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AGRICULTURE • INNOVATION • LIFE

UTILIZATION OF FOOD WASTE FOR BIOACIDS, BIOPLASTICS AND BIOFUEL PRODUCTION

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FACULTY OF BIOTECHNOLOGY AND BIOMOLECULAR SCIENCES

At present, poor solid waste management become the prime environmental problem in Malaysia.

Over the past 10 years, generation of Malaysia MSW has increased more than 91% (Periathamby et al, 2009).

The highest average generation rate per capita of MSW was reported in Penang at 1.1 kg/capita/day

MSW generated in Kuala Lumpur for 1998-2005

Year	population	tons/day
1998	1 446 803	2257
2000	1 787 000	3070
2005	2 150 000	3478

(Saeed et al., 2009)

The composition of waste (percentage of wet weight) in Malaysia for 1975-2005

	1975	1980	1985	1990	1995	2000	2005
Organic	63.7	54.4	48.3	48.4	45.7	43.2	44.8
Paper	7.0	8.0	23.6	8.9	9.0	23.7	16.0
Plastic	2.5	0.4	9.4	3.0	3.9	11.2	15.0
Glass	2.5	0.4	4.0	3.0	3.9	3.2	3.0
Metal	6.4	2.2	5.9	4.6	5.1	4.2	3.3
Textiles	1.3	2.2	NA	NA	2.1	1.5	2.8
Wood	6.5	1.8	NA	NA	NA	0.7	6.7
Others	0.9	0.3	8.8	32.1	4.3	12.3	8.4

(Saeed et al, 2009)

PROBLEMS AND CHALLENGES

- ***Public Awareness***
- ***Environmental Education***
- ***Technical Skills***

Waste treatment method practised in Malaysia

	2002	*2006*	*est. 2020*
Recycling	5.0	5.5	22.0
Composting	0.0	1.0	8.0
Incineration	0.0	0.0	16.8
Inert landfill	0.0	3.2	9.1
Sanitary landfill	5.0	30.9	44.1
Other disposal sites	90.0	59.4	0.0
Total	**100.0**	**100.0**	**100.0**

(Periathamby et al, 2009)

The most advance sanitary landfill in Malaysia

(Bukit Tagar Sanitary Landfill)

The Stake Holders

KUB-Berjaya Enviro Sdn. Bhd. (KBE)

Joint-venture company between KUB Malaysia Berhad and Berjaya Corporation Berhad

Location

Approximately 50Km north of Kuala Lumpur

Developed on 700 acres land area

1,000 acres of buffer zone

Surrounded by palm plantation


FUTURE PROSPECT MSW MANAGEMENT IN MALAYSIA

√*Waste Recycling*

√*Energy Recovery – incineration, renewable energy*

√*Improved on landfill system*

√*Biocomposting*

(Samsudin and Mat Don, 2013)

RESEARCH PROJECT

Bioconversion of food waste for value added product

- Biogas → H_2, CH_4
- Bioacids and PHA
- Biosugar and Bioethanol

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Microbial characterization of hydrogen-producing bacteria in fermented food waste at different pH values

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ABSTRACT

An anaerobic fermentation of food waste was conducted in a 0.5 L bioreactor
a thermophilic temperature of 55 °C to evaluate the effects of different contro
(5.0, 5.5 and 6.0) on biohydrogen production. Effective biohydrogen produc
at controlled pH 5.5 and 6.0 corresponding to lower lactic acid production
5.0. It was demonstrated that biohydrogen production from food waste w
with hydrogen yields of 79, 76 and 23 mmol H_2/L-media/d for pH 5.5, 6
tively. Specific microbial determination for *Clostridium* sp. and total ba
were carried out by the fluorescent in-situ hybridization (FISH) techr
Clostridium sp. for acclimatized sludge, fermentation broth at pH 5.0, 5.5
2.9×10^8, 3.6×10^8, 7.8×10^8 and 5.4×10^8 cells/ml, respectively. The quantification analysis showed that 92% of the total bacteria belonged to *Clostridium* sp. from clusters I and XI from the sample at controlled pH 5.5. The denaturing gradient gel electrophoresis (DGGE) bands of the sample after heat-treatment, acclimatization and during fermentation indicated the presence of *Bacteroidetes*, *Caloramator australicus* sp. and *Clostridium* sp.

The Open Renewable Energy Journal, 2009, 2, 124-131

Open Access

Statistical Optimization of Biohydrogen Production Using Food Waste Under Thermophilic Conditions

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Abstract: In this study, optimization of biohydrogen production from food waste was investigated using response surface methodology. The fermentation was conducted in a serum bottle with 100 mL working volume. A Preliminary experiment showed that initial pH and temperature significantly influenced biohydrogen production. According to the central composite design, the optimal conditions for hydrogen yield were initial pH of 7.5 and temperature of 55.7°C, while the optimal conditions for hydrogen production rate were initial pH of 7.2 and temperature of 55.6°C. The maximum values for hydrogen yield and hydrogen production rate were 120 mL/g carbohydrate and 35.69 mL/h, respectively.

Keywords: Biohydrogen, hydrogen, response surface methodology, food waste.

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Review

Food waste and food processing waste for biohydrogen production: A review

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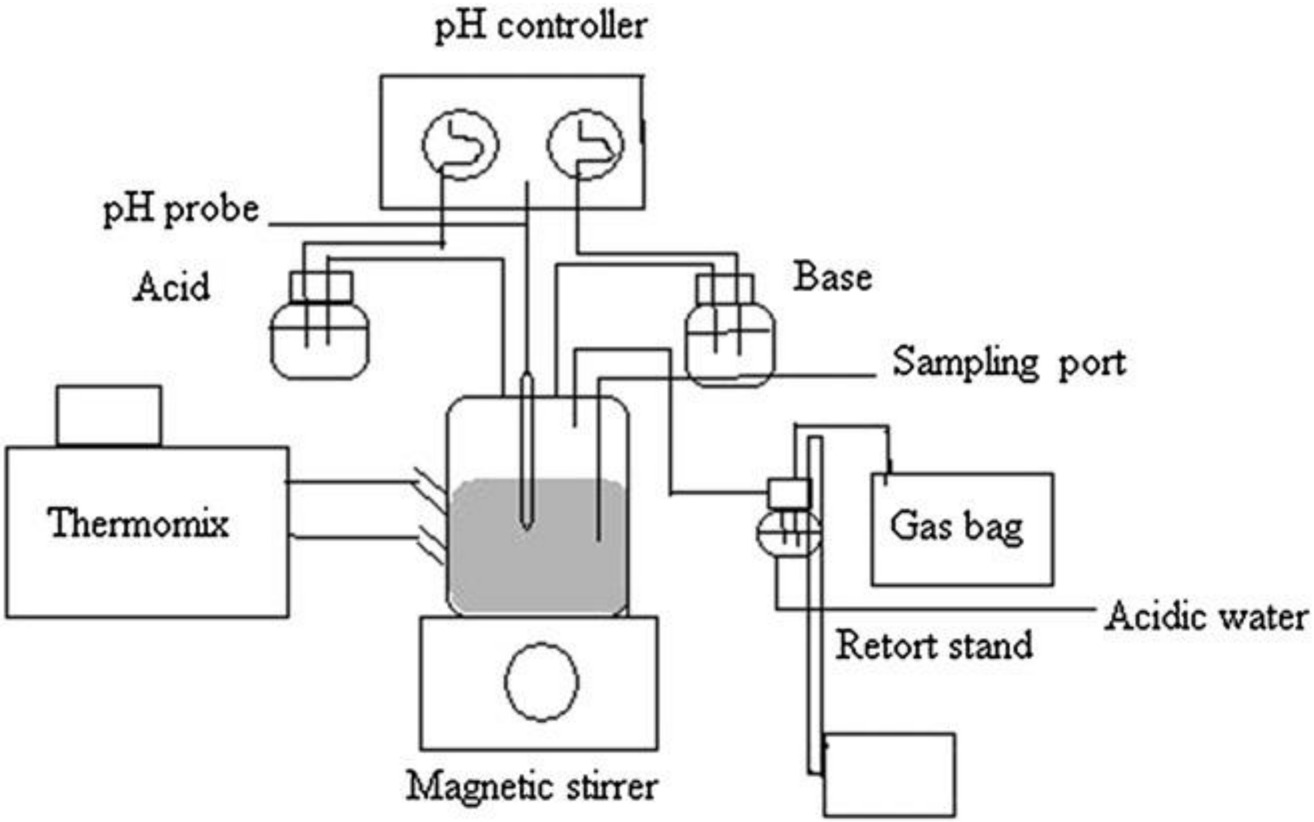
ABSTRACT

Food waste and food processing wastes which are abundant in nature and rich in carbon content can be attractive renewable substrates for sustainable biohydrogen production due to wide economic prospects in industries. Many studies utilizing common food wastes such as dining hall or restaurant waste and wastes generated from food processing industries have shown good percentages of hydrogen in gas composition, production yield and rate. The carbon composition in food waste also plays a crucial role in determining high biohydrogen yield. Physicochemical factors such as pre-treatment to seed culture, pH, temperature (mesophilic/thermophilic) and etc. are also important to ensure the dominance of hydrogen-producing bacteria in dark fermentation. This review demonstrates the potential of food waste and food processing waste for biohydrogen production and provides a brief overview of several physicochemical factors that affect biohydrogen production in dark fermentation. The economic viability of biohydrogen production from food waste is also discussed.

Characteristics of food waste used in this study

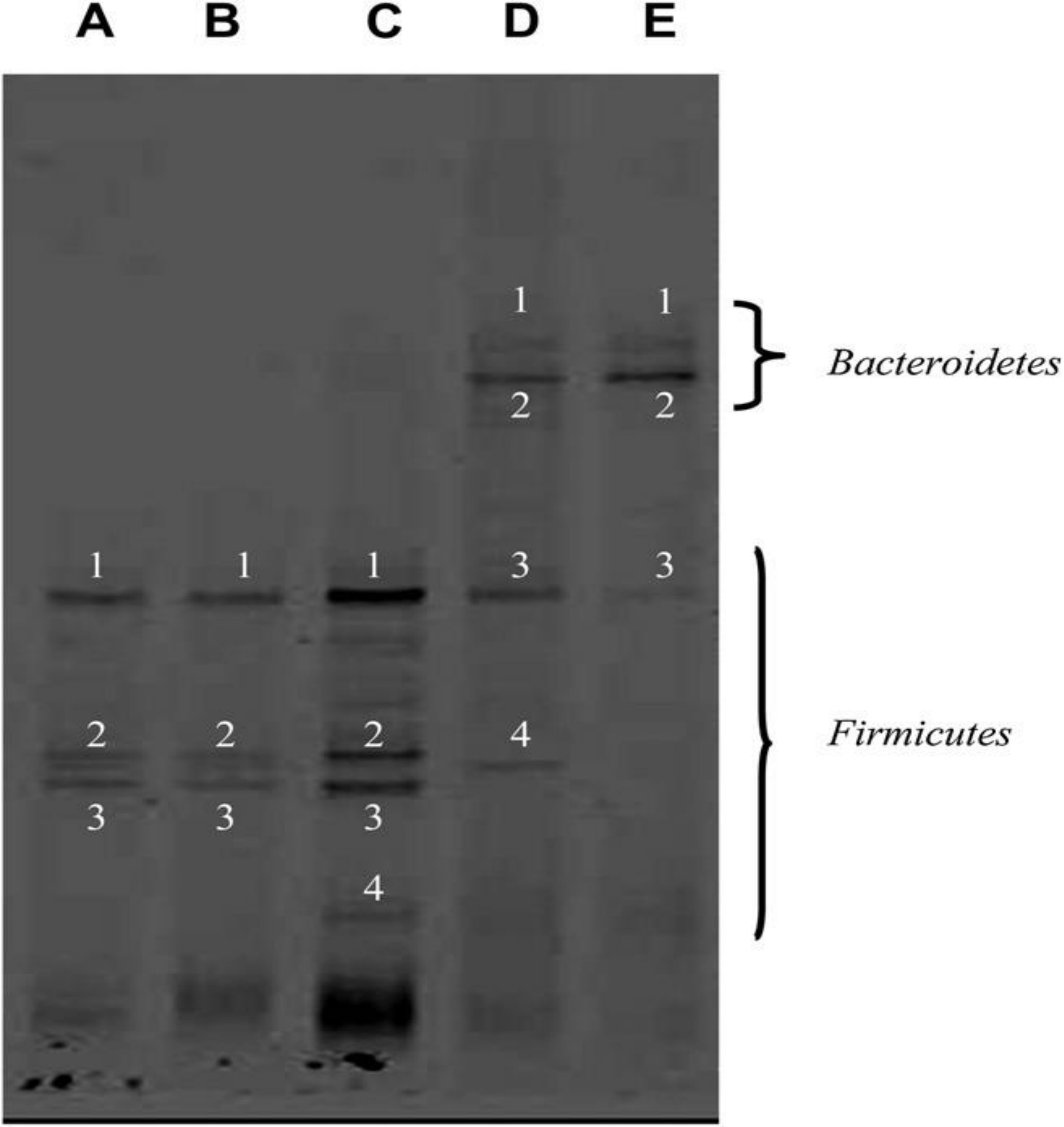
Parameters	Values
pH	6.1-6.4
Total solids (g/L)	285-376
Ammonia (g/L)	0.15-0.27
Total sugar (g/L)	49-62
Moisture (%)	71-73
Protein (%)	24-31
Fat (%)	22-28
Fibre (%)	1-3
Ash (%)	4-6



Schematic diagram of the hydrogen-producing reactor used in this study. The working temperature is 55°C with agitation speed of 100 rpm. 500 mL water jacketed bioreactor with 200 mL working volume

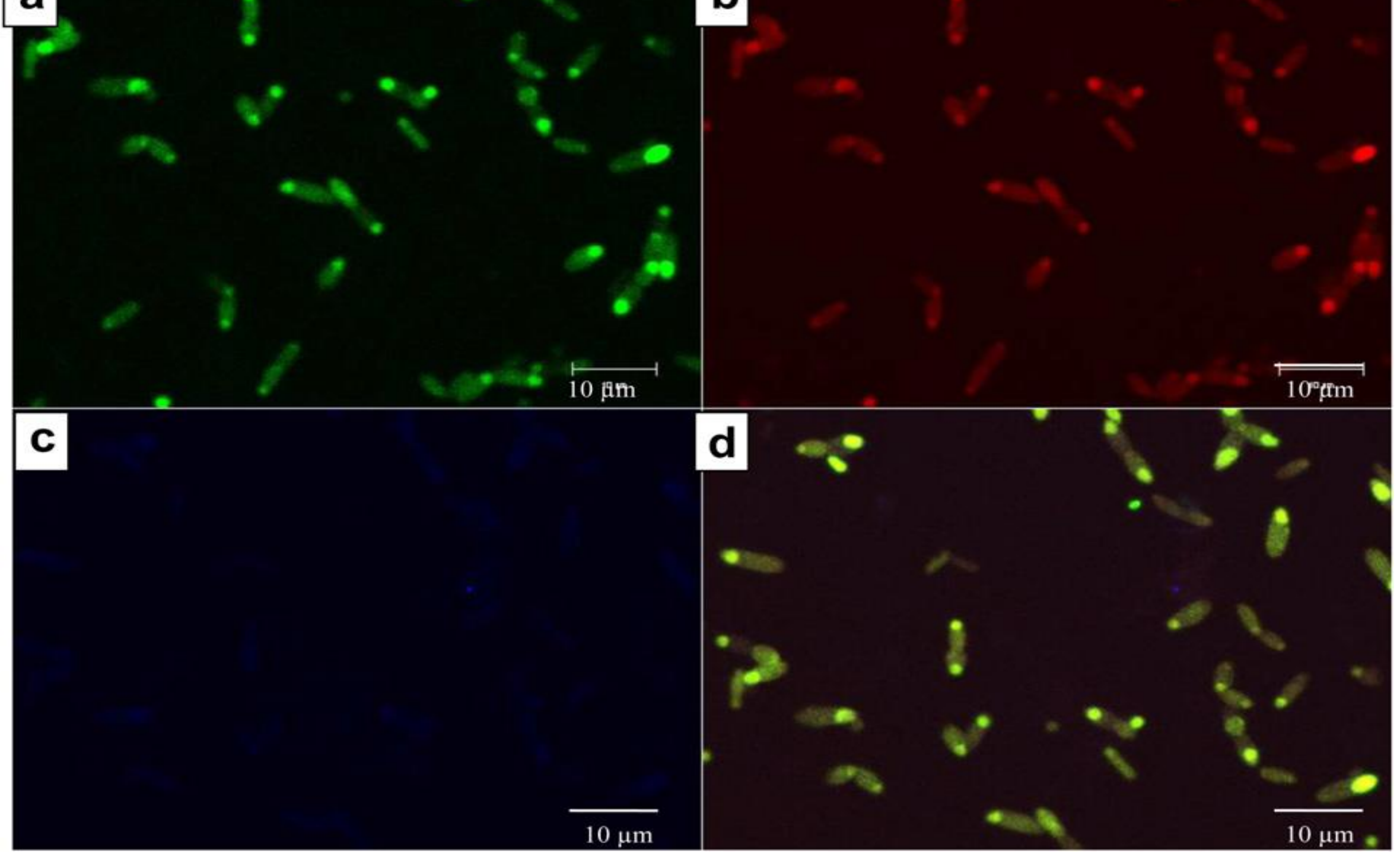
Kinetics parameters, yield of biohydrogen production, cumulative organic acids concentration and substrate degradation at different pH values for food waste fermentation at 24h.

pH	P (N ml)	$BioH_2$ content (%)	$BioH_2$ yield(mmol /L/d)	Organic acids (g/L)	CHO (%)
5.0	129	27.5±1.5	23	32	52
5.5	444	54.4 ± 1.3	79	31	70
6.0	426	32.9 ± 2.1	76	31	78

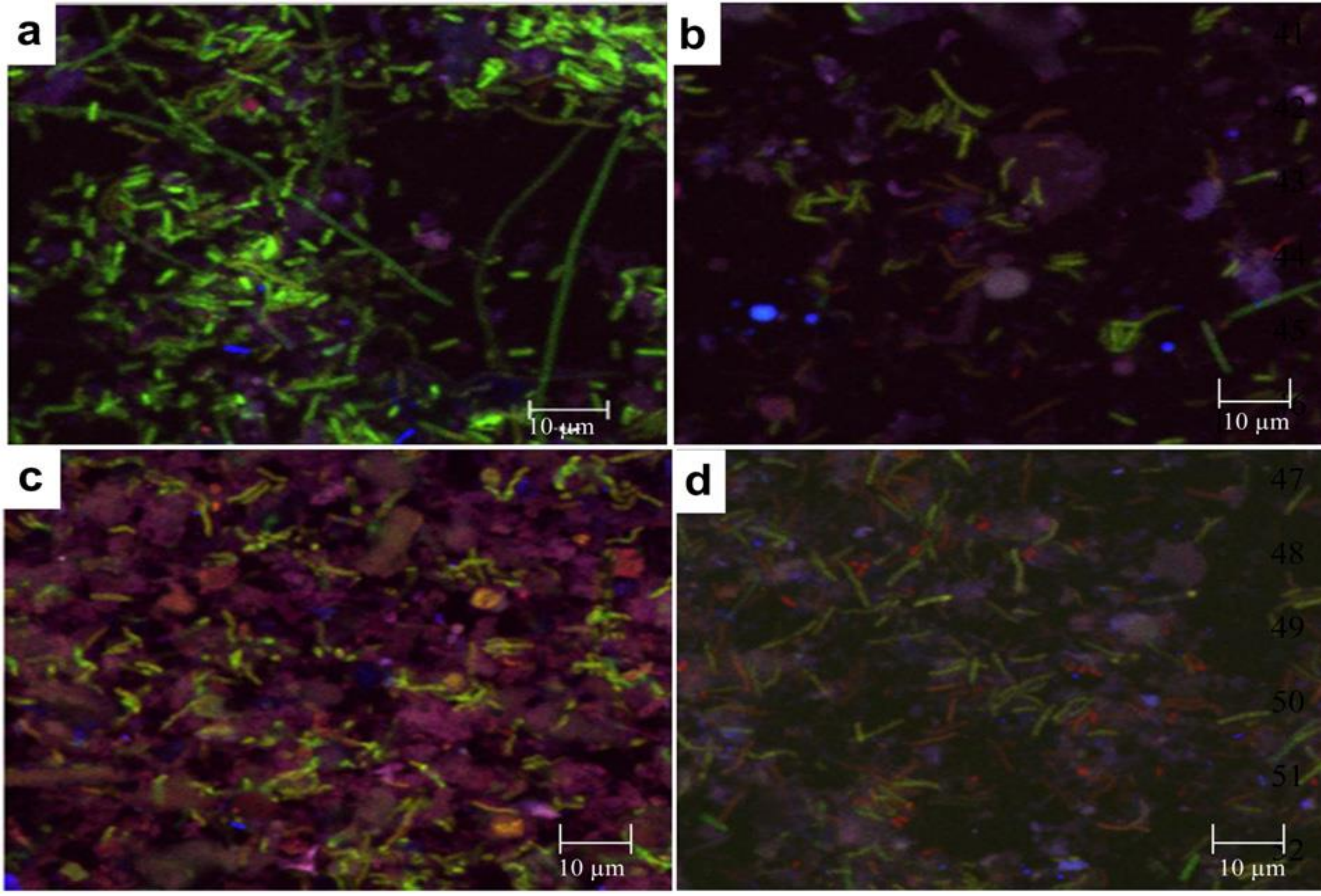


DGGE profile of 16S rRNA band fragments under 40e65% denaturant.
Lanes A: sample taken from fermentation at pH 6.0;
B: sample taken from fermentation at pH 5.5;
C: sample taken from fermentation at pH 5.0;
D:sample taken after acclimatization;
E: sample taken after heat-treatment.

Numbers indicate DNA bands excised and sequenced for identification of microbes.



In-situ hybridization with FITC-labelled probe P932 (a), in-situ hybridization with Rhodamine-labelled probe mixture of EUB338, EUB338II and EUB338III (red) (b) in-situ hybridization with Cy5.5-labelled probe Arch915 (blue) (c) and in-situ hybridization of all labeled probes used in this study (d) of FISH micrograph of *Clostridium butyricum* EB6. Hybridization was performed under optimal condition with 20% formamide at 46 C for 2h followed by washing at 48 C for 20 min



Acclimatized heat-treated anaerobic sludge (a), fermentation at pH 5.0 (b), pH 5.5 (c) and pH 6.0 (d) of in-situ hybridization of all labeled probes used in this study.

Biomethane from food waste

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Optimization of Methane Gas Production From Co-Digestion of Food Waste and Poultry Manure Using Artificial Neural Network and Response Surface Methodology

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Abstract

Food waste with high carbohydrate content is considered as a suitable substrate for fermentation of methane gas. In this study, co-digestion of poultry manure (PM) and food waste (FW) was used. Response surface methodology (RSM) and artificial neural network (ANN) were applied to optimize parameters of co-digestion of PM and FW at different ratios, initial pH values and temperatures. A comparative analysis was done using RSM and ANN in a predictive model of the experimental data obtained in accordance with the central composite design. The combined effects of the independent variables (ratio, pH and temperature) as the most significant parameters of methane fermentation of PM and FW were investigated. Optimization using RSM and ANN showed a good fit between the experimental and the predicted data as elucidated by the coefficient of determination with R^2 values of 0.991 and 0.998, respectively. Quadratic RSM predicted the maximum methane yield to be 537 mL CH_4/g VS at the optimal conditions; ratio 80:20 (PM : FW); temperature 35 °C; and initial pH 7.11. The maximum predicted methane yield by the ANN model was 535.82 mL CH_4/g VS at the following conditions; ratio of poultry manure to food waste 80:20; temperature 35 °C; and pH 7.00. The verification experiments successfully produced 538 mL CH_4/g VS within 14 days of incubation. These experiments indicated that the developed model was successfully used to predict the fermentable methane production.

Keywords: food waste, poultry manure, response surface methodology, central composite design, artificial neural network

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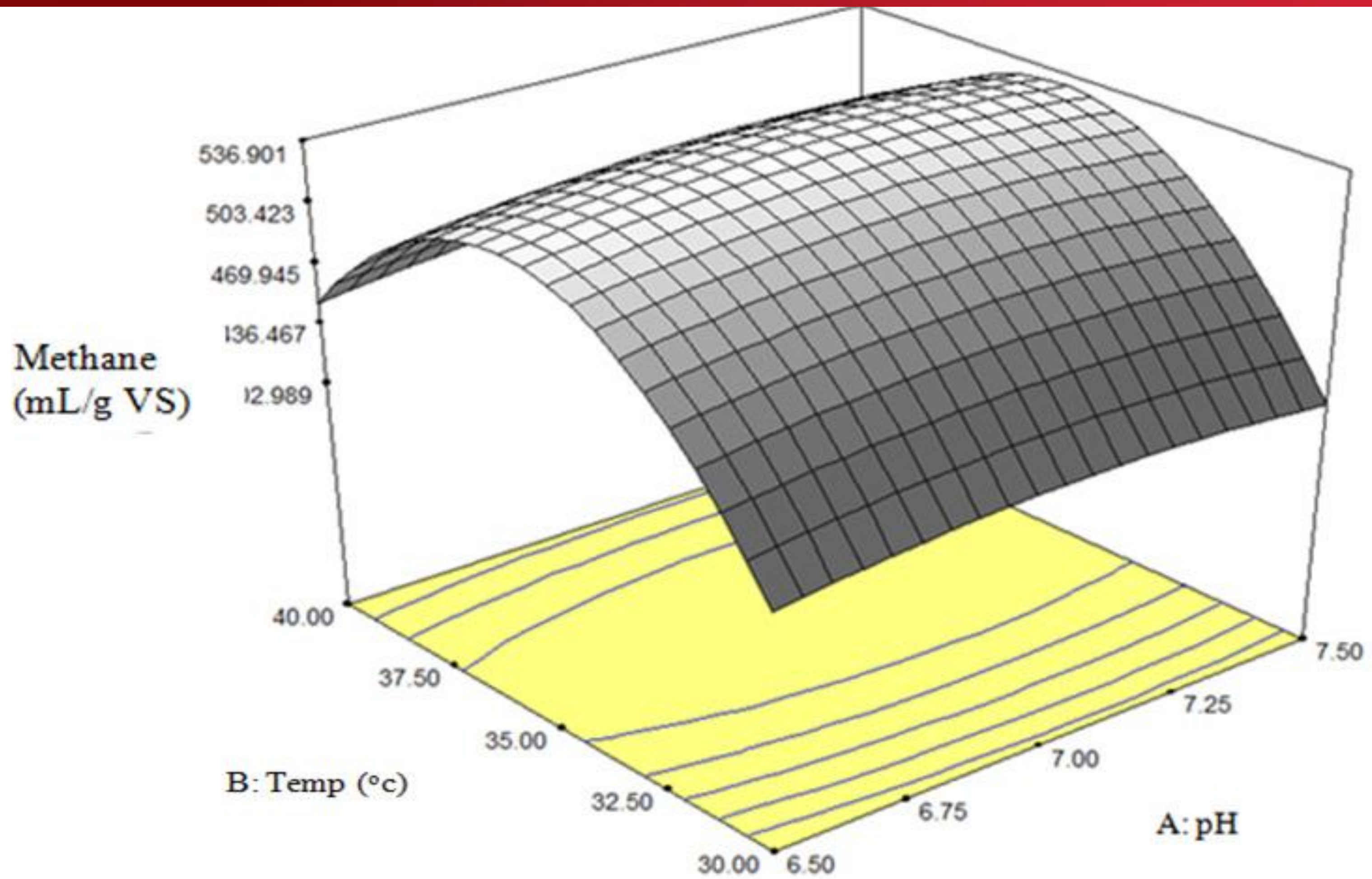
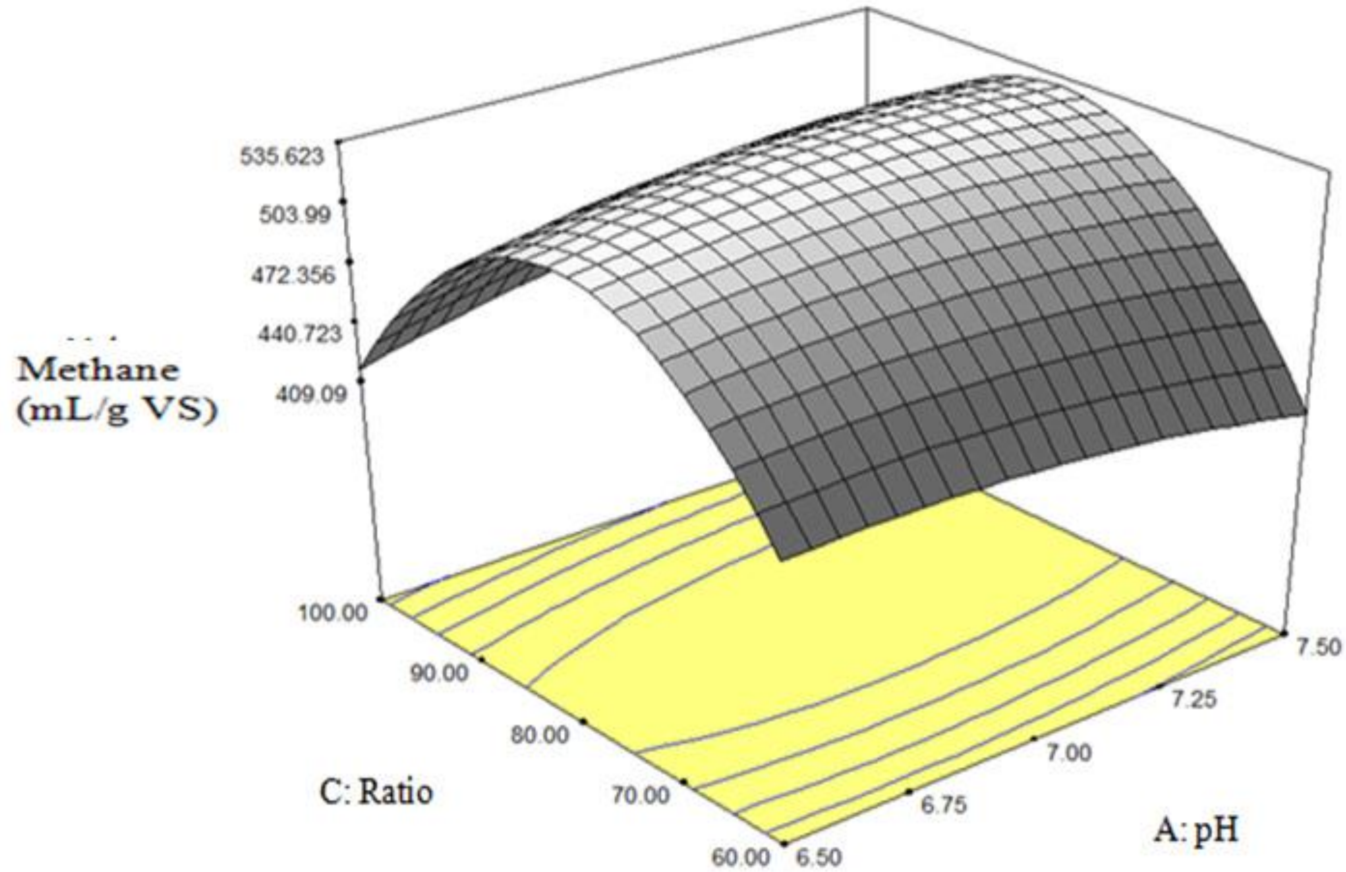
Characteristics of the poultry manure and food waste used

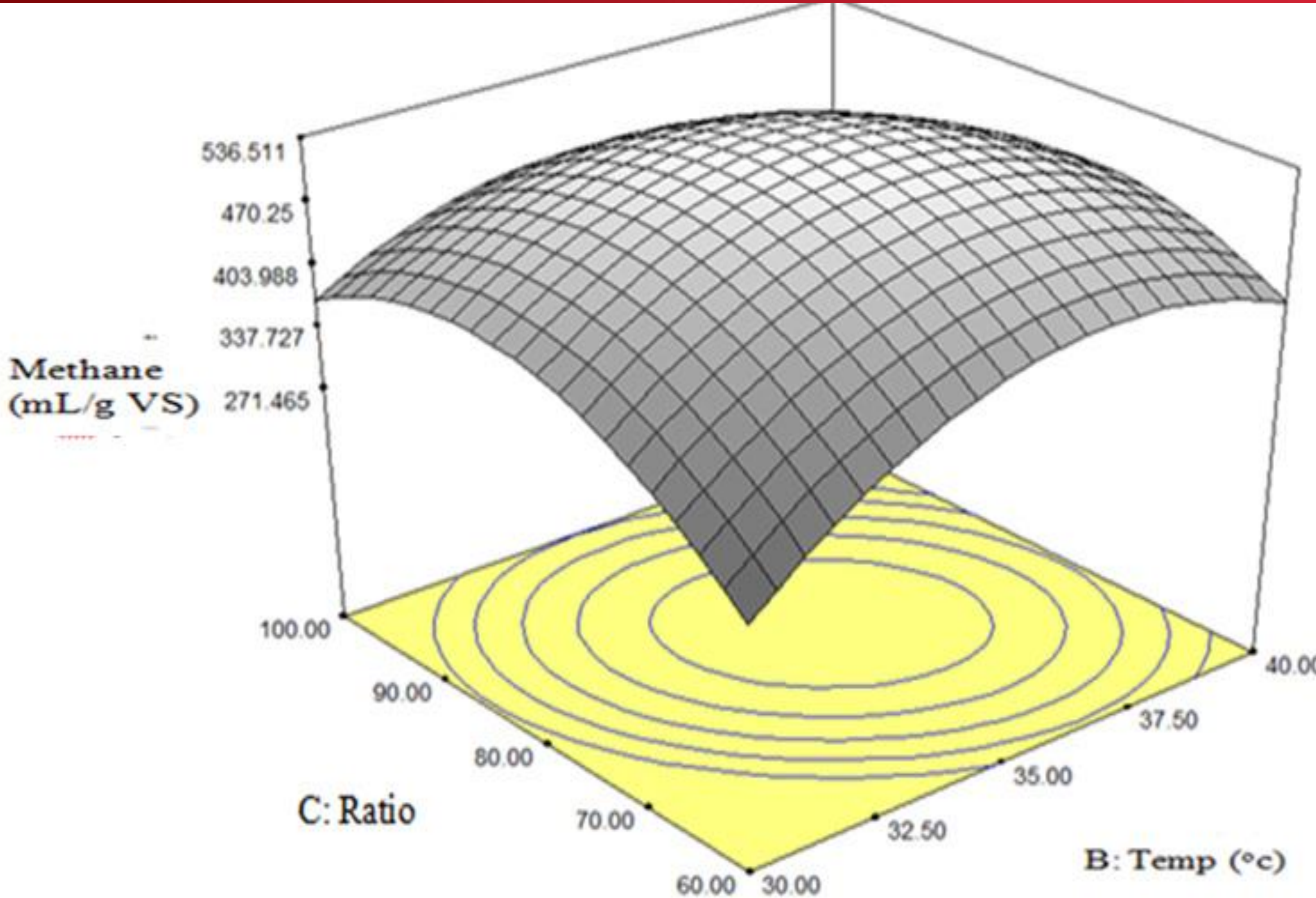
Parameters	Unit	Poultry manure	Food waste
pH	--	8.25	5.25
Total Solid (TS)	mg/L	92400	95300
Total Suspended Solid (TSS)	mg/L	90100	74700
Total Volatile Solid (TVS)	mg/L	71400	68300
Volatile Suspended Solid (VSS)	mg/L	48500	46500
Chemical Oxygen Demand (COD)	mg/L	65900	34500
Moisture content	%	55.1	60



Response surface and contour lines for the interactive effect of initial pH and different temperature on methane yield



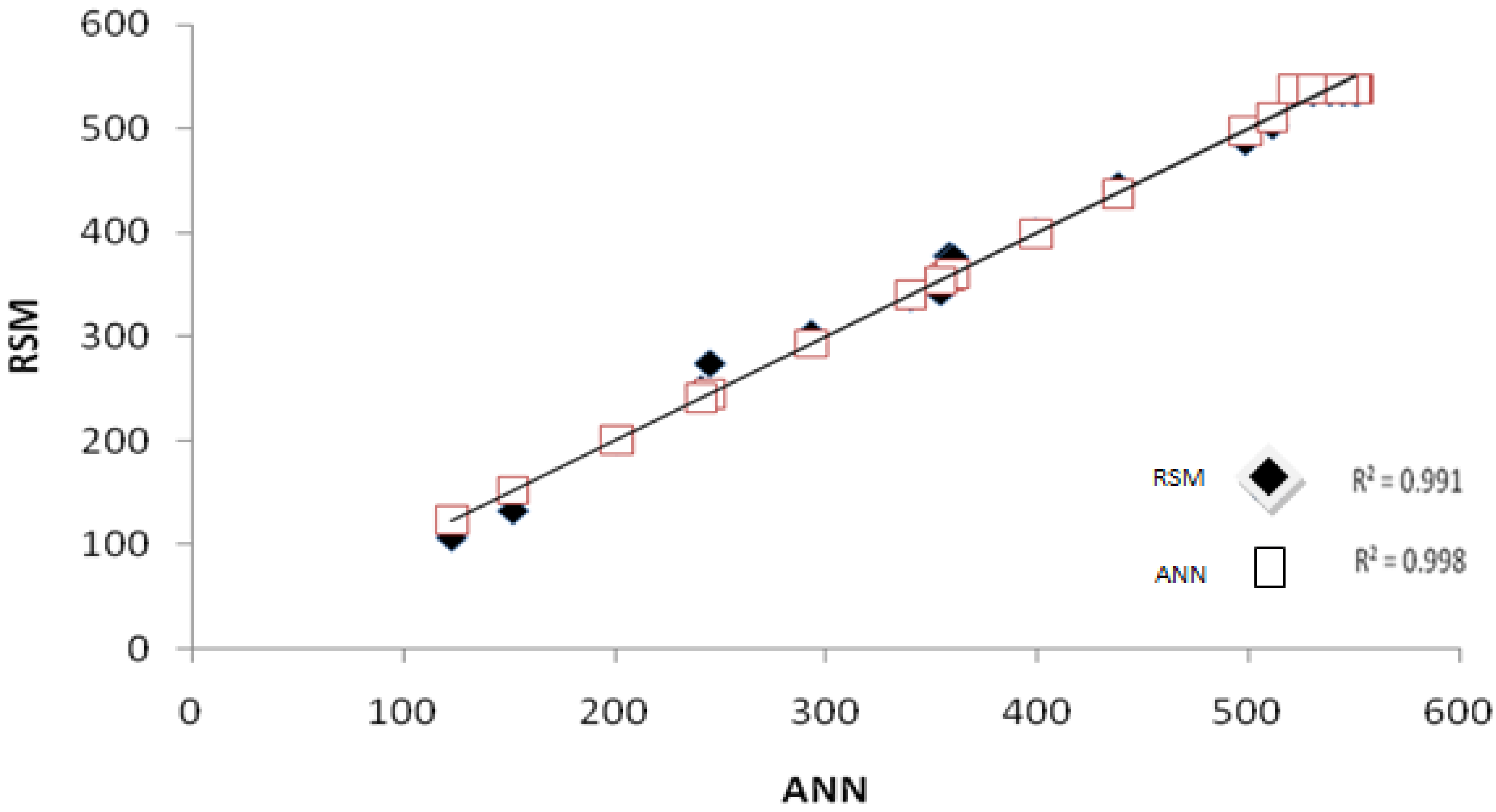
Response surface and contour plots for the interactive effect of the initial pH and ratio of the poultry manure and food waste.



Response surface and contour plots for the interactive effect of different ratio of substrates and different temperatures on methane yields

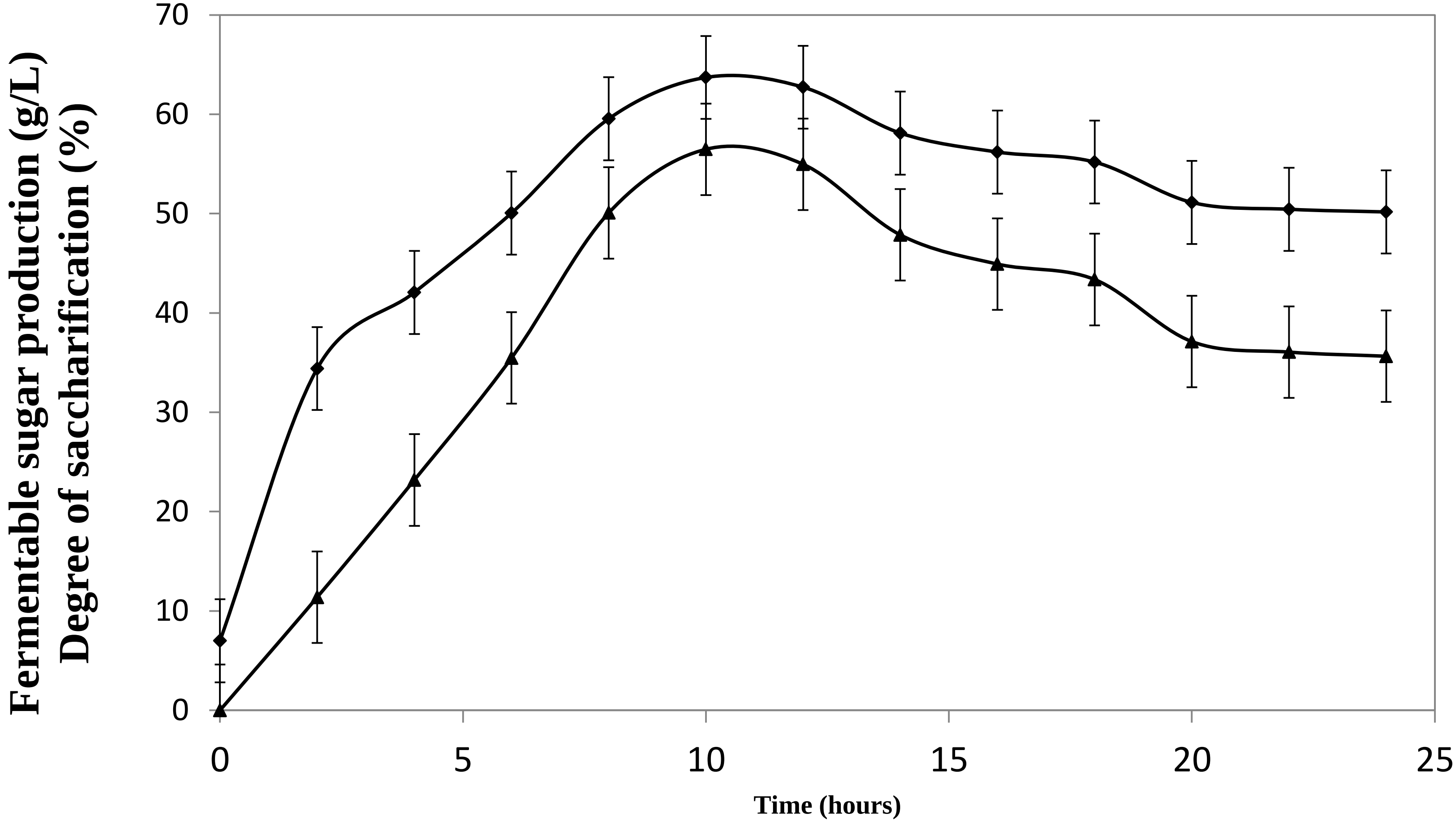
The optimum parameters and methane production for RSM and ANN

pH	Temp (^oC)	Ratio (PM:FW)	RSM ($mL\ CH_4/g\ VS$)		ANN ($mL\ CH_4/g\ VS$)	
			Actual	Predicted	Actual	Predicted
7.11	35	80:20	535.13	537	-	-
7	35	80:20	-	-	-	535.82

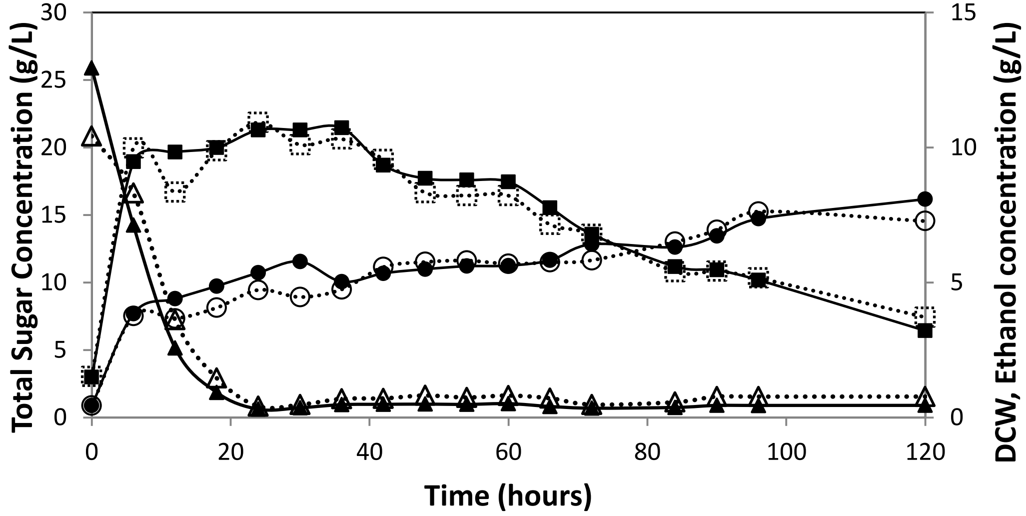


Prediction of R_2 by using response surface methodology (RSM) and Artificial Neuron Network (ANN)

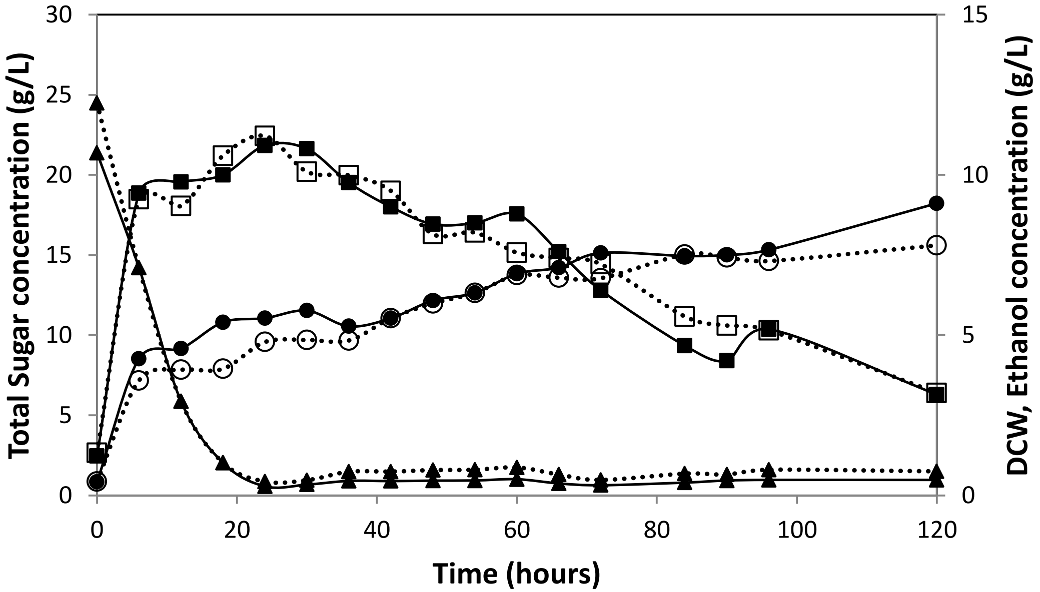
SUGAR AND BIOETHANOL PRODUCTION FROM FOOD WASTE



Fermentable sugars production (♦)and degree of saccharification (▲) under Optimized conditions (pH 5, temperature 60°C, glucoamylase activity 85 U/mL, kitchen waste loading 60 g/L and hydrolysis time 10 hours)



Time profile of S.cerevisiea for bioethanol production from hydrolysed waste and technical glucose



Time profile of Lanchachea fermentati for bioethanol production from hydrolysed waste and technical glucose

Legends;
glucose (▲); dry cell weight (●);
ethanol (■);
……………… parameters for kitchen waste hydrolysate

ORGANIC ACIDS AND POLYHYDROXYALKANOATES (PHA) PRODUCTION FROM FOOD WASTE

African Journal of Biotechnology Vol. 10(65), pp. 14507-14515, 24 October, 2011
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 ©2011 Academic Journals

Full Length Research Paper

Enhancement of organic acids production from model kitchen waste via anaerobic digestion

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Accepted 27 July, 2011

The aim of this study was to obtain the optimal conditions for organic acids production from anaerobic digestion of kitchen waste using response surface methodology (RSM). Fermentation was carried out using 250 ml shake flask which was incubated using an orbital shaker set at 200 rpm. Fermented kitchen wastes were used as inoculums sources. The individual and interactive effects of pH, temperature and inoculum size (%) on organic acids production from kitchen waste were investigated. The highest level of organic acid produced was 77 g/L at optimum pH, temperature, inoculum size of 6.02, 35.37°C and 20% inoculum, respectively. The results indicate that the most significant parameters affecting the bioconversion of kitchen waste to organic acids were temperature and inoculum size. Verification experiment of the estimated optimal conditions confirmed that RSM was useful for optimizing organic acids production from fermented kitchen waste.

Key words: Bioconversion, model kitchen waste, anaerobic fermentation, organic acids, optimization, response surface methodology.

African Journal of Biotechnology Vol. 8 (21), pp. 5807-5813, 2 November, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Separation and recovery of organic acids from fermented kitchen waste by an integrated process

Farah Nadia Omar, Nor'Aini Abdul Rahman*, Halimatun Saadiah Hafid, Phang Lai Yee and Mohd Ali Hassan

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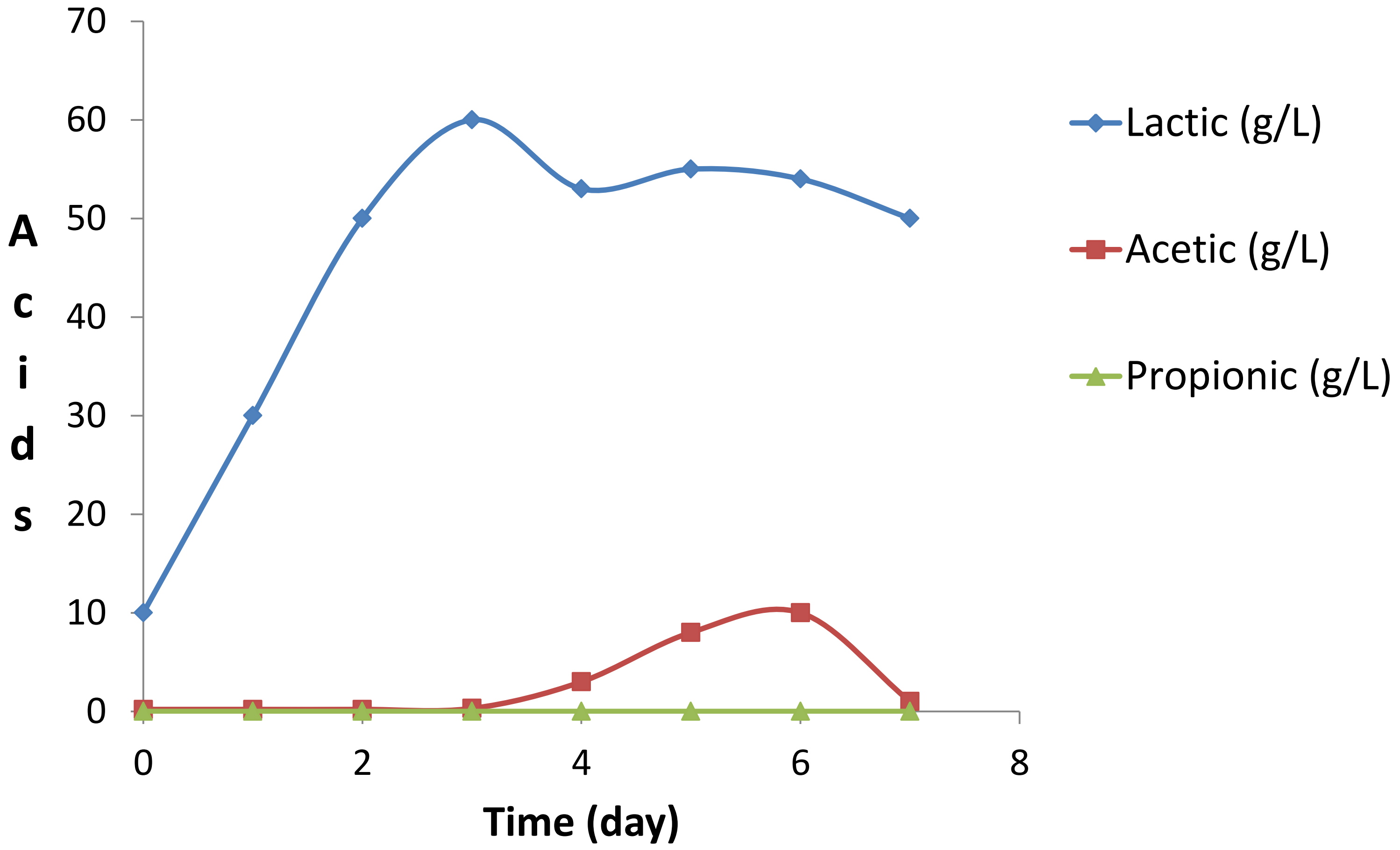
Accepted 4 September, 2009

Organic acids produced from anaerobic digestion of kitchen waste were recovered using a new integrated method which consisted of freezing and thawing, centrifugation, filtration and evaporation. The main organic acid produced was lactic acid (98%). After the freezing and thawing process, 73% of the total suspended solids were removed and the organic acids were elevated from 59.0 to 70 g/L. The evaporation technique was used to further concentrate the organic acids up to 224 g/L. Using the integrated recovery method, the reduction of the total suspended solids in the solution achieved was about 93%. The material balance for the recovery process was also presented.

Key words: Anaerobic digestion, kitchen waste, organic acids, recovery.



Organic acids profile in 50 L bioreactor. Results are mean of duplicate experiments

Full Length Research Paper

Utilization of kitchen waste for the production of thermoplastic polyhydroxybutyrate (PHB) b *Cupriavidus necator* CCGUG 52238

Farah Nadia Omar, Nor'Aini Abdul Rahman*, Halimatun Saadiah Hafid, Tabassu Phang Lai Yee and Mohd Ali Hassan

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Accepted 30 May, 2011

Polyhydroxybutyrate (PHB) was produced by *Cupriavidus necator* CCGUG 52238 using from fermented kitchen waste. HPLC and nuclear magnetic resonance (NMR) analyses re acid comprised mainly of lactic and acetic acids. In shake flask culture, the lactic acic above 10 g/L inhibited both cell growth and polyhydroxybutyrate (PHB) produc production by the strain was achieved at the highest PHB content of 52.79% in bat using the kitchen-waste derived organic acids. The PHB yield and productivity were 0. g/L/h, respectively. In fed-batch culture, about 4-fold increase in PHB productivity (achieved by applying intermittent feeding strategy.

Key words: *Cupriavidus necator* CCGUG 52238, kitchen waste, organic acids, polyhydroxyt

Bioconversion of restaurant waste into Polyhydroxybutyrate (PHB) by recombinant *E. coli* through anaerobic digestion

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Nor 'Aini Abdul Rahman
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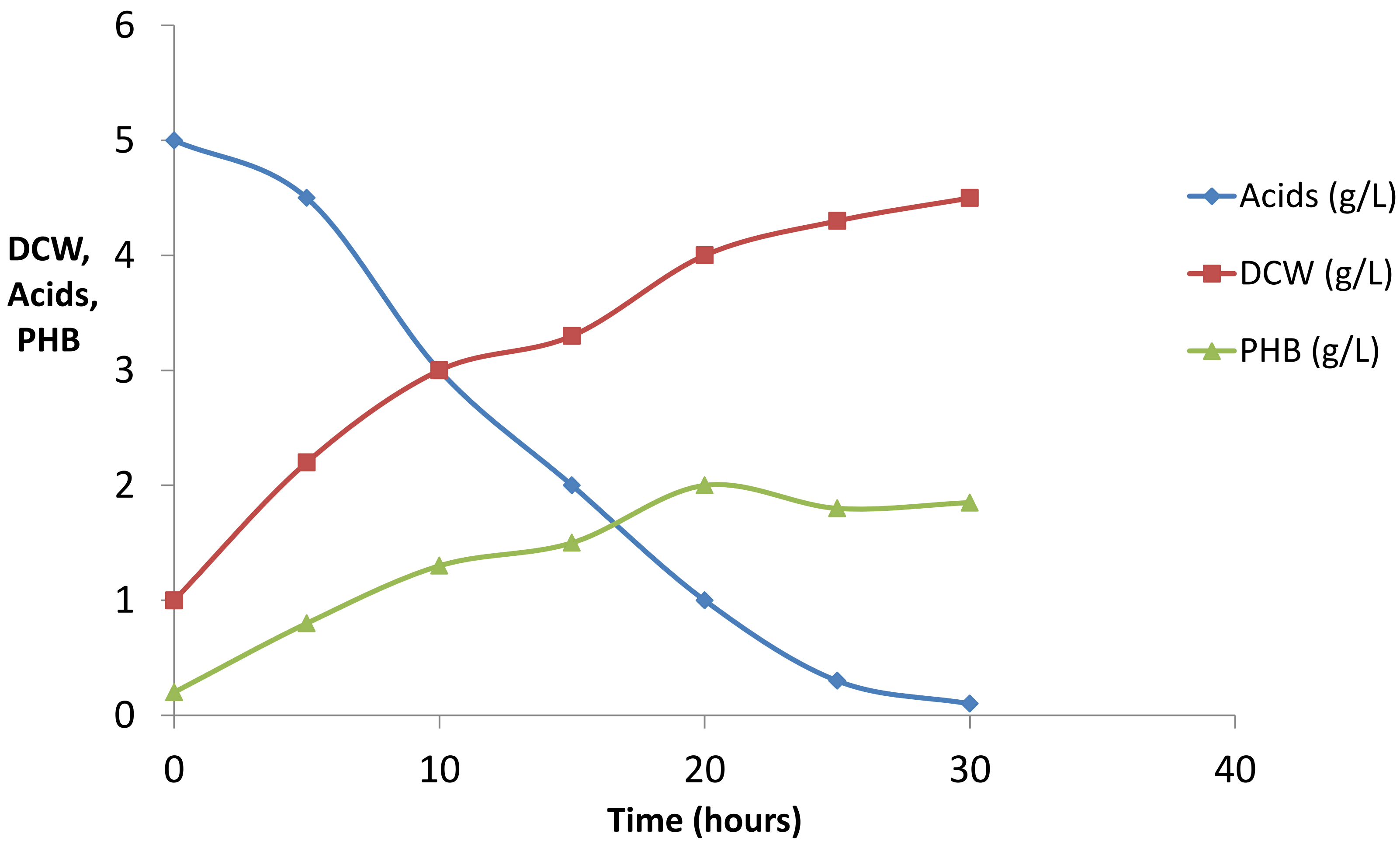
Abstract: The effect of temperature (30°C, 37°C, uncontrolled) and initial pH adjustment at pH 7 in the anaerobic digestion process was investigated to enhance the production of organic acids from restaurant waste. The highest organic acid level obtained was 39.6 g/L on the fifth day of fermentation conducted at 30°C and initial pH 7. The acids produced corresponded to 39.4% of the yield based on the initial concentration of substrate. The main organic acids produced were lactic and acetic acids. Using organic acids from fermented restaurant waste, recombinant *Escherichia coli* pnDTM2 gave PHB concentration, PHB content and PHB productivity of 9.2 g/L, 44% w/w and 0.54 g/L/h, respectively, in a pH stat fed-batch culture.

Keywords: organic acids; anaerobic digestion; restaurant waste; polyhydroxybutyrate.

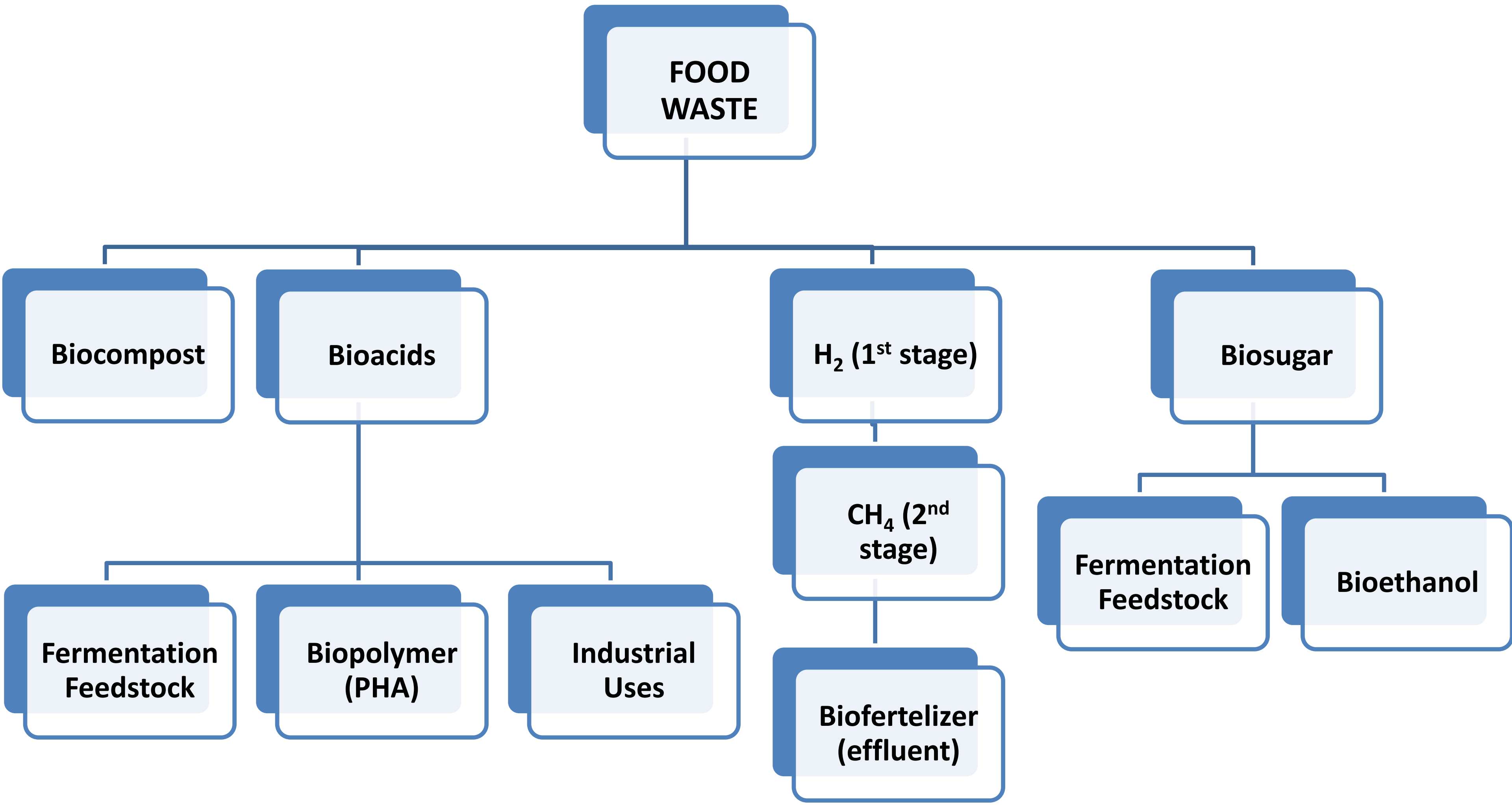
Polyhydroxybutyrate (PHB) production by recombinant *Eschelichia coli* pnDTM2 utilizing organic acids from food waste in batch and fed batch mode in 2 L bioreactor

Parameter	Batch	Fed-Batch
Dry cell weight (g/L)	6.8	20.9
PHB content (%)	36.4	44
PHB concentration (g/L)	2.5	9.2
Specific substrate uptake rate (g/g/h)	0.14	0.14
Productivity (g/L/h)	0.78	0.54



Time course of PHB production from *Cupriavidus necator* CCUG 52238 using organic acids (kitchen waste) in 2 L bioreactor

Proposed utilization of food waste for zero waste emission system



CONCLUSIONS

- Organic fraction (food waste) of MSW has potential to be converted to bioacids, biopolymer, biosugar, and biofuel.
- Zero waste system will be realized when integrated approach implemented in MSW management.
- Environmental awareness, education and continuous campaign should be emphasized.

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- Universiti Putra Malaysia
- All my colleagues, post-graduate students

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