CHAPTER II

THEORETICAL AND RELATED LITERATURE

1. Biomass

Biomass is renewable resource, which implies that it is part of flow of resources occurring naturally and repeatedly in the environment. The energy source that induces the renewability of biomass, a dynamic process, is the sun in the form of photosynthesis from the photoactive properties of radiation, sustaining the growth of plants with subsequent release in the biosphere and also be looked at in another way as a mass of biological material produced from living processes, with the term "biomass" used to describe all living matter derived the five kingdom in biology, namely, plants, animals, fungi, protists and monerous.

The basic biochemistry consist of a reaction sequence leading to the overall conversion

$$nCO_2 + mH_2O \longrightarrow C_n(H_2)_mO_m + nO_2 \quad \text{kJ/gmol} \qquad (1)$$

1.1. Categories of Biomass

In general there are three main categories of biomass, woody, non-woody and animal waste [4] classify from these three broad classes flow seven forms of biomass types.

1.1.1. Forests woodlands and plantations. This includes forest/ woodland and plantation residues derived exclusively from the woody vegetation.

1.1.2. Agro-industrial plantations. Distinguished from forestry plantations in that they produce ago-industrial raw materials and have woody biomass recorded data as by-products.

1.1.3. Trees outside forests. Trees, those grow outside forest/woodland formations, including bush trees, urban trees and non-farm trees.

1.1.4. Agricultural crops. Crops, those are grown specifically for food fodder, fiber or energy production.

1.1.5. Crop residues. Including crop and plant residues produced in the field.

1.1.6. Processing residues. Including residues resulting from the ago-industrial conversion or processing of crop (including tree crop).

1.1.7. Animal wastes. Wastes from intensive and extensive animal husbandry

2. Biomass Conversion

There are actually only 2 principal classes of conversion process, thermal and biological.

2.1. Bio-chemical conversion

There are 2 principal classes of Bio-chemical conversion.

2.1.1. Anaerobic Digestion, bio-chemical that formation of methane and CO_2 by anaerobic digestion of animal and vegetable matter.

2.1.2. Ethanol Fermentation, bio-chemical that production of ethanol by yeast fermentation.

2.2. Thermo-chemical conversion

Thermo-chemical conversion is type of biomass conversion process; whereby biomass is convert into useful fuel by mean of heat treatment. The main thermal conversion processes are as following;

2.2.1. Direct combustion, the direct combustion of biomass conversion produce heat should be an efficient route of utilization, since, with no conversion process involved, there are no conversion losses. Moisture is the major problem to consider the likely limits of direct combustion.

2.2.2. Carbonization or Pyrolysis, the basic conversion of the process in which biomass is simply heated in the absence of any air or additional reactance of any kind. The basic reaction is being a driving off of water from typical biomass at the oxidation level of carbohydrate.

2.2.3. Gasification, a producer gas is produced from biomass through the process of gasification. It is the common term given to a gas of relatively low calorific value formed by the reaction of air and steam with organic fluid fuel.

The reactions take place in 4 zones of a deep fuel bed, namely, hearth or combustion zone, reduction zone or gasification zone, distillation zone or pyrolysis zone and drying zone are described in part 4.

3. Moisture Content

All analyses, and combustion engineering working with solid, liquid and gaseous fuels usually calculate moisture content on the "as-fires", actual, total or wet weight basis, hence.

$$\%\ M.C._{wb} = \frac{(w_1 - w_2)\times 100}{w_1} \qquad (2)$$

On the other hand

$$\%\ M.C._{db} = \frac{(w_1 - w_2)\times 100}{w_2} \qquad (3)$$

Where $\%\ M.C._{wb}$ = moisture content on the "as fired", actual wet or total weight basis

$\%\ M.C._{db}$ = moisture content on the "bone-dry", absolutely dry or oven-dry basis

w_1 = Weight of sample

w_2 = Weight of sample after oven-drying; oven-dry or bone-dry weight

Either M.C. value can be converted into the other, thus

$$\% \text{ M.C.}_{db} = \frac{\%m.c._{wb}}{(100-\%m.c._{wb})} \qquad (4)$$

$$\% \text{ M.C.}_{wb} = \frac{\%m.c._{db}}{(100+\%m.c._{db})} \qquad (5)$$

4. Chemical Reaction in Gasification

Producer gas is formed by partial combustion and the reactions take place in 4 zones of a deep fuel bed. The main reactions are:

4.1. Hearth or Combustion Zone

In the hearth zone, the Oxygen in an air steam blast reacts with the Carbon in the fuel to produce CO_2 .

$$C + O_2 \longrightarrow CO_2 + 393.8 \text{ kJ/gmol} \qquad (6)$$

$$2H_2 + O_2 \longrightarrow 2H_2O + 285.6 \text{ kJ/gmol} \qquad (7)$$

The CO_2 formed is reduced in the presence of glowing Carbon over 90 %of CO_2 is reduce to CO at temperature between 900-1,200 °C

4.2. Reduction or Gasification Zone

In the reduction zone, water vapor reacts with the Carbon to form Hydrogen and Carbonmonoxide. The Carbondioxide coming from the combustion zone is also reduced to Carbonmonoxide in the reduction zone .The main reaction are:

$$C + CO_2 \longrightarrow 2CO - 172.6 \text{ kJ/gmol} \qquad (8)$$

Boudouard reduction reaction (endothermic reaction) at temperature 500-1,000 °C

$$C + H_2O \longrightarrow CO + H_2 - 131.4 \text{ kJ/gmol} \qquad (9)$$

Water gas reaction (endothermic reaction) at temperature more than 800 °C

$$C + 2H_2O \longrightarrow CO_2 + 2H_2 - 90.2 \text{ kJ/gmol} \qquad (10)$$

$$CO + H_2O \longrightarrow CO_2 + H_2 + 41 \quad kJ/gmol \tag{11}$$

Water shife reaction (exothermic reaction) at temperature 700 °C

$$C + 2H_2 \longrightarrow CH_4 + 74 \quad kJ/gmol \tag{12}$$

Methane reaction (exothermic reaction)

4.3. Distillation Zone or Pyrolysis Zone

Volatile matter and solid (fix Carbon) are produced from this zone at temperature 135-600 °C. The main reaction is:

$$\text{Dry wood (biomass)} + \text{Heat} \longrightarrow \text{Charcoal} + CO + CO_2 + H_2O + C_2H_6 + \text{Pyroliggneouse Acid} + \text{Tar} \tag{13}$$

4.4. Drying Zone

In drying zone moisture are vaporized from biomass by heat coming from pyrolysis zone at temperature 100-135 °C.

$$H_2O_{(liquid)} \longrightarrow H_2O_{(gas)} \tag{14}$$

5. Type of Gasifier

The gasifiers are classified according to method of gas/fuel contact are fixed bed gasifier and moving bed gasifier [5].

5.1. Fixed bed gasifiers

There are 3 main types of fixed bed gasifiers.

5.1.1. Downdraft gasifier/Co-Current/Down-Flow

In the downdraft gasifier combustion zone nearer the top of the fuel bed and far removed from the ash layer, which collects on the grate at the bottom of the bed and the condensable from the volatile matter of the fuel pass though the combustion. Resulting in higher decomposition of combined water and richer gas. However, the combustion zone may be chilled if too much condensable material passes through resulting in less CO and higher CO_2 in a producer gas. The downdraft gasifier is shown in Figure 3.

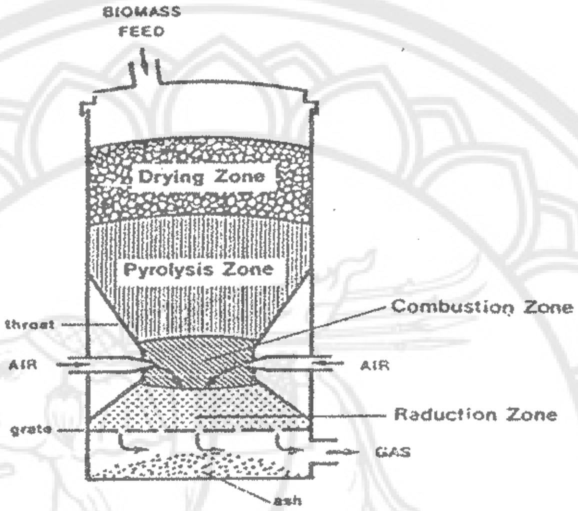

Figure 3 Schematic Diagram of Downdraft Gasifier [6]

5.1.2. Updraft gasifier/ Counter-Current/Up-Flow

In the updraft gasifier the air/steam are fed into the vertical producer at the base of combustion zone, where temperature of 900 °C and above are obtained. With the large-scale industrial units, the addition of steam helps to reduce the local temperature in the combustion zone, but many case jackets cooling this zone is employed to prolong combustion zone life. The gases produced in the combustion zone then pass through the reduction zone into the pyrolysis zone respectively. The up draft gasifier is shown in Figure 4.

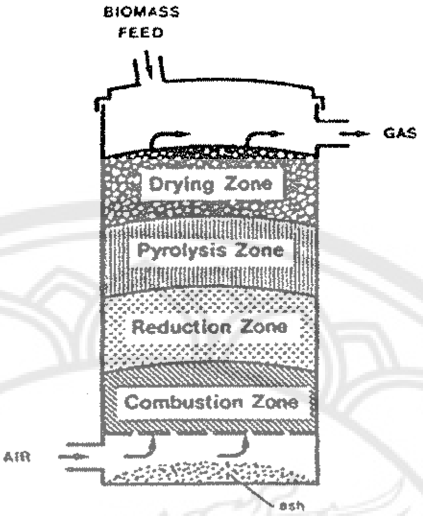

Figure 4 Schematic Diagram of Updraft Gasifier [6]

5.1.3. Crossdraft gasifier/Cross Flow

In the crossdraft gasifier air is introduced on one side of the gasification chamber, normally through an inlet nozzle that bring into the center of the combustion zone, and product gas is expelled on the opposite side. The air velocity as it enters the combustion is considerably higher than the other design. Both the combustion zone and reduction zone are concentrated into small volume surrounded by a mass of fuel that insulates the reactor walls against extremely high temperatures. Refractory materials are thus not normally need to line the reactor walls, making this gasifier lightweight. The crossdraft gasifier is shown in Figure 5.

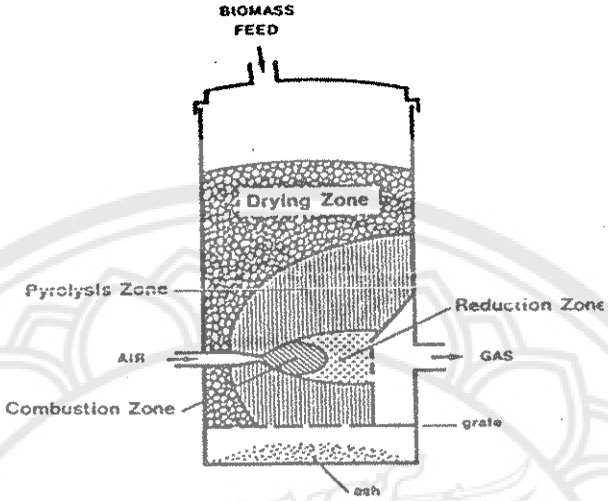

Figure 5 Schematic Diagram of Crossdraft Gasifier [6]

5.2. Moving bed gasifier

Moving bed is designed the feed stock is in suspension in gases, either with or without an inert heat transfer material, of which perhaps the most important are the fluidized bed reactors and cyclone reactors base upon the some principles as fluidized bed gasifier and suspended fuel gasifier. A further group of designs involves moving progressively from one level to the next one down, while gases flow counter-currently and vented from the top. The fluidized bed gasifier and the suspended fuel gasifier are shown in Figure 6 and 7, respectively.

Comparison between fixed bed gasifier and moving bed gasifier, the simplest shape and design of the reactor is the fixed bed reactor, which consists of an upright metal cylinder containing the bed of feedstock, having an inlet and outlet for gases, a means of feeding additional solid feedstock from above and a means of ash removal at the base. So fixed bed gasifier, downdraft gasifier is used in this thesis. Because of updraft gasifier permit the vapors of liquid organic products and tar to distill over, while in the downdraft design, such materials cannot find an exit from the reactor without passing through the highest temperature zone, in which they are destroyed. The crossdraft type does not have this advantage to the same extent as the downdraft type, but both the crossdraft and downdraft designs serve to prevent the re-contracting of reaction products with the freshest feedstock which, suitable for oyster mushroom substrate wastes feedstock.

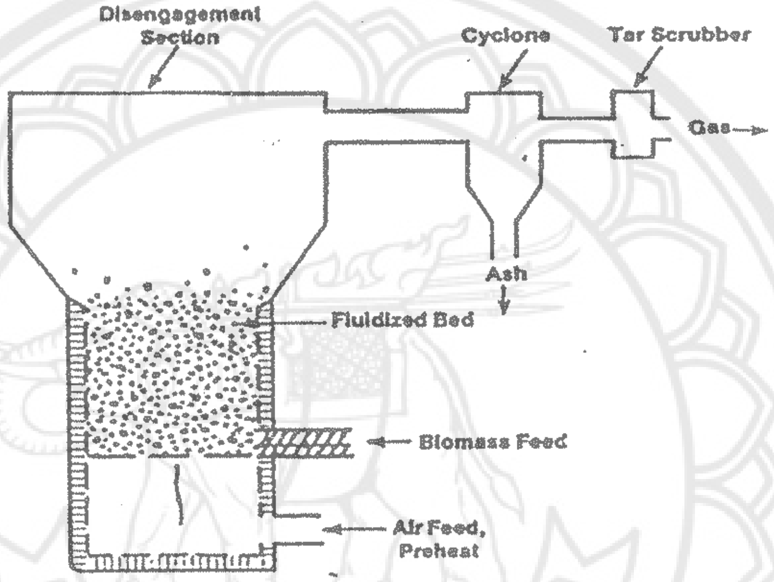

Figure 6 Schematic Diagram of Fluidized Bed Gasifier [7]

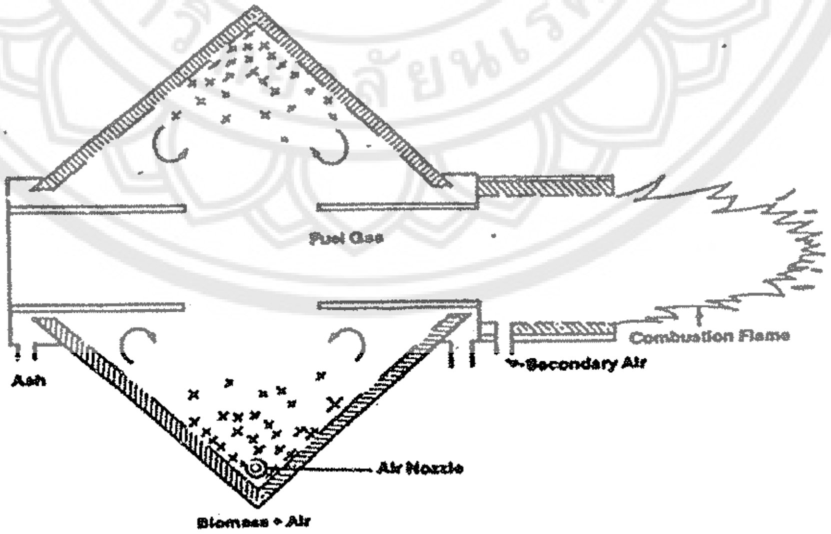

Figure 7 Schematic Diagram of Suspended Fuel Gasifier [7]

6. Sterilization and Pasteurization

The control of microbial growth is necessary in many practical situations, and significant advances in agriculture, medicine, and food science have been made through study of this area of microbiology. Control of growth usually involves the use of physical or chemical agents, which either kill or prevent the growth of microorganisms. Agents, which kill cells, are called cidal agents; agents that inhibit the growth of cells (without killing them) are referred to as static agents. Thus the term bactericidal refers to killing bacteria and bacteriostatic refers to inhibiting the growth of bacterial cells. A bactericide kills bacteria; a fungicide kills fungi, and so on.

Sterilization is the complete destruction or elimination of all viable organisms (in or on an object being sterilized). There are no degrees of sterilization: an object is either sterile or not. Sterilization procedures involve the use of heat, radiation or chemicals, or physical removal of cells. Heat most important and widely used. For sterilization always considers type of heat, time of application and temperature to ensure destruction of all microorganisms. Endospores of bacteria are considered the most thermoduric of all cells so their destruction guarantees sterility. The protocol and recommendations for the use of heat to control microbial growth are given in Table 1.

Table 1. Recommended use of heat to control bacterial growth [8]

Treatment	Temperature	Effectiveness
Incineration	>500°C	Vaporizes organic material on nonflammable surfaces but may destroy many substances in the process
Boiling	100°C	30 minutes of boiling kills microbial pathogens and vegetative forms of bacteria but may not kill bacterial endospores
Intermittent boiling	100°C	Three 30 min intervals of boiling, followed by periods of cooling kills bacterial endospores
Autoclave and pressure cook(steam underpressure)	121°C/15 min at 15 lb/in^2(1.03x10^5 N/m^2) pressure	Kills all forms of life including bacterial endospores. The substance being sterilized must be maintained at the effective temperature for the full time
Dry heat (hot air oven)	160°C/120 min	For materials that must remain dry and which are not destroyed at temperature. between 121°C and 170°C Good for glassware, metal, not plastic or rubber item
Pasteurization (batch method)	63°C/30 min	kills most vegetative bacterial cells including pathogens such as streptococci, staphylococci and Mycobacterium tuberculosis
Pasteurization (flash method)	72°C/15 seconds	Effect on bacterial cells similar to batch method; for milk, this method is more conducive to industry

7. Oyster Mushroom

Oyster mushrooms (*Pleurotus spp.*) in nature grow mainly in the temperate zones of the world on rotting trees such as robber tree, maple, poplar, birch, wild cherry, oak, elm, etc. They have a fragrant flavor including a good texture for various cooking purposes. The cultivation technique for oyster mushroom is simple and cheap due to simplicity of cultural steps and availability of growing substrate such as sawdust, straw, cornstalks, hardwood chips and other plant fibers, which have high cellulose contents. There are various growing methods for oyster mushrooms. In the household and small industry scale the mushroom farmers prefers to use sawdust culture.

7.1. Sawdust Culture

7.1.1. Mushrooms inoculate. Starts at the *P. cubensis* mycelium, which has been grown on an agar, plate. Potato dextrose agar (PDA) is the agar media. This contains Potato dextrose broth and regular agar at 1.5 g/L. The extract agar would be just as good or even some home made version of PDA. The agar was autoclaved at 121 ° C, 15 lb/in^2 ($1.03x10^5$ N/m^2) for 30 minute and then cooled to 50 ° C. At this temperature, the agar was aseptically poured into plates and allowed to cool and solidify. These plates can now be stored in a plastic bag in a cool location for as long as want. If there was any contamination, it should show up after about 3-4 days at room temperature. If there is none, then the plates are good to use for mushroom inoculated.

7.1.2. Substrate preparation, sawdust culture, sawdust to be used should be between six months and two years old. Sieve the sawdust and thoughtfully mix of sawdust with some components such as rice husk, Calciumoxide, Calciumchloride, and Calciumsulfate with add clean water in suitable ratio m/m, respectively.

7.1.3. Pasteurization. Compact the substrate in plastic bags, trays or beds. Using steam to increase temperature of the substrate no over than 100 ° C for at least 120 min and then keeps the substrate at 50-55 ° C for 3 days.

7.1.4. Spawning. When temperature of the substrate lowers down to 24 ° C, mix about 1 to 5 percentage of spawn (base on the wet weight of the substrate) thoroughly with the substrate, or place approximate 1 percentage of spawn 1 cm. underneath the substrate surface. Spawn may be purchased from supply companies or mushroom farmers.

7.1.5. Mycelium growth. Seal the bags, tray or beds. Keep them at 23-26 ° C in a dark condition for up to 4 weeks.

7.1.6. Pinhead formation. Lower the ambient temperature to 12-18 ° C depends on strain types grown. Introduce fresh air to lower CO_2 concentration and illuminate surface of the substrate (about 100 lux at substrate surface). Spray clean water if necessary to keep an air humidity of 90 percentage.

7.1.7. Fruiting body growth. One day later raise the temperature to 18-25 ° C for summer strains, or to 12-15 ° C for winter strains.

7.1.8. Yield. Yields may vary from 30 to 50 percentage of the net weight of substrate.

7.1.9. Storage. The oyster mushroom does not have long storage life. It is handled the same as regular mushrooms stored at 0 ° C with 95 percentage relative humidity.

8. Review Related Literatures

Rajeev Jopapur and K. Rajvanshi [9] studied on sugarcane leaf-bagasse gasifier for industrial heating application: the results of the studying are the Gasifier can handle fuel such as sugarcane leaf and bagasse. The system was experiment for >700 h under laboratory condition at 288-1080 MJ/h output level. The HHV of gas was 3.56-4.82 MJ/Nm^3 and produce char 24 vol% of original fuel. It can be to form an excellent fuel for wood stove. After successful laboratory trial, the system also experiments at a company, where it was retrofitted to an oil-fired furnace for testing specially ceramics. The furnace was operated exclusively on the gasification system and the product quality was on a par with, if not better than, that obtained during oil-fired operation.

Wipawan Sangsa-nga [10] studied of gas process for ceramics firing by updraft gasifier and downdraft gasifier: The result of the studying is the gasifier was 0.309 m^2 in volume and the airflow was fed at three difference flow rates at a constant temperature and pressure at 30 °C and 1 atm. The fuel consumption rate increased with increasing airflow rate, 3.0x10^{-3}, 4.0x10^{-3} and 5.0x10^{-3} m^3/s were 9,10.79 and 18 kg/hr, respectively. The CO gases produce were approximately 26.79,32.78,29.55% and the average heating values of gases were 4.07, 4.39, 3.86 MJ/N m^3, respectively.

The appropriate flow rate the produce gas was 4.0x10^{-3} m^3/s due to contributing the highest heating value. For glost firing, the final temperatures and the firing time for updraft and downdraft gasifier were approximately at 1185.6 and 1102 °C, and 600 and 540 minutes, respectively. The conclusion is the producer gas by updraft gasifier is better to be used as fuel for the ceramics firing process and some other industries.

Suree Jaroonsak [11] studied on heat utilization of producer gas from rubber tree wood downdraft gasifier for ceramics production: The results of the studying is the downdraft gasifier 0.28 m^3 can produce 82 MJ/hr at working time 8 hr, at difference airflow rate, 1.0 x10^{-3}, 3.0 x10^{-3} 5.0 x10^{-3} m^3/s (at 30 °C 1 atm), the average fuel consumption rates are 3.83, 5.33, 6.17 kg/hr, respectively. The corresponding higher heating value (HHV) and CO yield are 3.13, 3.26,3.52 MJ/N m^3 and 20.99%, 22.12%, 25.60% respectively. Three experiments are conduct for biscuit firing, the final temperature of the experiment was 800 °C and average firing time was 480 min. The maximum and average airflow rates are 3.67 x10^{-3} m^3/s and 1.61 x10^{-3} m^3/s, respectively. The average fuel consumption rate is 4.12 kg/hr. In case of glost firing, the final temperature is 1102 °C and firing time is 540 min. The maximum average airflow rates are 3.03 x10^{-3} m^3/s and 2.2 x10^{-3} m^3/s, respectively. The average fuel consumption rate is 4.11 kg/hr. The final temperature is 1102 °C lower than the meting point of ceramic coating, the surface did not become to glassy. In terra cotta, the final temperature of the experiment was 1030 °C, 1070 °C and 1110 °C and firing time is 540 min/batch. The maximum and average airflow rate are 2.87 x10^{-3} , 3.35 x10^{-3} , 3.78 x10^{-3} m^3/s and 1.51 x10^{-3},1.59 x10^{-3} ,1.7 x10^{-3} m^3/s, respectively. The corresponding fuel consumption rates are 3.38, 3.72, 3.78 kg/hr. The shape and size of product is smaller than factory product surface is not distinct.

H. Susanto, A.A.C.M. Beenackers, W.P.M. VAN Swaaij [12] studied a wood gasifier with internal recycle of pyrolysis gas. Air is introduced through a pipe from the top of the gasifier. This air also acts as the motive gas in the injector for suction of the recycle ash grate in the discharge of the injector. Recycle ratios in the range of 0.4 to 1.6 resulted in stable combustion of the recycle gas. Recycling pyrolysis gas to the air feed significantly reduced tar and further reduction of the tar content was obtained by using a separate combustor. Optimum recycle ratio was about 0.9 or below where tar was reduced from 1.4 without recycle to 0.05 g/Nm^3 with recycle.

R.O.Williams, J.J. Mehlschan, B. Jenkins [13] Ramming described the modification of a standard diesel engine to convert it to dual fuel operation on producer gas. A 6-cylinder, 4 stork, direct-injection diesel engine with 8.7x10^{-3} m^3 of displacement and a compression ratio of 14.5 to 1 were used. It was turbo-charged intercooled, had a power ratting of 202 bhp intermittent, 172 bhp continuos variable speed governor. The engine was coupled to a 100-kW alternator.

GEMCOR [14] reported that for stationary gasoline engines with gasifier, 1 kilogram of coconut shell charcoal is equivalent to 1 KW-h. For vehicles retrofitted with gasifiers, 1 kilogram of wood charcoal id equivalent to 1 liter of gasoline and single-cyliner 5-horsepower diesel engine consumed 0.1 to 0.9 kilograms of coconut-shell charcoal per KW-h at 80% substitution of diesel fuel by producer gas.

Kjellstrom [15] classified agricultural residues in four categories to their suitability for downdraft gasifier. The classification was based upon their tendency to slag ash during gasification. Corncobs, coconut shells and coconut woods were among those identified as good fuels, whereas rice hulls and many kinds of straw were among problematical fuels.

Vanichayakool [16] for instance found that the rice husk gasifier is impractical in manually operated gas producers due to its high ash contents and bulky nature. He compared quality of fuels and concludes that ipil-ipil chipped wood yielded. The best producer gas is followed by coconut shells, coconut woods, coconut fiber and rice husk.

M. Barrio and M. Fossum [17] described the gasifier in detail (500-mm height and 100 mm diameter). One of the singularities of the gasifier design is that it allows for variation of the point of air injection and that air preheating is also possible. The gas engine was originally a diesel engine but it has been modified for producer gas and/or natural gas operation. These changes mainly affect the compression ratio and the fuel injection system. The paper describes the gas engine and explains the modifications. Experiments have been performed of gasification of wood pellets. The feeding rate was about 5 kg/h, giving an effect of 30 kW. The amount of air supplied to the reactor has been varied in the experiments, in addition to the location of the supply. The fuel gas composition has been measured with a gas chromatography. The amount of product gas obtained is about 12.5 N-m^3/h and has a heating value of 4.9 MJ/N-m^3. From these data, the power produced by the gas engine is expected to be about 5 kW. The gas engine will be operated with mixtures of synthesis gas and natural gas and detailed measurements of cylinder pressure, compression ratio and heat released by the engine are planned in addition to emission measurements of CO, unburned hydrocarbons and NO_x. The dependency of the results on the ratio of synthesis gas/natural gas will further be evaluated.

R. Pletka, R.C. Brown and J. Smeenk [18] reported the experiments carried out in an indirectly heated biomass gasifier successfully demonstrated that using latent heat ballast could increase throughput and gas heating value. A mathematical model describing heat transfer and chemical reaction in the system was developed. The heat transfer submodel is accurate to within 13 K for both ballasted and unballasted scenarios. However, the chemical submodel, based on thermodynamic equilibrium calculations, proved inadequate and under predicted cooling times during the pyrolysis phase of the process by about 50%.

A. Zainal, R. Ali, and C. H. Lean [19] described the equilibrium modeling has been used to predict the gasification process in a downdraft gasifier. The composition of the producer gas and, hence, the calorific value has been determined. The effects of initial moisture content in the wood and the temperature in the gasification zone on the calorific value have been investigated. The predicted value compare reasonably well with experimental data.

J.M. Encinar, J.F. Gonzalez and J. Gonzalez [20] was studied the pyrolysis of Cynara carduncul us L with the aim of determining the main characteristics of the charcoal formed and the nature and quantity of gases produced. Variables investigated were temperatures between 300°C and 800°C, particle sizes between 0.4 and 2 mm diameter, initial sample weights between 2.5 and 10 g, and nitrogen flow rates between 100 and 300 cm^3/ min. Experiments were carried out isothermally. Under the conditions of this study, particle size, nitrogen flow rate, and initial sample weight generally did not exert any influence, whereas temperature was very significant. An increase in this variable led to an increase in the fixed carbon content, gases produced and, to a lesser extent, ash percentage. On the other hand, volatile matter and solid yields decreased with increasing temperature. The principal gases generated were H , CH , CO and CO_2. Heating values of both gas and solid phases were determined from gas composition and elemental analysis. The quality of charcoals and heating value allow the conclusion that the optimal temperature for pyrolysis should be between 600°C and 700°C. Finally, a kinetic study of the pyrolysis, based on gas generation from thermal decomposition of the residue, was carried out. From this model, rate constants for the formation of each gas and their corresponding activation energies were determined.

From the related literature and research, there are fixed bed gasifier and moving bed gasifier that can generate heat supply for industrials heat require and the simplest shape and design of the reactor is the fixed bed reactor that suitable for household and small industrials. So fixed bed gasifier, downdraft gasifier is used in this thesis. While comparison with updraft type, it is lower vapors of liquid organic products and tar and crossdraft type does not have this advantage, and downdraft designs serve to prevent the re-contracting of reaction products with the freshest feedstock which, suitable for oyster mushroom substrate wastes feedstock.