Assessment of the biogas potential from agricultural waste in northern Thailand

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ABSTRACT

In 2014-2015, there was approximately 26,823.44 x10⁶ kg of the residue leftover from agricultural products in Northern Thailand and roughly 18,943.57 x10⁶ 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/g VS added followed by sugarcane leaves and corn cob having 333 and 318 ml/g VS added, 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 x10⁶ kg of the residue leftover from agricultural products in Northern Thailand and roughly 18,943.57 x10⁶ 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.
Moreover, digester residue which is the byproduct from AD, the digester residue can be further 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°C).
- Measured the quantity of biogas once a day for 60 days using measurement gas pressure
- Analyzed biogas to find proportion of methane

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.

| 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 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 from 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.

| Agricultural waste | The biogas production potential* (ml N2/g VS added) | The methane production potential* (ml N2/g VS added) | 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/g VS added followed by sugarcane leaves and corn cob which yielded 333 and 318 ml/g VS added, 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;

| 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 | 1,505.22 | 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 x10^6 kg of the residue leftover from agriculture and roughly 18,943.57x10^6 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.

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