Estimating the A Solar Assisted Drying System Capacity for Marine Products

SUPRANTO[1], M. H. RUSLAN[1], M.A.ALGHOUL[1],
M.Y. SULAIMAN[1], AZAMI ZAHARIM[2] AND K. SOPIAN[3]
[1]Solar Energy Research Institute,
[2]Head for Renewable Energy Resources and Social Impact Research Group
Solar Energy Research Institute, and
Head Centre for Engineering Education Research
Faculty of Engineering and Built Environment,
[3]Director of Solar Energy Research Institute,
Universiti Kabangsaan Malaysia
43600, Bangi, Selangor
MALAYSIA
supranto@yahoo.com, azaminelli@gmail.com

*Abstract :-*The procedures for estimating the capacity of a solar drying system using arrays of double pass collector were presented. The drying system has been designed for drying of wet fish with moisture content about of 76% to 25% moisture content, for drying time of about 16 hours. The dryer has three major components, the solar collector, the auxiliary heater/control system, and the drying chamber. The blower is used for flows the hot air to the drying chamber. The solar collector was designed is a double-pass solar collector with porous media. The collector array consists of 3 collectors in series and 2 rows in parallel. The dimension of each collector was 1.20 m in width and 2.40 m in length. The estimated capacity of this system is about of 100 kg wet fish with 76% moisture content wet basis (initial) to 25 % moisture content wet basis (final) as dried product.

Key word:- Solar drying system, double-pass solar collector, fish drying.

1 Introduction

Fish is one of the sea products with high protein and low fat. Fish has traditionally been view as a source of high-quality animal protein, supplying approximately 6% of global protein requirement and 16% of total animal protein (Ayyappan & Diwan, 2003). The composition of fresh fish is about of 76.0% water, 17% protein, 4.5% fats, and 2.52-4.5 of minerals and vitamins (Anonim, 1979). Fish is highly perishable with a short storage life. Cooling is a widely used and important preservation technique to maintain quality and prevent spoilage (Dincer, 1995) and the simplest method of cooling of fish is icing (Jain, *et al.*, 2005). When, the fresh fish is not utilized by consumers and converted into finished product then it remains surplus and goes waste. Spoilage of fish is caused by enzymatic decomposition, bacterial action, and oxidation reaction. Enzymes are powerful biological chemicals that occur in the tissue of all living animals. The enzymes will start attacking the flesh of the body, breaking large compounds down to smaller ones, just like the process of digestion. Enzymes can only operate in the presence of water. They are also sensitive to temperature.

Bacteria or germs are tiny living organisms that are found everywhere in the nature. A problem in the handling of food not only do they spoil food, but they can cause food poisoning. Fish carry millions of bacteria on their external surfaces (skin and gills) and in their intestine. A healthy, living fish uses its natural defense mechanism to protect it against the harmful effects of bacteria. However, when the fish dies, the defense mechanism is stop working. This allows the bacteria the opportunity to feed on the flesh, multiply in their millions, and eventually spoil the fish.

Rancidity is a more widely-used term for oxidation reaction. It occurs when oxygen in the air reacts with oil or fat in the flesh of the fish. This leads to a sour or stale, unpleasant smell or taste. When frozen, fatty fish are store improperly they can still spoil through oxidation, even though the temperature is too low for bacteria to grow or enzymes to work effectively.

When, the fresh fish is not utilized by consumers and converted into finished product then it remains surplus and goes waste. Around 20% of fish is wasted due to poor and insufficient methods of cold storage and improper post harvest practices (Prakash *et al.*, 2003). For extend the saved period of fish may be used cooling or freezing process. By this process, fish may have longer saved period. Not all of bacteria will death by cooling and freezing. So the frozen product must be handled by cooling chain, start from storage, transport, and sale. This method is very expensive. The other process for fish preservation are salting process, smoking process, and drying process. One of the cheaper processes for fish preservation is drying. Drying is an excellent way to preserve food. This paper presents the procedures in estimating the capacity of s drying system using the double-pass solar collector suitable drying of fish.

2 Water activity

Water activity is the main factor of numerous important food processing operations, such as microbial growth, toxin formation, enzymatic and non-enzymatic reactions. It is the availability of water for microbial, enzymatic or chemical activity that determines the shelf life of food and this is measured by the water activity of a food also known as the relative vapor pressure (Fellows, 2000).

Water activity (A_w) is defined as the ratio of vapor pressure of water (P) in a food to the saturated vapor pressure of water (Ps) at the same temperature.

$$A_w = P/P_s \qquad (1)$$

The water activity is a function of moisture content in food and temperature and water connections in food can be defined by water activity as follows:

Free water $A_w = 1.0$
Loosely bound water $A_w > 0.7$
Moderately bound water $0.3 < A_w < 0.7$
Tightly bound water $A_w < 0.3$

Measurement of water activity implies cognition of many factors such as vapor pressure, osmotic pressure, freezing points depression, boiling point elevation, psychrometric assessments (dew point and wet bulb depression) and suction potential. Salunkhe, et al. (1991) proposed the following water activity values:

It is also reported that almost all microbial activity is inhibited below $A_w = 0.6$, most fungi are inhibited below $A_w = 0.7$, most yeasts are inhibited below $A_w = 0.8$ and most bacteria below $A_w = 0.9$. The interaction of Aw with temperature, pH, oxygen and carbon dioxide, or chemical preservatives has an important effect on the inhibition of microbial growth (Fellows, 2000, Wang & Bremen, 1991).

Table 1**.** Food classification according to moisture contents

A_w	Moisture content	Food	Characteristics
>0.7	>30%	High moisture	Soft, must be heated to prevent microbial growth
0.85	20-30%	Interme-diate	Semi-moist, firm, prone to Maillard reactions, less susceptible to fat oxidation than low moisture food
<0.7	<20%	Low moisture	Hard, firm, resistant to microbial growth and less prone to Millard reactions, prone to fat oxidation

Salunkhe, et al., 1991

3 Drying methods

Drying can take place under the sun and wind (natural drying) or in the mechanical dryer. Salting helps the drying process too, as it binds the water, making it unavailable to bacteria. Drying preserves foods by removing enough moisture from food to prevent decay and spoilage. When drying fish, the key is to remove moisture as quickly as possible at a temperature that does not seriously affect the quality, texture and color of the fish. If the temperature is too low in the beginning, microorganisms grow before the fish adequately dried. If the temperature is too high and the humidity is too low, the fish may harden on the surface. This make difficult for moisture to escape and the fish does not dry properly. During drying two processes take place simultaneously such as heat transfer to the product from heating source and mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air. In drying processes heat transfer by conduction, convection and radiation. For drying with flowing air, the heat is transferred by convection. The heat transfer constant by convection can be estimated using equation (2)(Gardner, 1982).

$$h_c = 0.0128\, G^{0.8} \quad (2)$$

Heat is supplied to the dried material for change water from liquid phase to vapor phase. The weight lost by drying may be estimated using equation 3.

$$\frac{dW}{d\theta} = \frac{[h_c(T_d - T_w)]}{\rho_b L h_{fg}} \quad (3)$$

The vapor transfer by diffusion, the rate of diffusion has been estimated by Strumillo and Kudra (1986), the equation is expressed as equation 4.

$$W_D = k_g\,(Y_{st} - Y) \quad (4)$$

The water move both inside the material and on the material surface. Inside the material, water flow to the surface via the pore of the material. Convective heat and mass transfer coefficient was a function of moisture removal, physical properties of moist air, operating temperature and surface area (Jain, 2006). In the surface, water change to vapor phase, so the vapor pressure at the surface is saturated (Mujumdar and Menon, 1995). Absolute humidity on the surface may be estimated using equation (5).

$$Y_s = \frac{P_W^0}{P - P_W^0} \cdot \frac{M_W}{M_G}. \quad (5)$$

And absolute humidity of drying air is show as equation (6)

$$Y_s = \frac{P_W}{P - P_W} \cdot \frac{M_W}{M_G}. \quad (6)$$

The energy supplies from the drying agent to the dried material. This energy is used for change phase of water from liquid phase to vapor phase. Lopez (1998) expressed the heat transfer at equilibrium state as equation (7).

$$m_v h_{fg} = m_u C_p (T_{ou} - T_{ok}) \quad (7)$$

Equation (7) shown that increasing of air temperature will increase of the drying rate.

The basic essence of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain period of time, normally regarded as the safe storage period (Ekechukwu, 1998). The advantages of dried foods are:

1). Extended shelf life because of inhibition of microbial and enzymatic reaction

2). Providing consistent product the seasonal variation are diminished

3). The dried product size, shape and form are modified and the price is constant throughout the year

4). Substantially lower cost handling, transportation and storage

5). Dried foods can be packed in recycle packages; this is not always done with fresh food.

But during drying, the changes associated with physical and biochemical structure are inevitable because the food subjected with thermal, chemical and other treatment. Drying is one of the most energy intensive unit operations and consequently many research works have been carried out to explore the possible energy utilization. Usage of renewable energy technologies has received considerable attention within the past five years for their potential to help basic needs in many countries. Also use of renewable energy today is much more desirable because most of other alternative sources of energy have adverse effect on the environment and are in most cases more expensive (Basunia and Abe, 2001).

4 Solar Assisted Drying System

The solar drying system as show in figure 1. The main components are solar collector array, auxiliary heater, blower, and drying chamber.

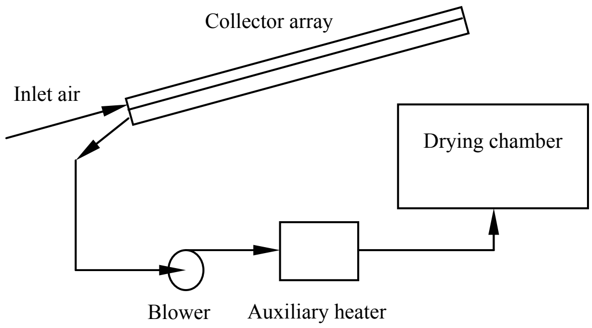

Fig. 1. Schematic of experimental setup

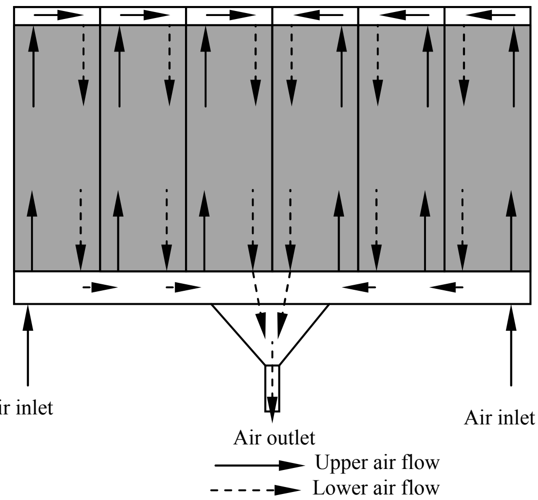

Fig. 2. Array of collector

5 Material Balance

Solar assisted drying system with porous media had been tested (Supranto, 2000), for drying of oil palm fronds. The collector surface area of about 17.28 m^2 and average solar radiation 550 W/m^2, the experiment data as follow:

1). Ambient air T_{dry} 30° C, T_{dew} 25° C.
2). Inlet temperature of air to the dryer 70°C
3). Outlet temperature of air from the dryer 50° C, with 90% relative humidity
4). Air flow rate 0.095 kg/s

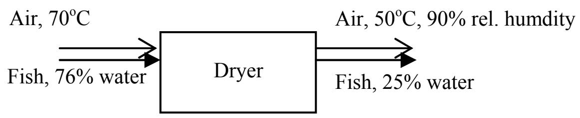

Figure 2. The Schematic of drying process

From psychrometric diagram, moisture content of inlet air 0.020 kg H_2O/kg drying air and moisture content of outlet 0.075 kg H_2O/kg dry air.
Evaporation capacity 18.438 kg H_2O/h
For fish drying the estimate capacity is about 100 kg fish, for drying time of 16 hours

6 Conclusions

The parameters used to estimate the capacity of the dryer are: solar radiation, air flow rate, air humidity, drying temperature, fish size, thick of fish bed, capacity of fish will be dried. Solar radiation is the energy source to the collector. Solar energy from the sun radiation is compared to energy for heating the air in the solar collector. Increasing solar radiation will increase the amount of energy to the collector. Fat content of the fish is the important variable for drying, fish with thick fat content more difficult to dry then the thin one. The drying system using double-pass solar collector with porous media consist of 6 collectors array, 3 collectors in series and 2 rows in parallel may dry 100 kg wet fish from 76 % moisture content to 25 % moisture content, for of about 16 hours drying time.

Nomenclature

A_w	water activity
C_p	heat capacity of air, kJ/kgK
G	air flow rate, kg/s
h_c	convective heat transfer coefficient, W/m^2K
h_{fg}	heat evaporation of water, kJ/kg
k_g	mass transfer coefficient, kg/m^2s
L	length, m
m_u	mass of drying air, kg
m_v	mass of evaporated water
M_g	molar mass of dry air, kg/mol
M_w	molar mass of water, kg/mol
P	total pressure, Pa
P_w	partial pressure of water vapor, Pa
P^o_w	saturated water pressure, Pa
T_d	dry bulb temperature, K
T_{ok}	inlet temperature, K
T_{ou}	outlet temperature, K
T_w	wet bulb temperature, K
Y	humidity,
Y_s	saturated humidity
ρ_b	air density, kg/cm^3

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