The 2013 World Congress on
Advances in Nano, Biomechanics, Robotics, and Energy Research (ANBRE13)
Seoul, Korea, August 25-28, 2013

The Industrial Biomass Combustor Design for Producing Heat in Dried Tuna Fish Production of Halla food Factory

*Sarayooth Vaivudh[1)] and Una Tontakulchanchai[2)]

[1), 2)] *School of Renewable Energy Technology , SERT, Naresuan University, Thailand*
[1)] *sarayooth_v@hotmail.com*

ABSTRACT

The industrial biomass combustor of Halla food factory, Thailand was designed by using thermal energy from the combustion to dry tuna fish product in the drying process of the factory. The tuna fish will be sliced to small pieces and place in a drying chamber which it's volume of 4.7x4.7x2.5 m^3. The drying chamber made from concrete room consisted with heat transfer tube for driving hot air inside the tube to warm the chamber. The biomass fuel was used acacia wood for burning in the combustor with consumption rate of 50.1 kg/h. The design of biomass combustor was set up for thermal energy for around 200 kW with the efficiency of around 32% The hot air driving pass from the combustor heat exchanger with the circulate flow in a closed loop tube between the combustor and the drying chamber that dries 2,680 kg of fresh tuna started with the moister content of 78.9% in wet basis to reach the final product which its moisture content of around 13.8% in wet basis for 5 days. The experimental result expressed that the fuel cost was decreased in the drying process comparing with fossil fuel. The drying temperature was controlled by the fuel consumption rate to set up at 70°C for keeping the product quality and the closed loop tube design by following the standard of benzo[a]pyrene (BaP) less from wood burning of the industrial process.

1. INTRODUCTION

Environmental clean technology of industrial production process is responsible for making the most important contributor to climate change by the fossil fuels burning. Many industries face to a crisis of fuels depletion resulting in high capital investment to the industrial process that requires more energy because the fuel price continues to increase. Some typical forms of energy used in the industrial processes are electricity and heat as elementary energy as use in some food factory such as Halla food (Thailand), a factory of smoked dry tuna fish in Thailand. This factory is one company in the group of

[1)] Professor
[2)] Graduate Student

the company that works on transform tuna raw material to be smoked dry tuna products, and finally exports to Korea for trading.

Fig. 1 Halla food (Thailand) Co., Ltd, Rayong, Thailand

Tuna industry is the forefront of the Thailand export qualities that important to Thai economy. In 2009, Thailand exported 534,491 tons of tuna products, with an export value worth USD $1,676.9 million which represents about 43.2 percent of the world's tuna market. However, the industrial process still uses more expensive fuel for drying tuna. For minimize this problem, the tuna industry set up a method for reducing fuel demand while seeking to substitute other forms of renewable energy. A renewable energy fuel for burning is biomass from acacia timber as firewood in a kiln and produce heat to drying chamber for substitute to electricity or other petroleum fuel.

Drying process is an important process in the tuna factory production that requires heat for producing hot air in the temperature range of around 50-90°C in the drying tuna cabinet. Thermal drying of tuna is characterized by a high energy consumption of the industry. Drying of tuna from wet material food to dry and smoked in the drying cabinet required standards of food production. The process of the industry includes washing, boiling and cutting tuna, and then feeding the tuna in a hot chamber that requires of no contamination by insects, dust and moisture that result to poor quality products. Thermal energy used in drying process from biomass combustion requires the cleaning performance from dirty smoke and some toxic contamination on the food product.

2. DRYING PROCESS AND MOISTURE CONTENT

The process of tuna drying started from cutting and sliced to small pieces and then removing the product waste and then boiling the flesh tuna raw material in a boiler before drying in the chamber with heat and smoke from the acacia firewood fuel burning in a combustor for transferring heat by the hot air into the drying chamber.

In the industrial drying process, the most energy consumption was drying the tuna that consumed around 90% of the whole heat whereas the surplus heat is 10% of boiled tuna before drying. The thermal energy consumption in the drying process was calculated from the heat of the water evaporate from the mass loss of tuna that related with the equation from wet basis drying (Tesfaldet Gebreegziabher et al, 2013)

$$M = \frac{m_w - m_d}{m_d} \qquad (1)$$

where M is the moisture content, %wb
m_w is the sample product mass, kg
m_d is the drying mass of the sample product, kg

For determining the tuna mass loss, the moisture content and the mass relation was derived in Eq.(2) as follow (Sarayooth V. and Sukruedee S,2011)

$$W_f = W_i \frac{1-M_i}{1-M_f} \qquad (2)$$

where W_f is the final tuna mass, kg
W_i is the initial tuna mass, kg
M_f is the final moisture, wb
M_i is the initial moisture, wb

From the data of Halla food industry product, tuna was dried in the drying chamber from the starting mass of 2,680 kg and the moisture content of 78.9 %wb (3.74 db) to the final mass when finished with the mass of 656 kg and the moisture content of 13.1%wb (0.15 db) The drying curve of moisture ratio in the dry basis (db) was shown in Fig. 2 for describing the drying performance of the product. Finally the energy was calculated in this drying data was 4626.4 MJ (Jompob W. et al., 2006)

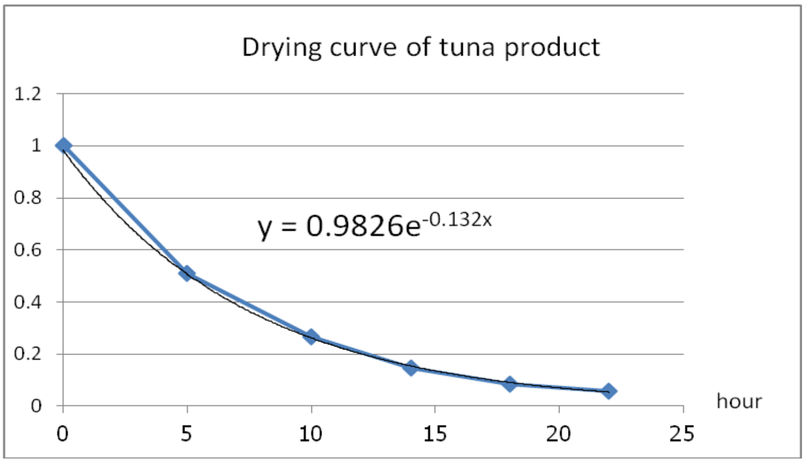

Fig. 2 drying curve of tuna product in 22 hours for 5 days

In particular of a drying tuna process sample from Halla food factory was informed as the total drying time of 5 days. In the first day the moisture content of fresh tuna was decreased by warm air in 5 hours and left in room temperature to reach the equilibrium alternately at the drying temperature of 90°C and the same performance repeated in the second day, but the temperature was reduced to 80°C. Similarly, the drying process was continued with the same process of lower drying temperature at 70°C, 60°C, and 50°C in the 3^{rd}, 4^{th}, and 5^{th} day respectively. Drying time in these three days were reduced to 4 hours and still left in room temperature alternately until the product reached the standard moisture content of around 13% wb (0.15 db) that corresponded with the water activity (a_w) of 0.6.

In fig. 2, the drying rate of tuna product was determined in exponential fitting curve according with the mathematical model of Henderson and Pebis (Siri Duanporn et al.,2012) when a is 0.982 where the model was following Eq. (3)

$$MR = a\,exp(-kt^n) \qquad (3)$$

where MR is the moisture ratio (simplified to M/M_0)

M_0 is the initial moisture content

M is the moisture content in dry basis, db

k = 0.132, and n = 1

3. **A COMBUSTOR DESIGN FOR DRYING ENERGY**

Thermal energy requirement for the drying process was calculated by using heat transfer principle (John H Lienhard IV and V, 2003) from the combustion of acacia wood fuel burning to produce heat and transfer by the hot air into the drying chamber. The result of total heat calculation from each day summation was around 4648.7 MJ. These data was related to the fuel mass by using a calculation of heating value as shown in the Fig. 3 for comparing the maximum energy on the first day and decreased every day with the fuel mass of 250 kg to 2.17 kg respectively.

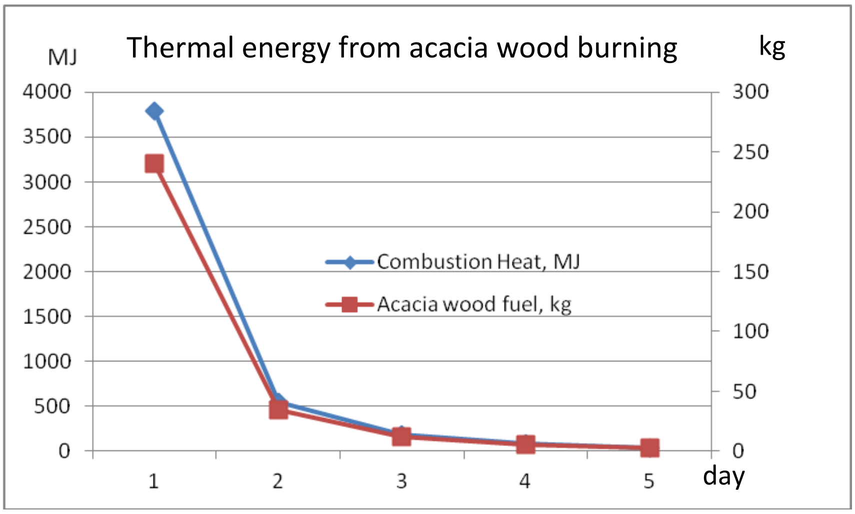

Fig.3 thermal energy from fuel burning in drying energy requirement

From Fig.3, thermal energy requirement from the combustion of acacia wood which the heating value of 15.8 MJ/kg. The combustion air volume was determined for achieving the complete combustion and the combustor size. The volume of air depended on the fuel mass by the principle of complete combustion with sufficient oxygen. A case of the fuel of 250 kg/day for drying fresh tuna from 2,680 kg to 1022 kg of the first day was consumed the combustion air of 4.54 m^3/h. Drying in the first day of tuna was done for 5 hours per day by the combustion heat of 790 MJ/h from the firewood of 50kg. The air inlet to the drying chamber was calculated for the volume of 0.62 m^3/s and was transferred heat to dry the product in the first day and decrease in next 5 days by the tube in a heat exchanger that located in the combustor.

The combustor structure was fabricated by firebricks and covered with concrete in the volume of 3 m^3 (1x2x1.5 m) for the maximum wood fuel of around 250 kg and the air requirement to meet a complete combustion. A tube which diameter of 15 cm was used to connect the combustor and the drying chamber for driving the hot air by a blower that located within the tube. A heat exchanger was placed in the combustor for transferring heat from the hot combustion air to the air inside the tube. The combustor power was varied with the fuel mass from 250 kg to 100 kg that produced heat of 219.4 kW to 109.7 kW which determined by the Eq.(4).

$$\dot{Q} = \dot{m}_f LHV \quad (4)$$

where $\dot{Q}$ is the power of combustion, kW
$\dot{m}_f$ is fuel mass rate, kg/s
LHV is the lower heating value of fuel, MJ/kg

The energy of combustor was transferred by the hot air to dry the product in the drying chamber. The hot air from the heat exchanger was flown to dry the product with the rate of 0.6 m^3/s to 0.1 m^3/s varied by the product as follow by the Eq. (5)

$$\dot{Q} = \dot{m}_a (h_f - h_i) \quad (5)$$

where $\dot{m}_a$ is the hot air flow rate for drying tuna, kg/s
h_f is the enthalpy of hot air, kJ/kg
h_i is the enthalpy of ambient air, kJ/kg

The combustor and connection tubes were installed by the design that mounted the tube to the heat exchanger for transferring heat by the air inside the tube. The hot air was flown from the heat exchanger to the drying chamber and circulated in closed loop back to the heat exchanger again for keeping clean drying air as shown in fig. 4

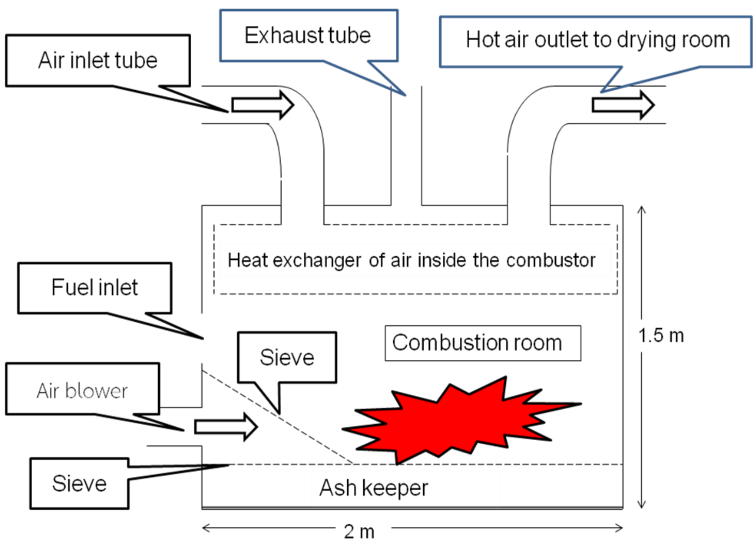

Fig. 4 the wood combustor and connection tube for drying product

The drying energy was depended on the tuna mass that it was controlled by the wood fuel mass and the blower of the hot air. Drying temperature in the drying chamber was controlled by the exhaust tube for removing the humid air from the drying chamber to reduce the drying air relative humidity.

4. EXPERIMENTAL SETUP

The data of combustion air flow rate was measured in the volume of 280 m^3/h when the maximum fuel of 250 kg per day with the consumption rate of 50 kg/h. An excess air was 1.23 and the whole air (280.4 m^3/h-140.2 m^3/h) was driven by the blower at the front of the combustor to the combustor. The drying chamber in each batch started to dry the various tuna fresh raw material. The experiment was set up for operate the combustor for producing heat to dry 6 batches of tuna that over 2,000 kg and dry for 7 days to meet the requirement final product with the high power performance of the combustor. The results of tuna drying performance were shown in table 1.

Table 1 Experimental results of drying tuna by the wood combustor energy.

No.	Starting product (kg)	Final Product (kg)	Drying energy (MJ)	Combustor power (kW)	Efficiency (ratio)
1	2378	582.08	4092.9	131.7	0.35
2	2472	605.10	4254.7	146.3	0.32
3	2210	540.96	3803.7	131.7	0.32
4	2419	592.12	4163.5	146.3	0.32
5	2434	595.80	4189.3	146.3	0.31
6	2114	517.46	3638.3	131.7	0.31
avg.	2337.8	572.25	4023.8	139.0	0.32

The drying rate of the smoked dry tuna product was left in the temperature of below 70°C for preventing high benzo[a]pyrene (BaP) that toxic for consumers. The combustor of firewood released this chemical from the wood burning in high temperature therefore the food product would be smoked after drying to avoid the toxic from high temperature burning. The combustor was not only produce heat but also smoke to meet favorite smell for consumers. From table 1 the wood combustor reached to the efficiency of average 32% for high amount of energy because of more tuna product. In the other case of lower product, the result would be changed to about 0.22 since the heat loss increased by the exhaust humid air removed out of the drying chamber.

5. CONCLUSION

The biomass wood combustor was designed for drying tuna product in Halla food factory. Tuna fish was the raw material of the process that started from the moisture content of around 78.9 %wb (3.74 db) in the mass of 2,680 kg to 656 kg at the moisture content of 13.1%wb (0.15 db). The energy was taken from the combustion in the wood combustor was around 150 kW at maximum power by the fuel consumption rate of 50 kg/h or 250 kg/d.

Heat from the combustor was transferred by hot air inside the tube that connected between the heat exchanger in the combustor and the drying chamber in the close loop circulation. In experiment of drying 6 batches in the factory product at average of 237.8 kg to 572.25 kg at the moisture content from 78.9%wb (3.74 db) to 13.8%wb (0.16 db), the combustor produced heat in average of 139 kW at the average efficiency of 0.32. In the case of product below 2,000 kg the combustor efficiency reduce to around 0.22 from the higher loss.

REFERENCES

V. Sarayooth and S. Sukruedee. (2011). "Biomass Bamboo Knot Furnace for Replacement to Heavy oil in Joss Paper Mill" 3rd Int. *Conf. on Addressing Climate Change for Sustainable Development through Up-Scaling Renewable energy Technologies*, October 12-14, 2011Kathmandu, Nepal.

Tesfaldet Gebreegziabher, Adetoyese Olajire Oyedun Chi Wai Hui. (2013). "Optimum biomass drying for combustion-A modeling approach" *Energy*, 53 (2013) 67-73

John H Lienhard IV and John H Lienhard V. (2003). *A Heat Transfer Textbook* 3rd Phlogiston press. Cambridge, Massachusetts.

Jompob Waewsak, Sirinuch Chindaruksa and Chantana Punlek. (2006). " A mathematical modeling study of hot air drying for some agricultural products" *Thammasat Int. J. Sc.Tech.,*Vol. 11. No. 1. Januarv-March 2006.

Siri Duangporn, Nattapol Pumsa-ard and Lamul Wiset. (2012). "Drying Equations of Thai Hom Mali paddy by using hot air, carbondioxide and nitrogen gasses as drying media" Food and Bioproducts Processing Vol. 90 (2012) 187-198.