isabe
Yogyakarta, August 28-29 2013

The International Symposium on Agricultural and Biosystem Engineering

Proceedings

Supported by:

Fakultas Teknologi Pertanian UGM

Korean Society for Agricultural Machinery
사단법인 한국농업기계학회

Sponsored by:

ASTRA AGRO LESTARI

WINGSFOOD

ISBN : 978-602-14315-0-4

Editor:

Lilik Sutiarso
Murtiningrum

Proceedings
The International Symposium on Agricultural and Biosystem Enginering 2013

Theme:
Improving The Role of Agricultural and Biosystem Engineering
Toward Food & Energi Self-Sufficiency and Sustainable Agriculture

© Publised by:
Jurusan Teknik Pertanian, Fakultas Teknologi Pertanian
UNIVERSITAS GADJAH MADA

Copyright Law Protected

Don't to quote, reproduce and translate some or all of these books
without the permission of the publisher

First Edition: 2013

ISBN : 978-602-14315-0-4

isabe

MAIN PAPER

Informatization Agriculture in Japan
Author : Takashi Okayasu
read

Sub-Theme : Post Harvest and Food Engineering

A-7
Continuous Dehumidification of Organic Sorbent Powder in Two Connected Fluidized Beds with a Cooling and a Heating Pipe
Authors : Sukmawaty, Syahrul
read

A-8
Method of Waxing on Quality and Shelf-life of Semi-cutting Mangosteen in Low Temperature Storage
Authors : Usman Ahmad, Emmy, Darmawati, and Nur Rahma Refilia
read

A-9
Acidified Sodium Chlorite Treatments for Improving Shelf-life of Unripe Shredded Papaya
Authors : Vinod K. Jindal, Pompailin Sinrat and Nipon Chamchan
read

A-10
Fighting for Malnutrition in Indonesia by Production of Artificial Rice Based on Arrow Root and Cassava with Addition of Cowpea
Authors : Danial Fatchurrahman, Wenny Bekti Sunarharum, Anugerah Dany Priyanto, Fathy Fasial Bahanan
read

A-11
Product Features and Cost Analysis of MOCAS (Modified Cassava Starch) Based Bakery Products
Authors : Darmawan Ari Nugroho, Ibnu Wahid FA
read

A-12
Fuel Feeding Rate Controlling Base on The Temperature Distribution Simulation on Rosella Pod (*Hibiscus sabdariffa linn*) Drying Process
Authors : Dyah Wulandani, Leopold Oscar Nelwan, I Made Dewa Subrata
read

A-13
Identification of Determinant Factors in Processing and Technology: A Case Study of Fruit Processing Industries (FPIs) in Indonesia
Authors : Ida Bagus Suryaningrat
read

A-14
Profile of The Peanut Moisture Content During Deep Bed Drying
Authors : Ansar, Sirajuddin,Widhiantari
read

A-15
Effect Lindak Cacao Fruit Maturity (*Theobroma Cacao F.*) With High Level of Polyphenols as Antioxidants

Authors : Jumriah Langkong and Mulyati M. Thahir
read

A-16

Study of Active Packaging System by Using Ethylene Adsorber to Prolong The Storage Life of Avocado Fruits (*Perseaamericana Mill*)
Authors : Lilik Pujantoro, andi Nurfaidah and Yadi Haryadi
read

A-17

The Development of Technology Bundle in Packaging of Export Quality of Mangosteens' Transportation
Authors : Ni Luh Yulianti and Gede Arda
read

A-18

SynThesis of Chitosan-Ag+ as Antibacterial Material
Authors : Shinta Rosalia Dewi, Sri Juari Santosa and Dwi Siswanta
read

A-19

Development of Coffee Beans Caffeine Extraction Using Pressure and Temperature Controllable Reactor
Authors : Sukrisno Widyotomo
read

A-20

Optimization of The High Refined Cellulose Process Production from The Sago Fiber Waste by a Delignification Process Involving Nitric Acid, Sodium Hydroxide and Hydrogen Peroxide as The Delignificating Agent
Authors : Supranto
read

Fuel Feeding Rate Controlling Base on The Temperature Distribution Simulation on Rosella Pod (*Hibiscus sabdariffa Linn*) Drying Process

Dyah Wulandani, Leopold Oscar Nelwan and I Made Dewa Subrata
Department of Mechanical and Biosystem Engineering,
Bogor Agricultural University, Indonesia. E-mail:
dwulandani@yahoo.com

Abstract

This paper is concerned to the energy balance analysis of single drying process of rosella pod using solar energy dryer. The study is aimed at determining of the optimum biomass fuel feeding rate in order to retrench the energy consuming of rosella drying. Using first law of thermodynamic, energy balance analysis was performed to estimate the temperature of; drying chamber, product and heat exchanger during drying process; and the impact of fuel feeding rate of biomass to the drying temperature. Temperature is the important parameter of convection drying that influences the dried product quality. The result showed that predicted values of drying chamber temperature are in reasonable agreement with experimental data that is shown by standard deviation value of 2.9^{o}C. Ten scenarios of drying simulation were conducted to reveal the operation conditions of rosella pod drying. The simulation calculation found that drying temperature can be controlled by biomass combustion rate by using biomass feeding adjustment. The drying simulation with air flow rate of 0.39 kg/s, drying temperature of 50^{o}C and drying time of 29 hours and mass of rosella pod of 200 kg needs the average of biomass combustion rate of 5.5 kg/h without adjustment. By adjustment of biomass feeding for 1 kg every 15 minutes, the average of biomass combustion rate can be reduced to 4.3 kg/h, so the energy supply is reduced and the increasing of drying efficiency resulted for the later treatment is about 3 %.

Keywords: Biomass fuel feeding rate, simulation, temperature, drying, rosella pod..

Introduction

The available of abundant solar energy in Indonesia at average of 4.50 kWh/m^2/day (Abdullah, 1999), is worth energy resource to be applied in agricultural sectors. There are several fields of application of solar thermal energy (Munir and Hensel, 2010; Jain, 2005, Wisniewski, 1999). Solar drying of agricultural product is become an appropriate alternative for drying of agricultural product. Due to the low temperature and dependency of weather of solar thermal energy application, biomass energy will be important as energy resource cover for solar thermal energy, especially keeping for the continuity of dried product outturn. Bennamoun and Bellhamri (2003) used additional heater for solar dryer has shown good improvement in the obtained results. It allows using the solar dryer in un-favorable climatic conditions . Utilization of both of energy resources is very important to specify the drying air temperature. Proper drying temperature influenced the dried product, especially of moisture content of dried product. The high temperature may resulted several spoilages of dried product such as burning or case hardening, however low temperature cause the growth of mold and pathogen microbiology. In order to gain the proper drying air temperature, it is necessary to control the rate of biomass energy input within the drying system, by adjusting the feeding rate of biomass fuel. The controlling of operating system of feeding rate of biomass fuel intends to prevent energy loss, hereinafter to increase the drying efficiency.

Several topics of research, especially design and performance test of dryer have been carried out (Wulandani, et al., 2009, Wulandani, et al.,2005, Nelwan, 2005, Ratnawati, 2003, Mursalim, 1995, Abdullah, et al., 1994), however the modeling of feeding rate of biomass fuel has not been explained in detail yet, therefore the aim of the research is to determine the modeling of biomass feeding rate into the burner as additional heating of green house effect solar dryer and to simulate biomass feeding rate at several scenarios of drying operation, in order to obtain the drying operation effectively.

Materials and methods

This study is base on the experiment result of rosella pod drying in the green house effect solar dryer have been conducted at our previous research (Wulandani, et al, 2009). The experiment was carried out at field laboratory (Soewardi Soepardjo Laboratory), Department of Bio-system and Mechanical Engineering, Faculty of Agricultural Technology, Bogor Agricultural University, Indonesia.

Sample and apparatus

The sample used in the former research was rosella pod *(Hibiscus sabdariffa L.)* and biomass. Measurement of temperature, RH, airflow velocity, solar irradiation, mass and moisture of product were implemented by thermocouple (CC type), thermo-recorder, anemometer, pyranometer, adiabatic bomb calorimeter digital electric balance and drying oven. The green house effect solar dryer was the main apparatus designed by Wulandani, et al. (2009). Figure 1 shows the dryer consists of; a drying chamber is a transparent building (dimensions of t =3.065 m, l =1.855 m, p = 4.45 m), 144 trays (dimensions of p = 0.5 m , l = 0.6 m), four blowers and an absorber plate were located on the drying floor, heat exchanger and burner. The dryer was designed to dry 400 kg of rosella pod.

Figure 1. The green house effect solar dryer

Methods and data analysis

The research is carried out at several stages as described at Figure 2. First stage is started by governing equation modeling of energy balance within drying chamber. Solution of differential equation is by numerical method analysis. Next stage, the simulation result drying temperature is verified by compared that to the measurement result during drying process. Further, base on the modeling, ten scenarios of operating condition of drying process are simulated to estimate the pattern of fuel feeding rate input into burner.

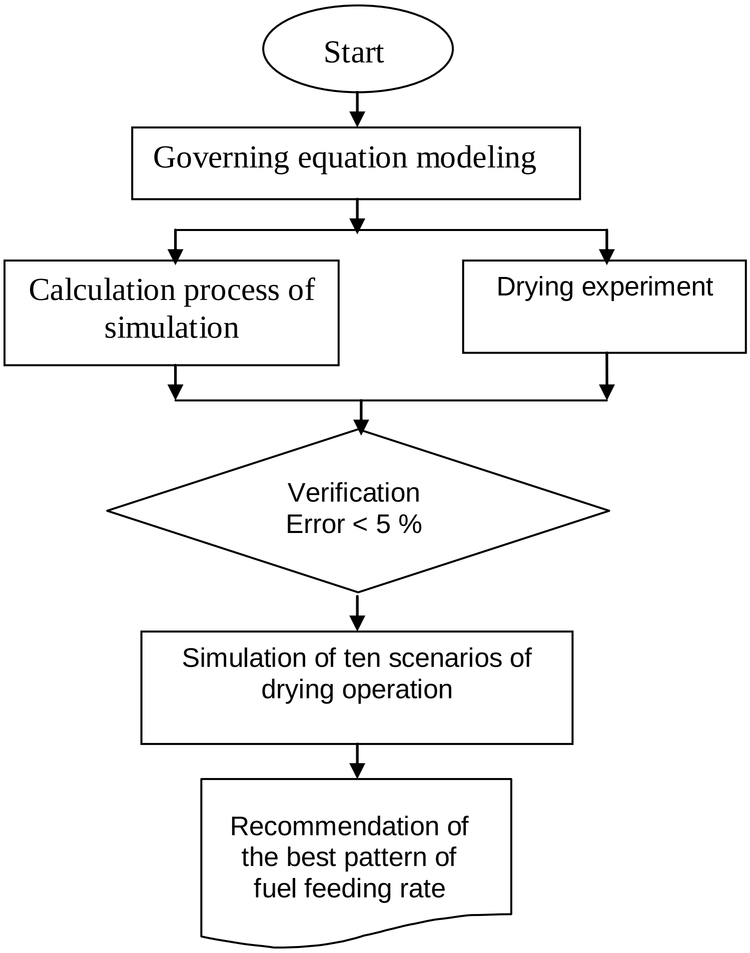

Figure 2. Flow diagram of research stages

Results and discussion

Drying experiment

The dryer was tested to dry of 32 kg of rosella pod. Fresh rosella was dried from initial moisture content of 89.9 % wet basis to 12.3 % wet basis during 28 hours (4 days) at average drying temperature of 43°C and ambient temperature of 32°C. Relative humidity of drying air was 52 % and air mass flow rate was 0.39 kg/s. Temperature of drying chamber air were found to be in the range of 34°C to 55°C. The drying process occurred at overcast condition which was represented by average of solar irradiation values of 46 W/m^2. Firewood combustion was used as additional heating energy at combustion mass flow rate of 2.5 kg/h. Energy consumption of rosella pod drying was still high about 49 MJ/kg of water evaporated from product, due to heat loses at the burner (Wulandani, et al., 2009). Temperature distribution of; drying air, heat exchanger and product were measured every 30 minutes was used as comparison to verify the simulation modeling.

Mathematical modeling

In order to simplification of actual condition, the simulation modeling have several assumptions, whereas drying temperature, heat exchanger temperature, product temperature are uniform at any location in the drying chamber. Thermal properties of each component are constant at any temperatures. The simulation is solved by quasi-steady numerical method. The boundary system of simulation is the dryer consisted of a transparent building, the rack of product dried, heat exchanger, absorber, and burner. Governing equation modeling developed is modified the equation based on the energy balance among the dryer components (Abdullah, et al. 1994) as represented by following several equations.

a) Energy balance for drying air

The ambient air entered into drying chamber and heated by heat exchanger, leads an exchange between the drying air, product and transparent wall:

$$(m\,Cp)_r\, dT_r/d\theta = (m\,Cp)_a\,(T_a - T_r) + U_{HE}\,A_{HE}\,(T_{wHE} - T_r) + U_{HEa}\,A_{HEa}\,(T_{HEa} - T_r) + U_{pr}\,A_{pr}\,(T_{pr} - T_r)$$

b) Energy balance for water in the solar collector pipe

The solar concentrator collects thermal energy from the solar irradiation. Thermal energy is stored in the water within the pipe and flowed into drying chamber through heat exchanger-1 and drain to hot water tank, furthermore the water is flowed-back to the collector. A part of energy losses to the ambient:

$$(m\,Cp)_{wk}\, dT_{wk}/d\theta = (m\,Cp)_{wt}\,(T_{wt} - T_{wk}) + (m\,Cp)_{wHE}\,(T_{wHE} - T_{wk}) + Fr\,I\,\tau\alpha\,A_k + U_k A_k (T_{wk} - T_a)$$

c) Energy balance for hot water tank

$$(m\,Cp)_{wt}\, dT_{wt}/d\theta = (m\,Cp)_{wt}\,(T_{wk} - T_{wt}) + (m\,Cp)_{wHE}\,(T_{wHE} - T_{wt}) + U_t A_t (T_a - T_{wt})$$

d) Energy balance for heat exchanger 1

Heat exchanger 1 (HE) is the system air-water heat exchanger. Hot water is circulated from the solar collector (concentrator) into HE. Solar irradiation gives the thermal energy to the HE system directly:

$$(m\,Cp)_{wHE}\, dT_{wHE}/d\theta = (m\,Cp)_{wt}\,(T_{wt} - T_{wHE}) + (m\,Cp)_{wk}\,(T_{wk} - T_{wHE}) + I\,\tau\alpha\,A_{HEw} + U_{HEw} A_{HEw} (T_r - T_{wHE})$$

e) Energy balance for heat exchanger 2

Heat exchanger 2 (HEa) is the system air-air heat exchanger. Ambient air is heated by HEa due to the biomass combustion within the burner, and then flowed into the drying chamber:

$$(\dot{m}\ Cp)_{wHEa}\ dT_{wHEa}/d\theta = m_r\ Cp_a(T_a - T_{wHEa}) + U_{HEa}\ A_{HEa}\ (T_r - T_{wHEa}) + \dot{m}_{bb}\ H_{bb}\ \eta_b$$

Where:	A	=	Area (m^2)
	Cp	=	Specific heat (J/kg ^oC)
	m	=	Mass (kg)
	T	=	Temperature (^oC)
	θ	=	Time (dt)
	a	=	ambient
Subscript:	bb	=	biomass
	HE	=	Heat exchanger
	k	=	collector
	r	=	Drying room
	t	=	Tank
	w	=	Water

Verification of simulation

The comparison between simulation modeling and actual measurement of drying air temperature and product temperature are presented in Figure 3 and 4, respectively. Simulation and measurement data takes place for 8 hours at daylight, started from 8 am until 4 pm. Although there are any discrepancy between simulation and measurement results, however residual error and standard deviation doesn't give the significant value. The residual error analysis results between simulation and measurement data for drying air temperature, heat exchanger (HE-2) temperature and product temperature are 9.2 %; 1 % and 8.7 % respectively, whereas the standard deviation are 2.89^oC, 0.43^oC and 2.57^oC, respectively. Base on the value of residual error and standard deviation of temperature, the modeling could perform well the actual condition of temperature distribution.

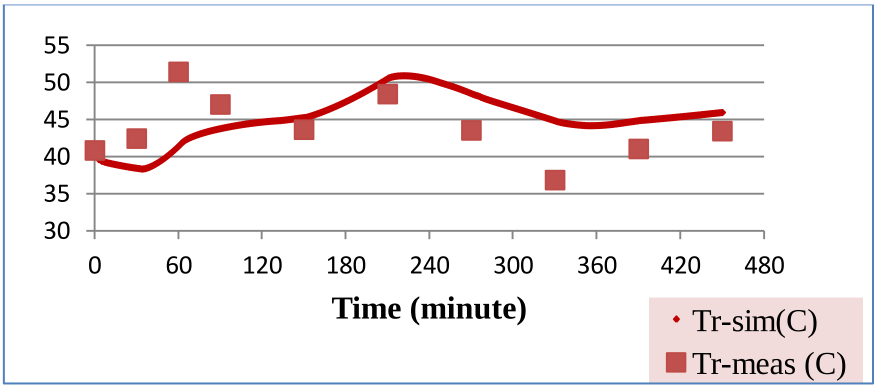

Figure 3. Comparison between simulation and measurement result of drying air temperature

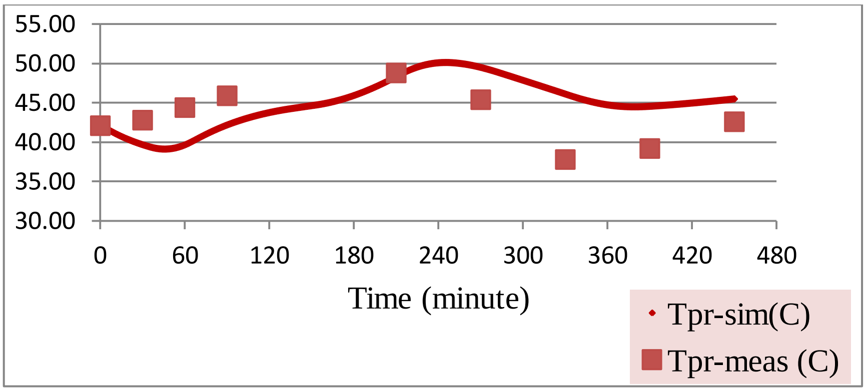

Figure 4. Comparison between simulation and measurement result of product temperature

Influence of the pattern of biomass fuel feeding rate

Base on the distribution of temperature as output simulation, four scenarios of simulation output were performed to determine the best pattern of biomass fuel feeding rate into burner.

1) *Scenario 1: feeding rate of biomass fuel at every 15 minutes for dried of 32 kg of rosella pod*
2) *Scenario 2: feeding rate of biomass fuel at every 30 minutes for dried of 32 kg of rosella pod*
3) *Scenario 3: feeding rate of biomass fuel at every 1 hour for dried of 32 kg of rosella pod*
4) *Scenario 4: feeding rate of biomass fuel at every 2 hours for dried of 32 kg of rosella pod*

The simulation intends to obtain constant drying air at 50^{o}C by implemented the adjustment of biomass fuel feeding rate. By using similar input parameters with actual condition, the simulation results of drying air temperature of four scenarios are presented in Figure 5. Biomass rate resulted by simulations are similar of 3.7 kg per hour.

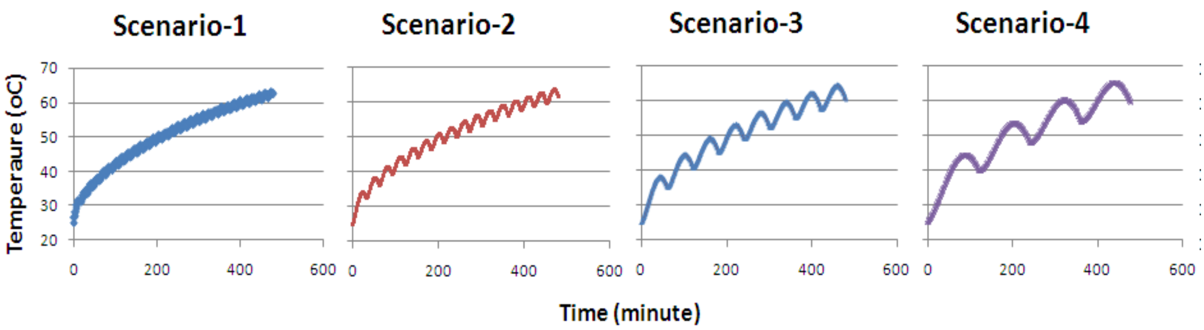

Figure 5. Simulation result of drying air temperature by adjustment of biomass feeding rate

In Figure 5, increasing of interval of feeding rate increases temperature variation which is indicated by standard deviation of 0.9^{o}C, 1.7 ^{o}C, 2.9 ^{o}C, and 4.8 ^{o}C, respectively for scenario 1, 2, 3 and 4. It shows that Scenario 1 gives the best drying temperature uniformity indicated by the least value of standard deviation of 0.9^{o}C.

Influence of adjustment of biomass feeding rate

Drying temperature is important parameter to produce the best quality of product, hence proper drying temperature is necessary to achieve during drying process. Controlling of biomass feeding rate is need to be carried out in order to result the appropriate drying temperature. Simulation scenario 5 and 6 show the influence of adjustment of biomass feeding rate to produce constant drying temperature as depicted in Figure 6 and 7. In scenario 5, biomass is input at constant value, whereas in scenario 6, rate of input biomass is controlled and lead to constant drying temperature.

1) *Scenario 5: Feeding rate of biomass fuel at every 15 minutes for dried of 200 kg of rosella pod (Without adjustment)*
2) *Scenario 6: feeding rate of biomass fuel at every 15 minutes for dried of 200 kg of rosella pod (Using adjustment)*

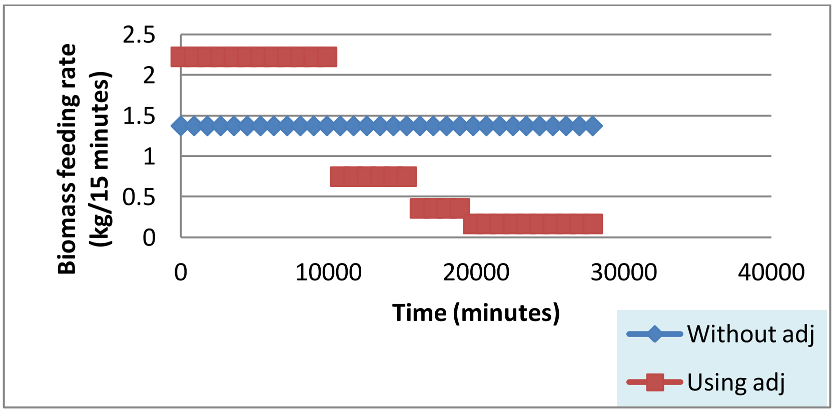

Figure 6. Comparison of biomass feeding rate pattern between both treatments (adjustment and without adjustment treatment)

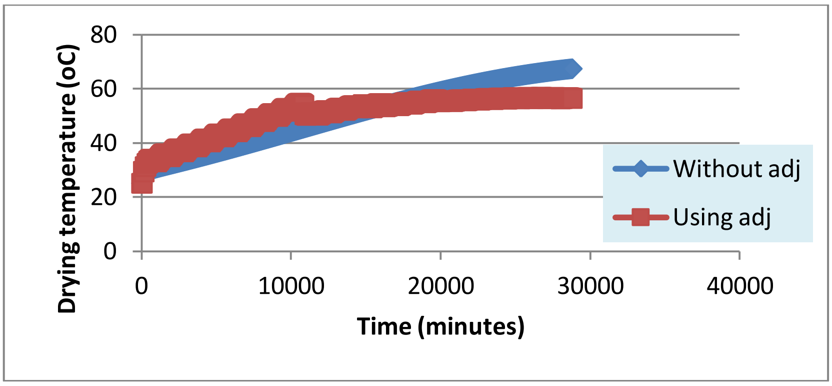

Figure 7. Comparison of drying temperature pattern between both treatments (adjustment and without adjustment treatment)

Both treatments gives an impact to the biomass consumption, moreover influences the drying efficiency. The simulation performed the drying of 200 kg of rosella pod, from moisture of 90 % wb to 10 % wb, required the drying time of 29 hours. The drying time at present work is less than that was resulted another researcher of 36 hours (Janjai and Tung, 2005) for dried rosella flower, from moisture content 96 % wb to 16 % wb, at similar drying capacity using solar collector integrated dryer. The calculation results biomass consumption of 5.5 kg/h and 4.3 kg/h, respectively for both treatments (without adjustment and using adjustment). Drying efficiency is the ratio of energy use to evaporate the moisture from the product to the energy supplied to the dryer. The drying efficiency of both treatments is therefore 14 % and 17 %, respectively for "without adjustment" and "using adjustment" treatment. Therefore increasing of drying efficiency after adjustment is 3 %, furthermore the saving of energy consumption is 18% (from 11 MJ/kg water to 9 MJ/kg water). The best treatment by using adjustment of input biomass is then used to simulate the next scenarios.

Influence of adjustment of the capacity of product

Base on the best pattern of fuel feeding rate at every 15 minutes and adjustment of input biomass, hence the last four scenarios are simulated to show influence of product capacity. The simulation is destined to produce constant drying temperature of 50^{o}C.

1) *Scenario 7: Dried of 100 kg of rosella pod*
2) *Scenario 8: Dried of 200 kg of rosella pod*
3) *Scenario 9: Dried of 400 kg of rosella pod*
4) *Scenario 10: Dried of 400 kg of rosella pod during daylight and night*

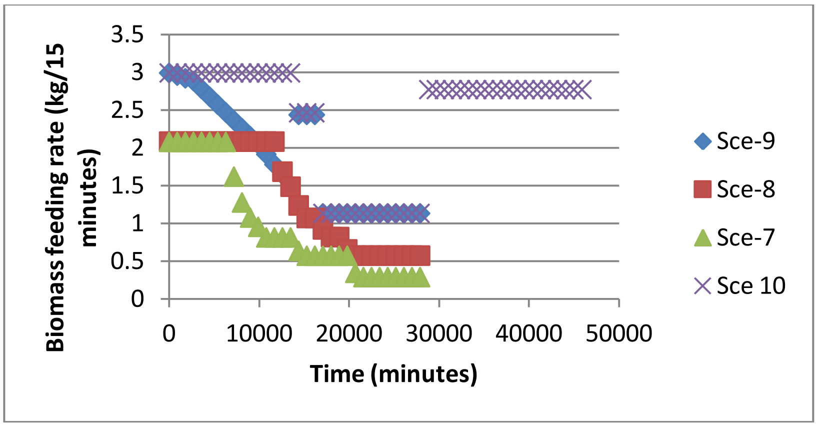

Figure 8. Simulation result of biomass feeding rate at various drying product capacity

The pattern of biomass feeding rate at drying capacity of 100 kg, 200 kg and 400 kg of rosella pod, respectively for scenario 7, 8 and 9 are illustrated in Figure 8. Whereas in scenario 10, the simulated is continue during daylight and night. It clearly shows that typical of biomass feeding rate is similar for all treatments, except for scenario 10. It is shown that for keeping of constant drying temperature, it is required more biomass energy due to absent of solar irradiation during a night. Increasing of capacity increases utilization of biomass hence, required more supply energy, however drying product at full capacity result the highest drying efficiency. Drying operation during night is not suggested to be carried out because of, huge energy supply is consumed. Consequently, drying efficiency of night drying operation is less than that of daylight drying operation, are 15.5 % and 16.7 %, respectively.

Conclusions

The following results may be drawn from the present work. Simulation modeling of temperature distribution has been developed. Base on the residual error analysis and standard deviation value, the model meet an agreement to the actual drying temperature at several drying operations. The best treatment to produce constant temperature is pattern of biomass feeding rate into burner at every 15 minutes, using adjustment. Drying of rosella pod at full capacity of dryer-in this case is 400 kg of rosella pod- is suggested to achieve drying process efficiently. Drying operation at night is not suggested to be carried out to saving the energy consumption. The significant of study is to provide the designer of solar dryer and the farmer to make better performance of drying.

References

1. Abdullah, K., A.H. Tambunan, Thamrin, F. Wenur, dan D. Wulandani. (1994). *Optimasi dalam perencanaan alat pengering hasil pertanian dengan energi surya*. Laporan Penelitian Hibah Bersaing. Bogor.
2. Bennamoun L. and A. Belhamri. (2003). Design and simulation of a solar dryer for agriculture products. *Journal of Food Engineering* 59: 259–266.
3. Jain, D. (2005). Modeling the performance of greenhouse with packed bed thermal storage on crop drying application. *Journal of Food Engineering* 71:170–178.
4. Janjai, S. and P. Tung. (2005). Performance of a solar dryer using hot air from roof-integrated solar collectors for drying herbs and spices. *Renewable Energy*, 30: 2085–2095.
5. Munir A. and O. Hensel. (2010). On-farm processing of medicinal and aromatic plants by solar distillation system. *Biosystem Engineering*. xxx: 1-10.
6. Mursalim. (1995). Uji performansi sistem pengeringan energi surya dan tungku batubara dengan bangunan tembus cahaya sebagai pembangkit panas untuk pengeringan panili (*Vanilla Planifolia*). FATETA IPB Bogor.
7. Nelwan, L. O., D. Wulandani, T. W. Widodo dan R. Paramawati. (2009). Pengembangan alat pengering efek rumah kaca (ERK)-hibrid dan *in-store dryer* (ISD) terintegrasi untuk biji-bijian skala komersial, Proceeding, Seminar hasil penelitian IPB, 22-23 December 2009, Bogor.
8. Othman, M.Y.H., K. Sopian, B. Yatim, and W.R.W. Daud. (2006). Development of advanced solar assisted drying systems. *Renewable Energy*, 31:703–709.
9. Wisnewski, G. (1999). Market development of the solar crops drying technologies in Poland and Europe. *Renewable Energy* 16: 1278-1283.
10. Wulandani, D., Abdullah, K., A. I. Siswantara dan E. Hartulistiyoso. (2005). Analysis of temperature distribution in the Greenhouse Effect Solar Dryer by CFD. Proceeding, Word Renewable Energy Regional Conggress and Exhibition-2005, 17 – 21 April 2005, Jakarta.
11. Wulandani, D. dan L. O. Nelwan. (2009). Rancang bangun kolektor surya tipe plat datar dan konsentrator surya untuk penghasil panas pada pengering produk-produk pertanian. Proceeding, Seminar hasil-hasil penelitian IPB, 22-23 December 2009, Bogor.