Maejo International Journal of
Energy and Environmental Communication

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Assessment of the biogas potential from agricultural waste in northern Thailand

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ARTICLE INFOR

Received 17th January 2019
Accepted 11th March 2019

Keywords:
Agricultural product
Agricultural waste
Biogas
Biochemical methane potential (BMP)

ABSTRACT

In 2014-2015, there was approximately 26,823.44 x10^6 kg of the residue leftover from agricultural products in Northern Thailand and roughly 18,943.57x10^6 kg or 70.62% were left unutilized. The aim of this research was to survey and calculate the proportion of agricultural area and products as well as their corresponding waste towards potential of biogas production using biochemical methane potential (BMP) method. The results showed that rice straw was the most promising feedstock for methane production with the highest biogas yield of 363 $ml_N/g_{VSadded}$ followed by sugarcane leaves and corn cob having 333 and 318 $ml_N/g_{VSadded}$, respectively. Additionally, the predicted areas for growing rice and corn decreased. Meanwhile areas for growing cassava, sugarcane and oil palm increase slightly. This study also found out that the unused agricultural waste generation was decreased due to improved waste utilization.

1. Introduction

Thailand has huge natural resources and has a good environmental condition suitable for agriculture. In Northern Thailand, several kinds of crops such as rice and corn are commonly cultivated.

At the same time, large amount of agricultural waste is accumulated from harvesting activities which are not utilized. In 2014-2015, there was approximately 26,823.44 x10^6 kg of the residue leftover from agricultural products in Northern Thailand and roughly 18,943.57x10^6 kg or 70.62% were left unutilized. The farmers normally burn crop residues in agricultural fields to get rid of the waste and to prepare area for next growing season. Burning of residue can cause air pollution problem, smog and dust. Pardthaisong et al. (2018) said that this problem has affected Northern provinces of Thailand tremendously, not only economic and tourism sectors, but also health of residents in both short and long term. Biogas is a renewable energy resource produced by anaerobic digestion (AD). It is an environmental friendly process that utilizes organic waste including plant residues (Horváth et al., 2016). Biogas works as a flexible and predictable alternative for fossil fuels, crude oil, diesel, LPG and coal. The advantages of biogas are to generate electricity and heat.

Nomenclature and Abbreviation

BMP	Biochemical methane potential
AD	Anaerobic digestion
STP	Standard temperature and pressure
LPG	Liquefied petroleum gas

Moreover, digester residue which is the byproduct from AD, the digester residue can be futher utilized as fertilizer due to its high nutrient content (Ward et al., 2008). Therefore, the objectives of study are to survey and calculate the proportion of agricultural products and their waste, to assess potential of biogas production from agricultural waste in Northern Thailand using biochemical methane potential (BMP) method and to predict the areas for agriculture, agriculture waste and biogas produced in 2016-2022.

2. Materials and methods

2.1 A survey on agricultural waste in Northern Thailand

Agricultural waste data of five (5) kinds of crops: oil, palm, corn, cassava sugarcane and rice in 2014-2015 were gathered from Office of Agricultural Economics, Agricultural Statistics of Thailand. The number of agricultural fields that surveyed was 150 plots in 5 provinces, Chiangrai, Nan, Kamphaengphet, Nakonsawan and Phitsanulok. The detail of crops and areas for this survey is shown in Table 1.

Table 1. Area for agricultural waste survey

Crops	Area (District, Province)	Number of agricultural fields
Oil palm	Mae Sai, Chiang Rai	30
Corn	Wiang Sa, Nan	30
Cassava	Khanu Woralaksaburi, Kamphaeng Phet	30
Sugar cane	Takfa, Nakhonsawan	30
Rice	Phrom Phiram, Phitsanulok	30

The mass of agricultural products and the proportion of their residue had been calculated based on the surveyed samples.

2.2 Assessment of the biogas production potential from agricultural waste

The process and some conditions of assessment of biogas production potential from agricultural waste using BMP method applied with VDI 4630 standard method were stated as follow:

- Ratio of raw materials (sample) to microorganism equals to 0.5 (by volatile solid) and no adjustment ratio of carbon to nitrogen in sample
- The volume of digestion was 400 ml
- After mixing sample and micro-organism, exhausting oxygen by pure nitrogen 99.99% had been taken for 3 minutes in temperature controlled room (35±2℃).
- Measured the quantity of biogas once a day for 60 days using measurement gas pressure
- Analyzed biogas to find proportion of methane

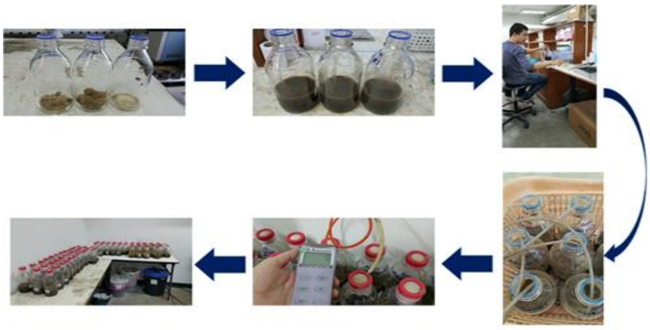

Figure 1. Biochemical Methane Potential (BMP)

2.3 Agricultural Prediction areas, agriculture waste and biogas produced in 2016-2022

According to Office of Agricultural Economics, Agricultural Statistics of Thailand (2016) data and surveyed data from 5 areas and predicted data were shown in section 3 (below the paragraph) including the prediction of biogas production.

3. Results and discussion

3.1 The agricultural waste in Northern Thailand

3.1.1 Proportion of agricultural waste

The quantities of oil palm, corn, cassava, sugarcane and rice at harvesting process that collected from surveyed agricultural fields are equal to 1,874.67 kg/rai, 963.80 kg/rai, 1,460.30 kg/rai, 3,154.68 kg/rai and 638.58 kg/rai, respectively. The mass of crops and products and the proportion of their residue based on the surveyed samples are presented in Table 2.

Table 2. The proportion of agricultural waste

Crops/waste		mass (g)	Proportion of waste to mass of crops (%)	Proportion of waste to mass of product (%)
Corn	Stems	129.84	18.06	43.52
	leaves	92.41	12.85	30.97
	Corn cob	63.44	8.82	21.26
	Another (roots, shell)	134.95	18.77	45.23
	Corn (product)	298.34	41.49	
	Total	718.98		
Cassava	Stems and leaves	868.29	19.81	28.93
	cassava root	513.82	11.72	17.12
	Cassava (product)	3,000.88	68.47	
	Total	4,382.99		
Sugar cane	Sugar cane leaves and tops	672.11	26.29	39.51
	dry leaves	183.41	7.17	10.78
	Sugar cane (product)	1,700.92	66.53	
	Total	2,556.44		
Major rice	Rice straw	137.70	20.61	29.37
	Rice stubble	61.70	9.23	13.16
	Paddy rice (product)	468.80	70.16	
	Total	668.20		
Second rice	Rice straw	2,057.16	20.61	29.37
	Rice stubble	338.12	9.23	13.16
	Paddy rice (product)	116.13	70.16	
	Total	184.07		
Oil palm	Palm leaves	790.00	59.02	260.40
	Palm bunch	3,485.48	14.98	66.10
	Palm fiber	129.84	3.33	14.70
	Oil palm (product)	92.41	22.67	
	Total	63.44		

3.1.2 Proportion of unused agricultural waste

Some agricultural waste such as corn cops are normally used as energy resource in household cooking but some agricultural wastes are not utilized. Table 3 shows the proportion of unused agricultural waste to all leftover residuals.

Table 3. The proportion of unused agricultural waste

Crops/waste		The proportion of unused waste (%)
Corn	Stems	73.71
	leaves	100.00
	Corn cob	73.64
	Another (roots, shell)	100.00
Cassava	Stems and leaves	14.87
	cassava root	90.25
Sugar cane	Sugar cane leaves and tops	93.24
	dry leaves	100.00
Rice	Rice straw	39.40
	Rice stubble	73.12
Oil palm	Palm leaves	95.00
	Palm bunch	0
	Palm fiber	0

3.2 Assessment of the biogas production potential from agricultural waste

Surveyed agricultural waste form 5 crops had been divided into 11 types to assess the potential of biogas production using BMP method. The results of experiment are shown in Table 4.

Table 4. The biogas production potential and methane production potential of agricultural waste

Agricultural waste		The biogas production potential* ($ml_N\ g_{VSadded}$)	The methane production potential* ($ml_N\ /g_{VSadded}$)	Proportion of methane (%)
Oil palm	Palm leaves	193	71	37.0
	Palm fiber	121	41	34.1
	Palm bunch	233	94	40.4
Corn	Stems	236	100	42.3
	Leaves	230	97	42.0
	Corn cob	318	145	45.6
Cassava	Stems	269	120	44.4
	Cassava root	139	48	34.4
Sugar cane	Leaves	333	160	48.0
Rice	Fresh rice straw	178	70	39.5
	Dry rice straw	363	176	48.4

Note: * Refers to standard (STP)

Dry rice straw has the highest biogas yield with 363 ml_N /$g_{VSadded}$ followed by sugarcane leaves and corn cob which yielded 333 and 318 $ml_N/g_{VSadded}$, respectively. The highest proportion of methane from dry rice straw is 48.4% that slightly different from sugarcane leaves, 48.0%. The proportion of methane from all types of agricultural waste are all lower than 50% since 5 kinds of crops are composed of carbohydrate that constitute to low methane. Moreover, the experiment has no adjustment ratio of carbon to nitrogen to find the optimal ratio.

3.3 Prediction the areas for agriculture, agriculture waste and biogas produced in 2016-2022

The agricultural areas in Northern Thailand for 2016-2022 was predicted based on the data from Office of Agricultural Economics, Agricultural Statistics of Thailand (2016). Table 5 reveals the prediction of areas for growing 5 crops as follows;

Table 5. Prediction of agricultural areas in 2016-2022

year	Agricultural areas (rai)				
	Corn	Cassava	Sugar cane	Rice	Oil palm
2016	5,064,079	2,119,889	2,666,640	21,922,016	56,756
2017	5,015,190	2,172,199	2,698,607	19,878,070	59,605
2018	4,932,877	2,209,833	2,727,524	17,449,290	62,181
2019	4,817,140	2,232,789	2,753,923	15,343,724	64,534
2020	4,667,979	2,241,069	2,778,208	14,955,701	66,698
2021	4,485,394	2,234,671	2,800,693	14,567,678	68,701
2022	4,269,385	2,213,597	2,821,625	14,179,655	70,567

The results showed that the predicted areas for growing rice and corn decrease while areas for growing cassava, sugarcane and oil palm increase slightly due to the demand of food and energy. The prediction of unused agricultural waste in 2015 – 2022 is presented in Table 6. The results presented that amount of unused agricultural waste decrease due to the reduction of growing area and the increase of agricultural waste utilization.

Table 7 shows the prediction of biogas production from unused agricultural waste in 2015-2022. The results are calculated by data from Table 6 and potential of the biogas production in Table 4.

Table 6. Prediction of unused agricultural waste in 2015 - 2022

Agricultural waste		Prediction of unused agricultural waste in 2015 - 2022 (x 10^6 kg)							
		2015	2016	2017	2018	2019	2020	2021	2022
Corn	Stems	1,080.07	999.50	989.85	973.60	950.76	921.32	885.28	842.65
	leaves	1,042.79	965.00	955.68	939.99	917.94	889.52	854.72	813.56
	Corn cob	527.13	487.81	483.10	475.17	464.02	449.65	432.06	411.26
	Another (roots, shell)	1,522.89	1,409.28	1,395.67	1,372.77	1,340.56	1,299.05	1,248.24	1,188.12
	Total	4,172.88	3,861.58	3,824.30	3,761.53	3,673.28	3,559.53	3,420.31	3,255.59
Cassava	Stems and leaves	251.43	260.28	266.70	271.32	274.14	275.15	274.37	271.78
	cassava root	903.05	934.81	957.88	974.48	984.60	988.25	985.43	976.14
	Total	1,154.49	1,195.09	1,224.58	1,245.80	1,258.74	1,263.40	1,259.80	1,247.92
Sugar cane	leaves	5,694.28	6,294.37	6,369.82	6,438.08	6,500.39	6,557.72	6,610.79	6,660.20
	dry leaves	742.21	820.43	830.27	839.16	847.29	854.76	861.68	868.12
	Total	6,436.49	7,114.80	7,200.09	7,277.24	7,347.68	7,412.47	7,472.46	7,528.31
Rice	Fresh rice straw	2,884.73	2,774.41	2,515.73	2,208.35	1,941.87	1,892.76	1,843.66	1,794.55
	Dry rice straw	4,225.13	4,063.55	3,684.68	3,234.47	2,844.17	2,772.25	2,700.32	2,628.40
	Total	7,109.86	6,837.96	6,200.41	5,442.82	4,786.05	4,665.01	4,543.98	4,422.95
Oil palm	Palm leaves	69.86	74.52	78.26	81.64	84.73	87.57	90.20	92.65
	Palm fiber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Palm bunch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	69.86	74.52	78.26	81.64	84.73	87.57	90.20	92.65
Total		18,943.57	19,083.94	18,527.63	17,809.03	17,150.47	16,987.99	16,786.75	16,547.42

Table 7. Prediction of biogas production from unused agricultural waste in 2015-2022

Agricultural waste		Prediction of biogas potential from unused agricultural waste in 2016 - 2022 (x 10^6 m^3)							
		2015	2016	2017	2018	2019	2020	2021	2022
Corn	Stems	1,063.24	983.93	974.43	958.43	935.95	906.96	871.49	829.52
	leaves	1,049.01	970.76	961.38	945.61	923.42	894.83	859.83	818.42
	Corn cob	529.54	490.03	485.30	477.34	466.14	451.70	434.03	413.13
	Another (roots, shell)	1,642.42	1,519.89	1,50t5.22	1,480.51	1,445.78	1,401.01	1,346.21	1,281.38
	Total	4,284.21	3,964.61	3,926.33	3,861.89	3,771.28	3,654.50	3,511.56	3,342.45
Cassava	Stems and leaves	257.01	266.05	272.61	277.33	280.21	281.25	280.45	277.81
	cassava root	967.75	1,001.78	1,026.50	1,044.29	1,055.14	1,059.05	1,056.03	1,046.07
	Total	1,224.76	1,267.83	1,299.11	1,321.62	1,335.35	1,340.30	1,336.48	1,323.87
Sugar cane	leaves	6,139.23	6,786.21	6,867.56	6,941.15	7,008.33	7,070.14	7,127.36	7,180.63
	dry leaves	758.63	838.58	848.63	857.73	866.03	873.66	880.74	887.32
	Total	6,897.86	7,624.79	7,716.19	7,798.88	7,874.36	7,943.80	8,008.09	8,067.94
Rice	Fresh rice straw	2,897.51	2,786.70	2,526.87	2,218.13	1,950.47	1,901.15	1,851.82	1,802.50
	Dry rice straw	4,315.17	4,150.15	3,763.20	3,303.40	2,904.78	2,831.33	2,757.87	2,684.41
	Total	7,212.68	6,936.84	6,290.07	5,521.53	4,855.26	4,732.47	4,609.69	4,486.91
Oil palm	Palm leaves	56.99	60.80	63.85	66.61	69.13	71.45	73.59	75.59
	Palm fiber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Palm bunch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total	56.99	60.80	63.85	66.61	69.13	71.45	73.59	75.59
Total		19,676.50	19,854.87	19,295.56	18,570.52	17,905.38	17,742.53	17,539.41	17,296.76

4. Conclusion

The study concluded the following based on the objectives:

1. In 2014-2015, there was approximately 26,823.44 x106 kg of the residue leftover from agriculture and roughly 18,943.57x106 kg, which was equivalent to 70.62%, remained unutilized.

2. The rice straw was the most promising feedstock for methane production with the highest biogas yield of 363 mlN /gVSadded followed by sugarcane leaves and corn cob which yielded about 333 and 318 mlN/gVSadded, respectively.

3. The predicted areas for growing rice and corn decrease while areas for growing cassava, sugarcane and oil palm increase slightly. The amount of unused agricultural waste decrease due to the reduction of growing area and the increase of agricultural waste utilization.

Acknowledgements

Authors thankful to the Office of the National Research Council of Thailand (NRCT), Energy Research and Development Institute – Nakornping, Chiang Mai University, Thailand and School of Renewable Energy, Maejo University, Thailand for provided facilities and funding.

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