Design Analysis of Bamboo Drying Oven Using CFD Software

Kurniawan[a], Heri Setiawan, Dede Sujana and Rivaldi Muhammad Alyansyah
Manufacturing Polytechnic Bandung, Kanayakan, Bandung, Indonesia

Keywords: Heat Transfer, CFD, Oven, Drying Bamboo.

Abstract: There is a design validation stage in the process of designing an oven. This step is crucial to demonstrate the oven's ability to perform as planned, which was to be able to dry 700 kg of bamboo material with an initial humidity of 14.08% and dry to a humidity of 10% in 8 hours. A trial tool is typically used for validation. However, it takes a lot of effort and money to create a prototype tool for trailing. As a result, with current technical advancements, software simulation can take the role of the trail tool method. Ansys software was used in this investigation to assess the oven. The program receives the oven specs as well as the outcomes of the calculations that have been done. A simulation of the heat distribution, oven temperature, and heat absorbed by the material will be calculated by Ansys and displayed.

1 INTRODUCTION

There is a design validation stage in the design process. This stage is required to demonstrate that the designed solution serves the intended purpose. This is crucial to prevent a mismatch between the designer's expectations and the final product.

In the construction of an oven whose primary purpose is to dry materials. It is necessary to analyze the heat produced in the oven space. It is intended that by using the application to observe the simulation approach, the oven design may be verified to dry the material to a specific humidity level in the anticipated amount of time.

The oven in the situation under investigation must be capable of drying 700 kg of bamboo material in 8 hours. Bamboo that was previously 14.08 percent humid was dried till it reached 10% humidity.

It is envisaged that performing an examination of the oven space using the ansys application will allow the simulation results to validate the accomplishment of the oven's intended function.

2 RESEARCH STAGES

The research flow chart below is referenced in the analysis study addressing the finding of hot air in this oven.

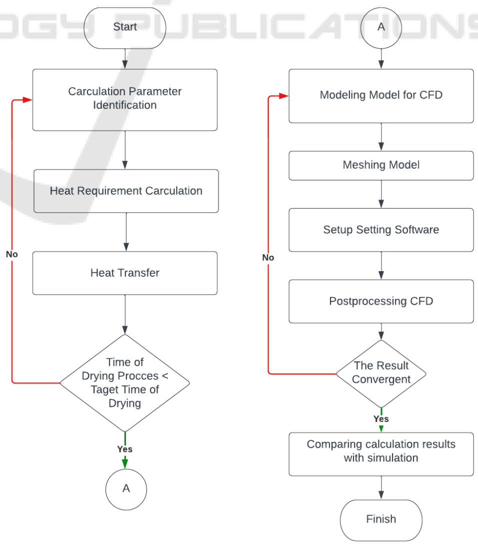


Figure 1: Research stages.

[a] https://orcid.org/0000-0003-4323-3325

Kurniawan, ., Setiawan, H., Sujana, D. and Alyansyah, R.
Design Analysis of Bamboo Drying Oven Using CFD Software.
DOI: 10.5220/0011766300003575
In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2022)*, pages 317-323
ISBN: 978-989-758-619-4; ISSN: 2975-8246
Copyright © 2023 by SCITEPRESS – Science and Technology Publications, Lda. Under CC license (CC BY-NC-ND 4.0)

3 STUDY

3.1 Carculation Parameter Identification

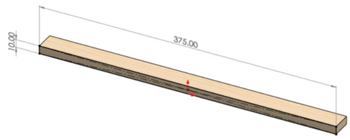


Figure 2: Dimension bamboo.

The humidity level of the bamboo that needs to be dried is 14.08%.(Tri Wulandari, 2020) Bamboo must be dried untuk humidity level of bamboo 10%. The properties of bamboo have a specific heat of 1.700J/kg°C. Bamboo to be dried has a size of 25x10x375mm.

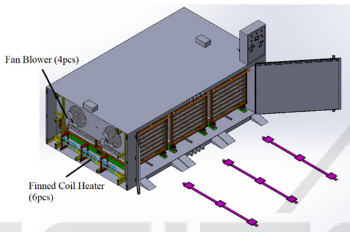


Figure 3: Design oven.

The oven must have be able to dry 700kg/day material bamboo. Knowing the heater and blower specs as calculation inputs is essential for heat transfer analysis.The oven have 4 blower, 2 blower each side and 3 finned coil heater each side in total 6 heater.

Figure 4: Finned coil heater.

The oven uses a finned coil heater with a 1500 watt power rating and a 240 volt operating voltage each heater.

Figure 5: Catalog of blower by Hanil.

The blower being used is a Hanil KE-400 industrial blower. The specification of blower have dimension blade 400mm with airflow 1540 $m^3/hour$.

3.2 Calculation

3.2.1 Heat Requirement

Heat is required to dry the skewer material, which initially had a humidity of 14,08% to 10%. Up until it reaches a humidity of 10%, bamboo material's heat demand is calculated.

Table 1: Calculation of heat requirement.

No	Description	Value
1	Temperature normal	27°C
2	Temperature when drying	70°C
3	ΔT	70°C − 27°C = 43°C
4	Characteristic termal of bamboo(C_p)	1.700J/kg°C
5	Q_1	$M \cdot C_p \cdot \Delta T = 51201798{,}5\ J$
6	Mass of water to be evaporated (m)	$700\ kg \cdot (14{,}08\% - 10\%) = 28{,}56\ kg$
7	Specific laten water (L)	22,6x10^5J/kg
8	Q2	$m \cdot L = 64545600J$
9	Heat requirement (Q_{tot})	Q1 + Q2 = $1{,}157\ x\ 10^8\ J$

So to dry bamboo material to a humidity of 10 requires $1{,}157\ x\ 10^8\ J$ of calor (Tobing et al., 2019).

3.2.2 Heat Transfer

The item being dried receives heat either directly from the heat source or indirectly in the instance of drying bamboo in an oven. The material will dry more quickly or slower depending on how quickly heat is transferred during this drying process(Putra, 2010). Temperature, wind speed, material, and the surface area that needs to be dried all affect how quickly heat transfers. The anticipated drying time can be calculated using the rate of heat transfer that takes place. The bamboo material in this instance weighs 700 kg, and the drying procedure aims to reduce the humidity from 14.08% to 10% in under 8 hours.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Table 2: Calculation of heat transfer.

No	Description	Value
1	Area of projection blower blade (A_f)	$r^2 \cdot \pi = 125600mm^2$
2	Air volume (Q_v)	$1540\ m^3/hour$
3	Velocity of air (V_{angin})	$\frac{Q_v}{A_f} = 3{,}404\ m/s$
4	Lenght of plate (L)	$3{,}210m$
5	Kinematic Viscosity (v)	$27{,}8\ x\ 10^{-6}\ m^2/detik$
6	Reylond number (Re)	$\frac{V_{angin} \cdot L}{v} = 3{,}926$
7	Conductivity termal (k)	0,03489 W/m.K
8	Prandtl number(Pr)	0,684
9	coefficient of heat transfer (h)	$0{,}664 \cdot \frac{k}{L} \cdot Re^{0.5} \cdot Pr^{0.33} = 3{,}985\ W/m^{2\,0}C$
10	Surface area perpendicular to the direction of the heat flux (A)	$375mm \cdot 10mm \cdot 9595stick = 4{,}556m^2$
11	Temperature coil (t_{coil})	250°C
12	Temperature room(t_{room})	27°C
13	Heat transfer(q_{kv})	$h\ A\ (t_{coil} - t_{room}) = 4{,}049\ kJ/sec$
14	The time required for the drying process (t_{drying})	$\frac{Q_{tot}}{q_{kv}} = 7{,}941\ hour$

Accordingly, it takes 7,941 hours for bamboo material to dry to 10% humidity with a heat transmission coefficient of 4,049 kJ/sec (Hadi, 2012).

3.3 CFD (Computational Fluid Dynamic)

The term "computational fluid dynamics" is derived from the phrases "computational" and "dynamics," where computational refers to anything having to do with mathematics, numerical computing, or computational methods. By definition, CFD refers to the study of predicting fluid flow, heat transfer, chemical reactions, and other phenomena by the solution of mathematical models. PDEs, or partial differential equations, which stand in for the principles of conservation of mass, momentum, and energy, are the fundamental building blocks upon which mathematical model fluid equations are constructed and studied. When running CFD simulations, there are three steps that must be completed: pre-processing, solution, and post processing. (Damayanti, 2012)

a. Pre-Processing

The first step in creating and analysing a CFD model is pre-processing. The process entails building a model using a CAD (Computer Aided Design) program, meshing the model as necessary to complete it, and setting up the model in accordance with the boundary conditions and fluid parameters that will be simulated.(Damayanti, 2012)

b. Resolving

The pre-processing phases from earlier are used by the CFD solution search algorithm to determine the conditions that arise.(Damayanti, 2012)

c. Post Processing

The final stage of CFD analysis is postprocessing. Organize and evaluate the CFD simulation data that has been obtained at this point by contrasting it with manual calculations.(Damayanti, 2012)

With a model that closely resembles the actual state of the oven, this simulation is used to examine the convection heat distribution circumstances that arise between the coil heater and the wind from the blower. Moreover, to guarantee that the dried material receives the necessary heat and energy. The following steps are carried out as the simulation progresses through various stages.

3.3.1 Model

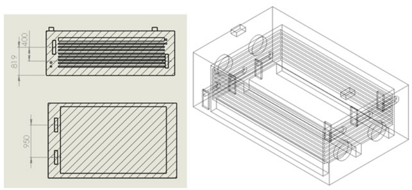


Figure 6: Model for simulation.

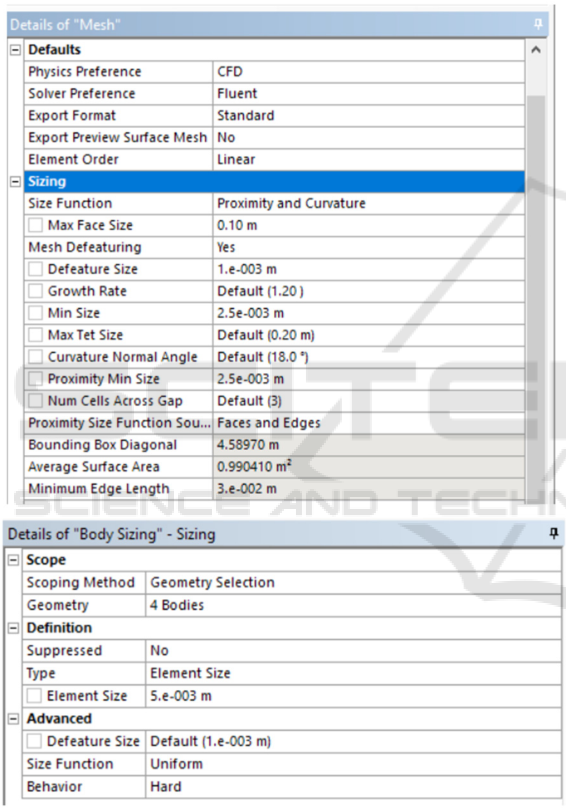
The simulation model receives tray construction as input. The tray model is then deleted and the "boolean" tool is used to turn the tray into an empty space in the rectangle model. When using the

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

"boolean" feature, the blower model is still present and is not deleted. Figure above depicts the model's shape in its final form.

3.3.2 Mesh

Choose the type of CFD and Fluent in the "Defaults" setting based on the simulation that will be run. Given that the oven has a pretty large size, the "Max Face Size" setting in the "Sizing" parameter is quite large at 0.1m. The "Min Size" setting, however, is now set at 0.0025m or 25mm. This size is narrower than the model's narrowest size, which is 50mm apart from the trays.



Details of "Mesh"

Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Export Format	Standard
Export Preview Surface Mesh	No
Element Order	Linear
Sizing	
Size Function	Proximity and Curvature
Max Face Size	0.10 m
Mesh Defeaturing	Yes
Defeature Size	1.e-003 m
Growth Rate	Default (1.20)
Min Size	2.5e-003 m
Max Tet Size	Default (0.20 m)
Curvature Normal Angle	Default (18.0 °)
Proximity Min Size	2.5e-003 m
Num Cells Across Gap	Default (3)
Proximity Size Function Sou...	Faces and Edges
Bounding Box Diagonal	4.58970 m
Average Surface Area	0.990410 m²
Minimum Edge Length	3.e-002 m

Details of "Body Sizing" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	4 Bodies
Definition	
Suppressed	No
Type	Element Size
Element Size	5.e-003 m
Advanced	
Defeature Size	Default (1.e-003 m)
Size Function	Uniform
Behavior	Hard

Figure 7: Setting mesh.

To achieve better simulation outcomes, the "Body Sizing" function is set to a smaller mesh size in the blower section. The mesh size is set to 0.005 meters, or 50 millimeters.

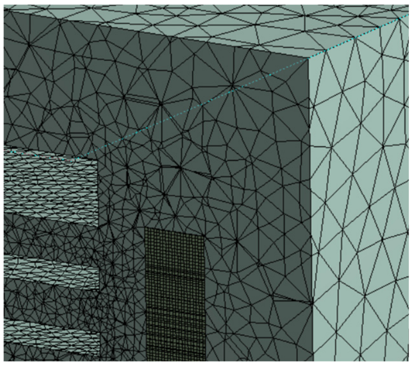


Figure 8: Result mesh.

3.3.3 Setup

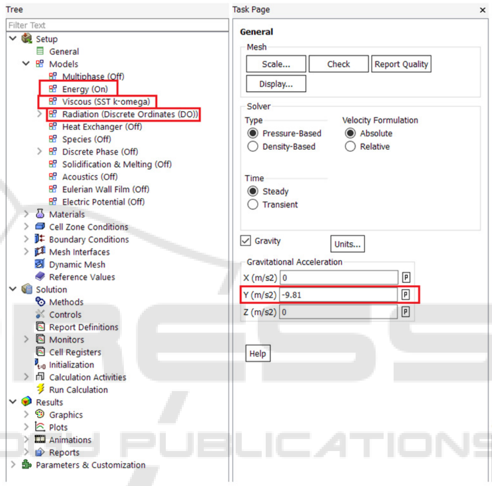


Figure 9: Setup energy.

Viscous is in SST k-omega mode, radiation is in DO mode, and the energy parameter is set at setup time. settings due to the simulation's inclusion of heat-related elements.

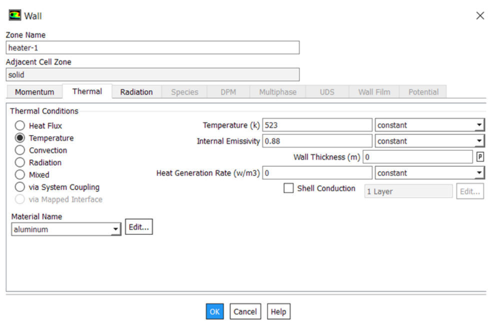


Figure 10: Setup heater.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Then use the preceding formula to determine the heater's heat, which is 523K with a 0.88 emissivity. The other six heaters all have this setting.

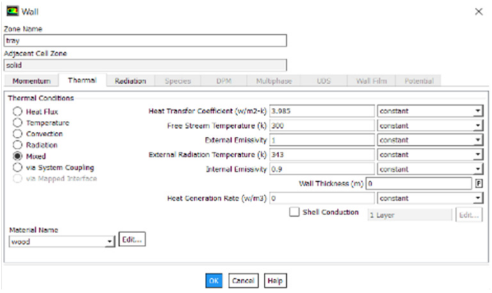


Figure 11: Setup tray.

The tray's material character in the simulation is set to wood or wood. This is due to the bamboo material not being used in the application; instead, it must be brought very close to the wood in order to be used. According to the outcomes of manual calculations, where the thermal coefficient (h) occurs at 3.985 W/m20C, the value of "heat transfer coefficient" is changed. The material is initially heated to the same 270C or 300K temperature as a typical room, and the oven temperature of 700C or 343K is entered in the value column for "external radiation temperature".

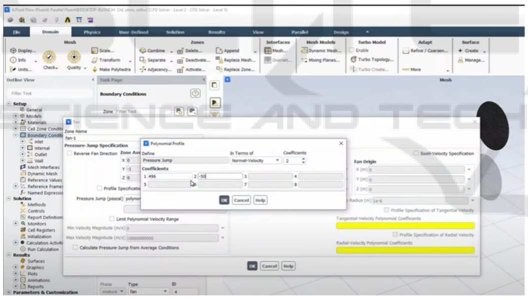


Figure 12: Setup blower.

The blower is programmed to increase the pressure. The coefficients for the pressure jump value are 496 and -50.

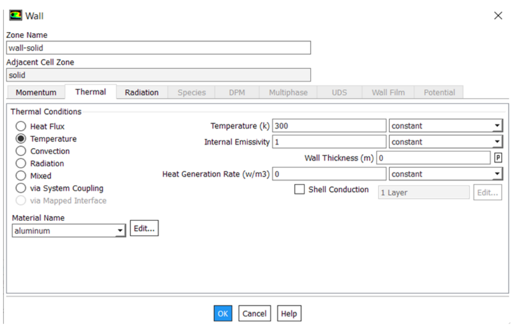


Figure 13: Setup air condition.

The oven room temperature before being operated is set by changing the “wall-solid” parameter to have a temperature of 300K or 27ºC.

3.3.4 Result

a. Heat Absorption

To be able to determine the amount of heat absorbed, it is necessary to observe the heat flux that occurs.

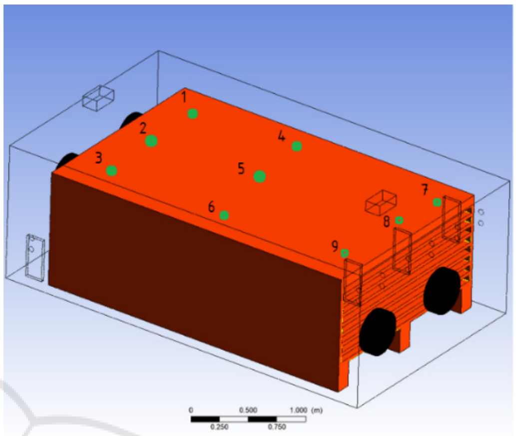


Figure 14: Heatflux on tray.

The average heat flux value is determined from 9 different sites using the simulation data. The table below shows the outcomes of the 9 point.

Table 3: Average heatflux.

Titik	Heat Flux
	W/m^2
1	16.2552
2	18.6113
3	13.7863
4	16.7524
5	18.4016
6	13.1118
7	14.258
8	19.8712
9	12.3409
Rata-Rata	15.93207778

The table shows that the average heat flux value in the tray is 15,932$\frac{watt}{m^2}$.. The heat energy that the material has received can be calculated using the heat flow value. The heat requirements that have previously been established by manual calculations can be directly correlated to these results. Here is how to calculate it:

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

Table 4: Calculation of heat absorption.

No	Description	Value
1	Area of surface material bamboo(A_m)	$0{,}028m^2$
2	Total area of surface material bamboo(A_{tot})	$A_m.9595stick = 268{,}18m^2$
3	*Heat flux* ($ø_q$)	$15{,}932\,\frac{watt}{m^2}$
4	The time required for the drying process (t_{drying})	$7{,}941\ hour$
5	Heat absorption (Q'_{tot})	$ø_q.L_{mtot}.t = (1{,}221 \cdot 10^8)J$

In the simulation, the energy absorbed is s $(1{,}221 \cdot 10^8)J$ if the drying process lasts for 7.941 hours. If the drying time necessary until heat energy absorption happens as needed (Q tot) with the heat flux value is calculated as follows.

Table 5: Calculation of time drying procces.

No	Description	Value
1	Heat requirement (Q_{tot})	$0{,}028m^2$
2	Heat flux ($ø_q$)	$15{,}932\,\frac{watt}{m^2}$
3	Total area of surface material bamboo(A_{tot})	$268{,}18m^2$
5	The time happend for the drying process in simulation result (t'_{drying})	$\frac{Q_{tot}}{ø_q.L_{mtot}} = 7{,}525hour$

So based on the conditions that occur in the simulation, the results of the calculation of the time needed are 7.525 hours.

b. Room Temperature

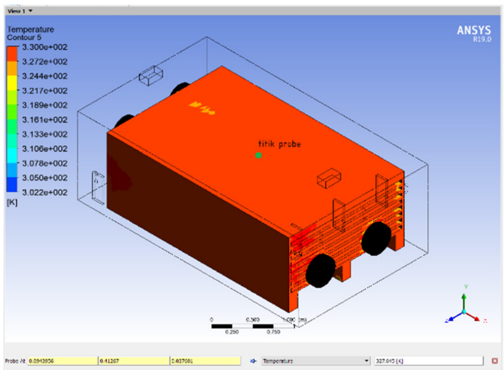


Figure 15: Temperature of room actual model.

The temperature of the tray was initially set at 300K to 330K or 57ºC. Previously, the target temperature was 70ºC, but in the simulation results, the tray temperature was 57ºC .. This is not a concern because what matters is that the required amount of heat is absorbed.

In calculation with 300 iterations, it is impossible to accurately examine the spread of heat while going to do so. As a result, changes to the Ansys settings were made to better understand how heat spreads because of the device's limited characteristics.

The tray settings were changed from "mixed" to "heat flux" with a value of 180 $\frac{watt}{m^2}$. Author may observe the heat spread when absorption is good even though only 300 iterations have been performed by using a large heat flux value to speed up the heat absorption process.

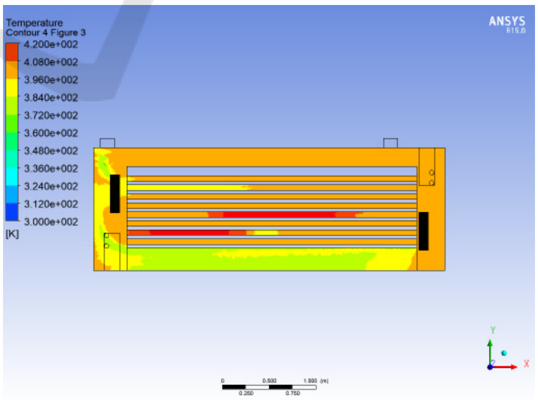


Figure 16: Heat distribution side view.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

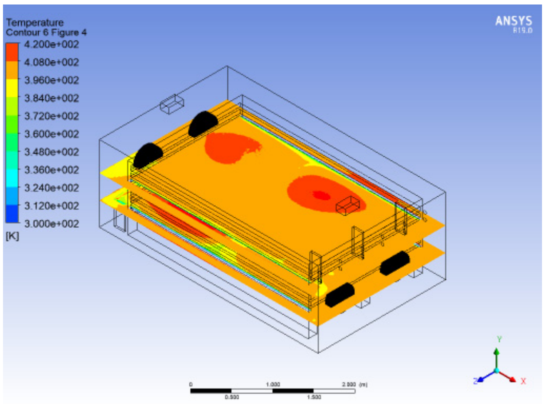


Figure 17: Heat distribution up view.

The results show the evenness of heat that occurs in the tray. It can be seen that the bottom of the trolley has a temperature of 370K to 396K or 97ºC to 119ºC. This temperature is lower than that which occurs in each tray, which is an average temperature of 408K or 135ºC.

4 CONCLUSIONS

The heat flow value from the simulation results is converted into energy received by the material, it can be estimated. The findings of the thermal energy acquired by the calculation material when done manually and those from simulations differ. As a consequence, when compared to the manual calculation results, as follows.

The temperature in the oven space is below the desired temperature, according to the temperature observation. Nevertheless, it doesn't matter because the substance has already absorbed enough heat energy to meet its needs.

Table 6: Compare data between manual calculation and simulation.

Manual calculation	Simulation calculation	Result difference
Heat requirement (Q_{tot})	Heat absorb (Q_{tot})	
$(1{,}157 \cdot 10^8)J$	$(1{,}221 \cdot 10^8)J$	5.53%
Drying time	Drying time	
7,941jam	7,525jam	5,24%
Room temperature	Room temperature	
70ºC	57ºC	18,57%

ACKNOWLEDGEMENTS

If any, should be placed before the references section without numbering.

REFERENCES

Damayanti, Y. P. (2012). SIMULASI TEMPERATURE CONTROL SYSTEM PADA INTERNAL FLOW FLUIDA VISCOUS DENGAN MENGGUNAKAN PERANGKAT LUNAK CFD (COMPUTATIONAL FLUID DYNAMICS). Skripsi Universitas Sebelas Maret.

Hadi, P. S. (2012). PENGERING PADI ENERGI SURYA DENGAN VARIASI TINGGI CEROBONG. TUGAS AKHIR.

Putra, A. K. (2010). RANCANG BANGUN OVEN UNTUK MENGERINGKAN. Tugas Akhir.

Tobing, I. F., Agustina, R., Studi, P., Pertanian, T., Pertanian, F., & Syiah, U. (2019). Modifikasi Pengering Tipe Tray Dryer Dengan Penambahan Insulator (Modification Of Tray Dryer With Insulator). Jurnal Ilmiah, 4(November).

Tri Wulandari, F. (2020). KARATERISTIK SIFAT FISIKA BAMBU TALI (GIGANTOLOCHLOA APUS KURZ) SEBAGAI BAHAN BAKU BAMBU KERAJINAN. Jurnal Fakultas Pertanian Universitass Mataram, 3(1), 69–77.

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS