# CHAPTER V

# CONCLUSIONS AND RECOMMENDATION

## 1. Conclusions

The results of the study on heat utilization of a producer gas from oyster mushroom substrate waste downdraft gasifier for oyster mushroom product processes, the experiments are divided into 2 parts. The results and discussions are as follows:

Part 1. To study the effect of airflow rate to a producer gas producing at difference airflow rate $3x10^{-3}$, $5x10^{-3}$ and $7x10^{-3}$ $m^3/s$ (30 °C, 1 atm). Part 2. To study a producer gas utilization for oyster mushroom agar media sterilization at 121 °C, 15 $lb/in^2$ ($1.03x10^5$ $N/m^2$) at least 30 min and oyster mushroom substrate pasteurization at 100 °C at least 120 min. The conclusions of this study are shown in Table 8.

Table 8 Results of Variable Airflow Rate Experiments

| Airflow Rate ($m^3/s$)* | Fuel Consumption Rate (kg/hr) | Combustible Gas (%) | | | Combustion Temp (°C) | Total heating value of gas ($MJ/Nm^3$) |
|---|---|---|---|---|---|---|
| | | CO | $CH_4$ | $H_2$ | | |
| $3.0x10^{-3}$ | 3.89 | 18.01 | 0.26 | 0.04 | 901.5 | 3.76 |
| $5.0x10^{-3}$ | 5.01 | 23.04 | 0.28 | 0.05 | 920.4 | 3.81 |
| $7.0x10^{-3}$ | 6.45 | 25.12 | 0.30 | 0.06 | 977.1 | 4.34 |

*At 30 °C 1 atm

### 1.1. The Conclusion of the Variable Airflow Rate Experiment

The study of a producer gas production at difference airflow rates, $3x10^{-3}$, $5x10^{-3}$ and $7x10^{-3}$ $m^3/s$ (at 30 °C 1 atm) at running time 300 min. Base on the results in Table 8 above. The fuel consumption rates are 3.89, 5.01 and 6.45 kg/hr, respectively. The difference airflow rates, they are corresponding conducted to the fuel consumption rates, the highest is $7.0x10^{-3}$, then $5.0x10^{-3}$ and $3.0x10^{-3}$ $m^3/s$, respectively. Also, the corresponding total heating value of gas and CO yields are concerned, the values of those are 3.76, 3.81, 4.34 $MJ/Nm^3$ and 18.01, 23.04, 25.12 %, respectively. In this thesis the fuel saving are concerned, it is conducted to gasifier advantage designing. Based on the above results, at $7.0x10^{-3}$ $m^3/s$ airflow rate, a higher fuel consumption rate and CO yields, while $3.0x10^{-3}$ $m^3/s$ airflow rate is lower combustion temperature and CO yields. Hence, in this thesis, at $5.0x10^{-3}$ $m^3/s$ will be used for downdraft gasifier to run the oyster mushroom products processes.

### 1.2. The Conclusion of Agar Media Sterilization and Substrate Pasteurization Experiments

The oyster mushroom agar media sterilization and oyster mushroom substrate pasteurization experiments are set at 3 times for investigating the parameters. The experiments testing time is set at 300 min/batch. The details of oyster mushroom agar media sterilization and substrate pasteurization experiments are shown in Table 9. For the oyster mushroom agar media sterilization, the average final temperature and pressure of the three experiments at testing time 300 min was 122.0 °C and 15.87 $lb/in^2$ ($1.09x10^5$ $N/m^2$), respectively. The average fuel consumption rate is 3.42 kg/hr. The average preheat time that reached sterilization condition and the average operating time of the three experiments were 113.3 and 143.3 min, respectively.

Table 9 The average results of Sterilization and Substrate Pasteurization Experiments

| Type of Exp | Fuel Con sump-tion Rate (kg/hr) | Combustion Temp (°C) | Sterilization Condition | | Pasteurization Condition | Time (min) | |
|---|---|---|---|---|---|---|---|
| | | | Final temp (°C) | Final pressure ($lb/in^2$) | Final temp (°C) | Operating time | Preheat time |
| 1* | 3.42 | 984.3 | 122.0 | 15.9 | - | 143.3 | 113.3 |
| 2* | 3.60 | 987.6 | - | - | 100 | 226.6 | 106.6 |

1* = Oyster Mushroom Agar Media Sterilization Experiments

2* = Oyster Mushroom Substrate Pasteurization Experiments

In case of oyster mushroom substrate pasteurization, the average final temperature of the three experiments at testing time 300 min is 100 °C. The average fuel consumption rate is 3.60 kg/hr. The averages preheat time that reached pasteurization condition and the average operating time of the three experiments are 106.6 and 226.6 min, respectively.

The experimental results are shown that a feasibility study on heat utilization of a producer gas from oyster mushroom substrate waste downdraft gasifier for oyster mushroom products processes is appropriate for oyster mushroom agar media sterilization and oyster mushroom substrate pasteurization. The energy saving from biomass conversion that instead LPG (LPG 1 kg = 14.80 Baht, 1 $ = 40.43 Baht at 2004-04-20), which using for sterilized and pasteurized are 42.05 MJ/sterilize batch (13.32 Baht (0.33 $)/sterilize batch) and 98.11 MJ/ pasteurize batch (31.08 Baht (0.76 $)/ pasteurize batch), respectively.

### 1.3. The Appropriate Downdraft Gasifier Designing for Oyster mushroom products processes

According from the oyster mushroom agar media sterilization and oyster mushroom substrate pasteurization experimental results, the downdraft gasifier (0.28 $m^3$, 480 min/batch, and using robber tree as biomass fuel) [11] is used for this study. It can be found that the operating time of the oyster mushroom agar media sterilization and oyster mushroom substrate pasteurization are approximately 143.3 and 226.6 min/experiment, respectively. Base on these results, this downdraft gasifier should be down scale for appropriate working and saving construction cost. The downdraft gasifier should be down scale from 480 min/batch to 300 min/batch and designing for the oyster mushroom products processes appropriate working, which using oyster mushroom substrate waste as biomass fuel. The advantages of the down scale designing should be obtained that the downdraft gasifier can run 2 times of the oyster mushroom agar media sterilization and appropriate working for oyster mushroom substrate pasteurization. The details of designing are shown in appendix A.

### 1.4. Financial Analysis

The simple payback period of the oyster mushroom substrate waste gasifier system is found to be 5 year, which concerning energy saving that substitute LPG. The results are considered reasonable when the present value cumulative energy saving cost equal the present value of cumulative system cost. The present value energy saving cost of ten year is 123,896 Baht.

### 1.5. Comparison the property of A producer gas with LPG

According from a producer gas can be instead LPG for the oyster mushroom product processes. A producer gas and LPG are combustible gas, the comparison of the properties are shown in Table 10.

Table 10. The Properties of a Producer Gas and LPG (EPPO, Thailand)

| A Producer gas Composition (%) | | LPG (%) | |
|---|---|---|---|
| CO | 23.04 | $CH_4$ | 63.93 |
| $CH_4$ | 0.28 | $C_2H_6$ | 8.25 |
| $C_2H_4$ | 0.22 | $C_3H_8$ | 4.85 |
| $H_2$ | 0.05 | $C_4H_{10}$ | 3.64 |
| $C_2H_6$ | 0.61 | $CO_2$ | 16.04 |
| $C_3H_8$ | 0.14 | $N_2$ | 3.42 |
| $CO_2$ | 5.32 | | |
| $N_2$ | 70.34 | | |
| Total Heating Value 3.81 MJ/$Nm^3$ | | Gross Heating Value 34 MJ/$m^3$ | |

2. Recommendations

The recommendations will be presented accompanied by brief comments about the suggestions are as follows:

2.1. Suggestions for Future Performance Improvement

2.1.1. The downdraft gasifier should be designed, the easy maintenance of fuel remain after the end of run.

2.1.2. The downdraft gasifier should be designed, the automatic temperature profile require by automatic heat damper for continuously heat supply.

2.1.3. A producer gas should be collected in pressure tank for utility utilization study.

2.1.4. The economical of heat utilization of a producer gas from downdraft gasifier should be studied.

2.1.5. Gas chromatography should be used to comparison with gasifier simulation program.

## 2.2. Suggestions for Future Research

2.2.1. Studies could be conducted to assess the other biomass or other processes waste for this gasifier.

2.2.2. Heat supply from this research should be applied to the other utilization.