum VFA yields from 7% to 25%, while the corresponding range of yields for the acidic pH was from 1,5% to 11,5%.



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