VOLATILE FATTY ACID (VFA) PRODUCTION DURING FERMENTATION OF FOODWASTE FOR BIOPLASTIC PRODUCTION

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Abstract

Volatile (or short-chain) fatty acids are a family of organic compounds naturally-produced in fermentations. VFAs have a variety of uses in manufacturing, including production of biodegradable plastics. Variables that affect VFA yield include feedstock type, makeup of the microbial community, and fermentation process variables. In this bench-scale study multiple mixed batch reactors were operated in parallel to investigate VFA yield from the fermentation of peach puree. Pertinent factors in VFA production are pH, temperature, solid retention time (SRT), hydraulic retention time (HRT), organic loading rate (ORL), nutrient additives, mixing, and cycle time. The objective of this study was to assess the effect of nutrient additives during fermentation of peach puree. Six reactors with working volume of 1.5 liters each were operated at almost constant room temperature of 72-73°F for 20 days and then 60°F for 10 days. The reactors were divided into two groups of three reactors on the basis of feeding cycle. The first group of reactors was operated on a 5 day feeding cycle while the second group was operated on a 10 day feeding cycle. In each group, one reactor was operated as control (no nutrient addition), a second was operated with low nutrient addition (5 mg-NH_4^+/L) and third reactor with high nutrient addition (20 mg/L). Mass loading rate for 5- and 10-day feeding cycle were 25 g COD/L-day and 12 g COD/L-day respectively.

After 5 days of operation VFA production values from each set of reactors nearly overlapped indicating that nutrient supplementation had no discernable impact on VFA production. The reduction of TSS was also similar for all the reactors. Results also indicate that pseudo steady state response was achieved within 30 days. Typical VFA concentration at the beginning of each 5- and 10-day feeding cycle was near 2,000 mg/L and typical values near the end of each 5-day and 10-day feeding cycle were near 4,000 mg/L and 7,800 mg/L, respectively, indicating that a significant amount of VFA mass was produced. At 10°F drop on Day 20 did not appear to affect the VFA production significantly. pH was 4 for the first 5 days then remained constant near 3 for the remainder of the study period.

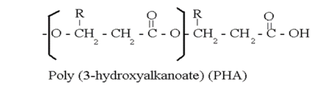
Introduction

The disposal of biodegradable solid wastes like food wastes creates serious environmental and economic challenges almost everywhere in the world.

The research in development for managing food wastes led to the idea of converting this material to valuable products such as bioplastic.

Food wastes have the potential to generate energy due to their high organic composition and readily biodegradable nature (Lim et al. 2000). This energy can be used to make VFAs and VFAs derived from acidogenesis of waste organic matter are highly suitable substrates for PHA production (Hong and Haiyun 2010).

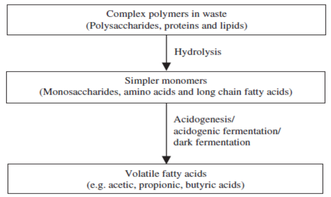
PHAs are bioplastics. Their properties are similar to many petroleum based thermoplastics and elastomeric materials. But unlike most petroleum plastics, PHAs are sustainable, biodegradable and biocompatible



Poly (3-hydroxyalkanoate) (PHA)

R = CH3, Poly(3 hydroxybutyrate)
R = CH2-CH3, Poly(3-hydroxyvalerate)

General Structure of PHA (Solaiman et al. 2006)



Production of VFAs from waste (Lee et al. 2014)

Objectives

Objectives for current research are as follows:

1. Assess the effects of nutrient additives on the VFA production during fermentation of peach puree.
2. Determine if a pseudo-steady state condition can be achieved during the 30 day study period.

Inoculum & Feedstock

The seed sludge was obtained 15 days before the startup from a peach processing facility.
One liter of seed sludge was then diluted by adding 0.5 liters of water and mixed with one-half liters of peach puree to make 2 liters of inoculum. Every other day 20% (0.4 liters) of inoculum was decanted and the same volume of peach puree added. Fresh peach puree was obtained before start up and was stored in fridge for future purposes.

Characteristics of peach puree and inoculum

Date	Sample	VFA (mg/l)	pH	sCOD (mg/l)	tCOD (mg/L)	TSS (mg/l)	VSS (mg/l)	TS (mg/l)	P (mg/l)	NH_4^+ (mg/l)
11/15/2013	Peach Puree	1091	3	78640	-	148700	2000	168700	28	-
11/15/2013	Inoculum	1497	4	99500	-	56200	2200	56600	17	-
12/10/2013	Peach Puree	880	3	103600	185800	-	-	-	20	4

Method

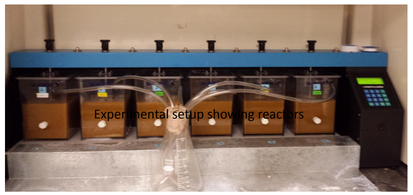
Six mixed batch reactors of working volume of 1.5 liters were utilized. The first 3 were operated in 5 day feeding cycle and the other 3 in 10 day feeding cycle

In each reactor, 80% peach puree (1.2 liters) and 20% seed sludge (0.3 liters) were mixed before startup.

At the end of each feeding cycles, 80% of the reactor volume was decanted and the filled back with 1.2 liters of peach puree.

Among three reactors in each feeding cycle, first reactor was used as control (no nutrient additives) while second reactor was operated with low nutrient additives and third reactor with high nutrient additives.

The reactors were operated in mixed batch mode for 30 days .



Experimental setup showing reactors

Method

The concentration of soluble Chemical Oxygen Demand (COD), VFA, TSS, VSS, TS, VS, pH, Ammonia and Phosphorous were regularly measured.

The mixer blade rotated continually at a speed of 120 rpm. Temperature ranged from 58˚F to 72˚F.
Hydraulic retention time (HRT) was equal to solid retention time (SRT).

The mixer speed was increased to 300 rpm for 3 minutes before collecting samples.

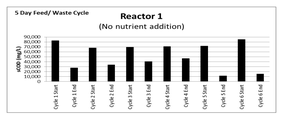
The experimental data obtained were hand-written in a lab journal notebook then transferred to Microsoft Excel 2013 and analyzed.

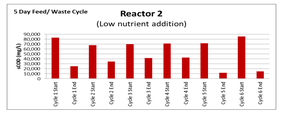
Operational parameters for the experiment

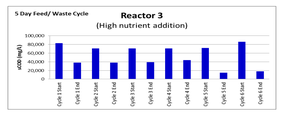
Parameter	Reactor					
	1 ($C1^a$)	2	3	4 ($C2^b$)	5	6
Feedstock Source: Wowona Frozen	Peach Puree	Peach Puree	Peach Puree	Peach Puree	Peach Puree	Peach Puree
Feed Frequency (days)	5	5	5	10	10	10
Feed Solids Target (% w/w)	As is	As is	As is	As is	As is	As is
Dilution Factor for Feed	0	0	0	0	0	0
Nutrient Addition (mg-N/L^c)	0	20	80	0	20	80
Solids Retained at Decant (%)	20	20	20	20	20	20
Solid Retention Time /Hydraulic Retention Time (days)	6.25	6.25	6.25	12.5	12.5	12.5
Feed Loading Rate (Kg/day)	0.16	0.16	0.16	0.08	0.08	0.08
Mixer Speed (determined at start up)	120	120	120	120	120	120

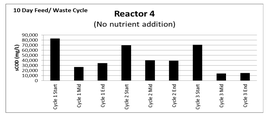
[a] Control for the 5-day feed frequency reactors (R1, R2, R3)
[b] Control for the 10-day feed cycle reactors (R4, R5, R6)
[c] A mix of nutrients are added, but nutrient dosing is based on amount of nitrogen added. Dosing calculation is stated in Appendix I.

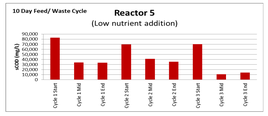
Result

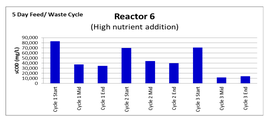






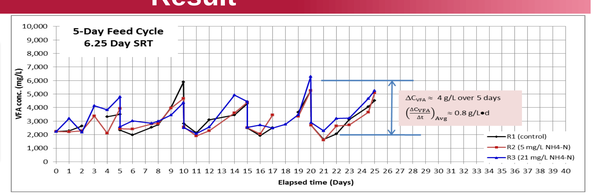




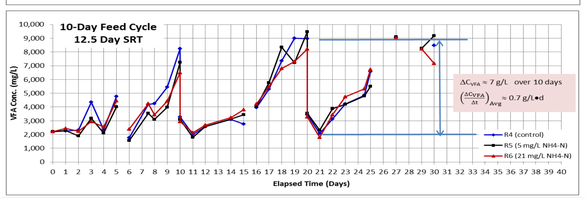


Result

5-day feeding cycle	
HRT/SRT:	6.25 days
Loading rate:	37.2 g/L-day of tCOD
Nutrient addition:	High
Experiment elapsed time:	20 days
Temperature:	72˚F
Results:	
VFA concentration (max):	6,297 mg/L
VFA production rate:	0.8 g/L-day
pH:	3



10-day feeding cycle	
HRT/SRT:	12.5 days
Loading rate:	18.6 g/L-day of tCOD
Nutrient addition:	Low
Temperature:	72˚F
Experiment elapsed time:	20 days
Results:	
VFA concentration (max):	9,462 mg/L
VFA production rate:	0.7 g/L-day
pH:	3



Conclusion

A significant reduction in COD (puree mass) was observed as peach flesh was converted into acids and gas. This reduction inCOD is very important because it translates into savings on industry waste disposal fees.

Added nutrients had very little or no impact on the production of VFAs. Significant amount of cost can be reduced if nutrient addition can be avoided.

VFA, pH and TSS/TS response pattern from one feeding cycle to the next in both 5- and 10-day feeding cycles days of the experiment suggest that steady state may have been achieved by 30 days.

The maximum VFA concentration obtained in this study (18,200 mg/L) observed was almost similar (19200 mg/L by Hong and Haiyun 2010).

pH was at a low value (3) relative to values found in previous studies in which similar feedstock was used (pH 5.5-7).

Acknowledgements/ References

Acknowledgements

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