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Performance of "Rotating Parts of Tray"-Type Indirect Contact Dryer on Cocoa Beans Drying Process

Susanto Johanes[1], F. EkoWismo Winarto[1], Soeadgihardo Siswantoro[1], SetyawanBekti Wibowo[1]
[1]*Mechanical Engineering, Vocational College, UniversitasGadjahMada, Yogyakarta, Indonesia 55281*
Corresponding Author: Susanto Johanes

ABSTRACT :*This research was conducted to determine the performance of "Rotating Parts of Tray" type indirect contact dryer for cocoa beans. This dryer is the result of a redesign of the previous dryer, the type of "Movable Tray", which still has many flaws, especially due to the less practical way of operating the machine. The "Rotating Parts of Tray" type dryer has five unit tray levels made of perforated stainless steel plate. The size of the unit tray area of each level is 70 x 100 cm, with dual fuel; LPG or firewood, and has 42 pieces of air heaterfins made of aluminum plate which installed on the top of two incline side of the heating plate. The mechanism of the trays' movement at each unit or level allows the trays to be rotated to a maximum of 90°, by turning the lever. When the trays in the one of units are rotated on maximum position, the cocoa beans fall, resulting in the relocation of cocoa beans to the tray level below. During the drying process, the temperature of several point in the drying chamber and outside air are recorded using a digital thermometer every 20 minutes. In this research, the relocation of cocoa beans was carried out every one hour interval, starting from the lowest level to the top by turning the levers of each unit tray. The drying process of cocoa beans is carried out with two variations in capacity, i.e. 19.5 kg and 30 kg until each drops to 8.2 kg and 12.6 kg or from the initial water content of 60% to 13.5% and 6.5% respectivaly. The drying time of each process is 8 hours and 20 hours, it required consumption of 3 kg and 9.1 kg LPG.The decreasing rate of water content every hour is 5.9% and 2.7%, and the drying thermal efficiency is 19.6 % and 9.7% respectivaly. The moisture content of the cocoa beans was calculated based on the cocoa beans samples which was dried using an oven until the water content became 0%.*

KEYWORDS: *rotating parts of tray type of dryer, relocation, cocoa beans, thermal efficiency and water content.*

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I. INTRODUCTION

Cocoa beans are one of the trading commodities that have the opportunity to be developed to increase the income of cocoa farmers and foreign exchange. The market opportunity is very high, because cocoa beans can be utilized by various industries.

The Minister of Industry at the time, Saleh Husain, stressed that the cocoa processing industry has an important role in increasing foreign exchange and improving the economy. He said that this was related to the inauguration of PT. Cargill Indonesia, in Gresik East Java, which has a production capacity of 70,000 metric tons. The majority of raw materials are supplied from Indonesia (Sulawesi, including Bone and Soppeng), and less than 10% are imported from Africa.

The production of cocoa beans in Indonesia is significantly increasing, yet the quality is very low and diverse, this is due to the not fermented enough of cocoa beans, not dry enough, not uniform bean size, high skin content, high acidity, and very diverse flavors. Good taste can be obtained from fruit that is ripe, healthy and through the perfect process of fermentation and drying of cocoa beans [1]. Thus the price of Indonesian cocoa beans is relatively low and subject to price deductions in comparison to other countries' cocoa products. But on the other hand Indonesian cocoa has the advantage which they contain cocoa fat and can produce good quality cocoa powder.

Some of the factors that cause the diverse quality of cocoa to be produced are the lack of processing facilities, the weak quality control and the application of technology at all stages of the farm level on cocoa bean processing, which are less quality oriented. Fermentation and drying of cocoa beans are critical stages in the order of the cocoa processing [2].

In general, the handling of post-harvest cocoa beans by farmers is done traditionally. The drying process only relies on sunlight. If the weather is good, and the sun shines brightly, the drying of cocoa beans in a natural way (drying) is able to reach 7% dryness level, which takes approximately 7 days, but in the rainy season it can be up to 22 days [3], depending on the weather, thus the operations costs are bigger and may hamper the national cocoa production.

From various research and the reasons stated above, the existence of a good cocoa dryer is very important. For small capacity dryers, it is very useful for farmers, both individually and collectively, as an alternative drying tool, especially used during the rainy season, so that cocoa beans dry quickly to supply national cocoa needs, and to avoid the emergence of fungus.

Several researches have been carried out, as well as the invention of various types of cocoa bean dryers. The description below shows some of the research that has been done.

DartaSembiring et al. examined the Contribution of Solar Energy Usage to the Wet Cocoa Seed Drying System at the Cocoa Seed Drying Plant, PTP-IV Adolina Farm Medan [4].

Fudholi, A. et al. In his review said that drying for agricultural and marine products is one of the most interesting and energy-saving applications using solar energy. Various types of solar dryers have been designed and developed in various parts of the world. Basically there are four types of solar dryers, namely direct, indirect, combined, and hybrid types of solar dryers [5].

Ruku, S., et al. have conducted research on the use of modified cocoa bean dryers from the Southeast Sulawesi BPTP. The drying process uses wood charcoal heat which heats the cocoa beans above three levels [3].

The "Ngupadi Koyo" Farmer Group, in Sawur Hamlet, Sawahan Village, PonjongSubdistrict, Gunungkidul, has long owned cacao bean dryers, as shown in Figure 1. The farmer group is one of the farmer groups that has a type of flat (open) cacao bean dryer. Two other farmer groups that also have the same cocoa dryer, are the farmers group "NgudiMulyo" in KalibawangSubdistrict, KulonProgo and the farmer group "SidoDadi" in PatukSubdistrict, Gunungkidul, D.I. Yogyakarta.

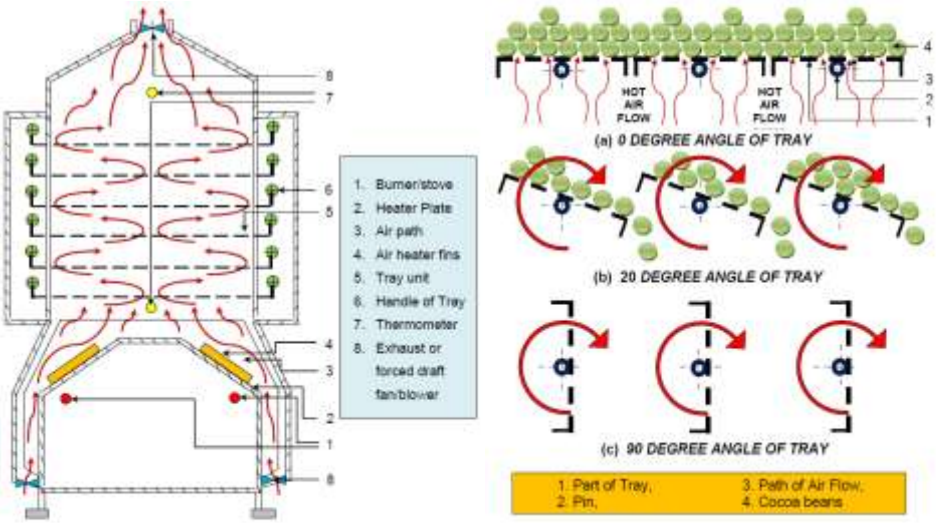
Figure 1. The flat tub-type dryers of cocoa beans, belonging to the "Ngupadi Koyo" Farmers Group, in Sawur Hamlet, Sawahan Village, PonjongSubdistrict, Gunungkidul, DIY.

The specifications of the dryer are: flat tub type, one layer of cocoa beans (heating air is used only once), kerosene fuel, capacity of approximately 1.5 tons, dimensions of approximately 2.1 x 3.5 x 0.9 m, one operating cycle to reach a dryness level of 6-7% requires more or less than 24 hours. The performance requirements of flat-type cocoa drying machines, the maximum temperature in the material stack is 55 °C and the drying rate is 1-2% per hour [6].

To improve the quality of good cocoa beans and to overcome the constraints of the national cocoa production mentioned above, the Research Team was called to try by making effective, efficient and practical cocoa beans dryer, and I hope in the future the farmers or farmer groups, who are in the upstream industry, whom is the pioneer of national cocoa seed production, a lot of them has this dryer.

Susanto et al. has made an indirect contact dryer for cocoa beans (or other agricultural products) in the type of "Rotating Parts of Tray", which is the result of a redesign of the previous dryer, the “Movable Tray” type, which still has many flaws, especially because of the operation tools that are less practical and the manufacturing process is complicated and old. The sketch of "Rotating Parts of Tray" type dryer is shown in

Figure 2 below. This dryer has five levels of tray made of perforated stainless steel plate, the size of the unit tray area of each level is 70 x 100 cm, dual fuel (LPG or firewood), and using 42 pieces of heating fins made of aluminum plate. By completing the mechanism of the trays' motion, it allows the trays at each unit or level to be rotated at a maximum of 90°, by rotating the lever of each unit tray. When the trays in a unit are rotated, the cocoa beans will fall, resulting in the relocation of cocoa beans to the tray level below [7].



(a) (b)

Figure 2. (a) Sketch of Cocoa beans dryer, (b) Sketch of three kinds of the tray unit positions, when slope of each tray at: 0, 20 & 90 degrees.

The relocation of cocoa beans with this method is very helpful for the operator, because the operator will avoid the heat of the cocoa beans that are in the drying process and save the energy. This method will be more useful if applied to large capacity dryers. The cocoa beans begin to be heated in the top tray with a low temperature, then sequentially relocated to the tray below which the temperature is higher, until finally at the highest temperature tray, so that the cocoa beans only experience one drying process until they dry out when Cocoa beans come out from the bottom tray level.

In the cocoa bean dryer the results of this new design is shown in Figure 3 below. Heat transfer takes place by radiation from the LPG combustion gas, then it is received by a stainless steel plate above it. Furthermore, some of the heat is transmitted by the conduction to the heating fins made of aluminum plate material. The air exhaled by the blower is heated by plates and heating fins, then the hot air produced is used to heat the cocoa beans, which are spread evenly over the five unit trays.

(a) (b) (c)

Figure 3. (a) Cocoa beans dryer in manufacture processing,
(b) The side view, and (c) The behindview of Cocoa beans dryer.

The specifications of the "Rotating Parts of Tray" type indirect contact dryer for cocoa beans (or other agricultural products) is as shown in Table 1.

Table 1. Dryer Specifications studied.

1.	Variety	Indirect Contact
2.	Type	"Rotating Parts of Tray"
3.	Capacity	Max 75 kg wet cocoa beans
4.	Levels	5 levels of trays, material: 0,8 mm perforated stainless steel plate
5.	Dryer's width	70 x 100 cm
6.	Fuel	Dual (LPG &Woodfire)
7.	Burner	4 unit, brand: Tian Liong H 203
8.	Temperature Setting	Manual
9.	Total Fins	2 x 21 pieces, material: 0,4 mm Aluminium plate
10.	Blower	1 unit, 3", straight curve vane, forced draft, brand: Modern
11.	Total dimension	80 x 120 x 200 cm

The total heat used in the drying process of the cocoa beans consists of:

1. Heat (energy) used to heating the cocoa beans (solid), from atmospheric or environmental temperatures to the desired temperature (drying chamber),
2. Heat used to heating (sensible heat) the water content in cocoa beans,
3. Heat used to evaporate (latent heat) the water content in cocoa beans,
4. Heat loss through the walls of the cocoa bean dryer,
5. The heat that comes out through the exhaust vents & pipes, and

Heat losses lost from the surface of the equipment and from the stove to the surrounding that are not absorbed by the cocoa bean dryer.
As for determining the thermal efficiency of drying cocoa beans using this dryer, a stepwise calculation is carried out as follows [7].
The total of heat(energy), Q_T, used in the drying process of cocoa beans is as follows:

$$Q_T = Q_D + Q_L \qquad (1)$$

The heat for heating or drying of wet cocoa beans (Q_D), consists of several energy components and is stated as follows:

$$Q_D = Q_C + Q_W + Q_{EW} \qquad (2)$$

The heating energy of solid cocoa beans is expressed by the following equation:

$$Q_C = W_{Cf}\, cp_C \left(T_d - T_f\right) \qquad (3)$$

The heating energy of the water content in cocoa beans is expressed by the following equation:

$$Q_W = W_{wf}\, cp_w \left(T_d - T_f\right) \qquad (4)$$

The evaporation heat of the water content of cocoa beans is expressed by the following equation:

$$Q_{EW} = \Delta W_w h_{fg} \qquad (5)$$

The thermal efficiency of the cocoa bean dryer, η, determined by equation (6), as follows:

$$\eta = \frac{Q_D}{Q_B} \qquad (6)$$

To obtain the operating standard of this dryer, several tests are needed. In the performance of the dryer there are many factors that influence it, including the capacity and type of the product being dried, the level of the initial or the desired product of dryness or water content, the drying temperature and the air environment temperature (T_{db}&T_{wb}), and the speed of air flow.

II. RESEARCH METHOD

In this research, the cocoa bean dryer was operated using LPG fuel, by manually setting the drying chamber temperature. Before the drying process of cocoa beans is carried out, the dryer is tested without load, the drying chamber of the cocoa beans is cultivated between 50 °C to 70 °C. To reach the temperature it takes approximately 20 minutes, then the drying process of cocoa beans is continued.

In testing with loads, air circulation is generated by a 3" blower, with maximum air flow speed, regulated by rotating the throttle at the full open position, then the air absorbs heat from the bottom heating plate and the heating fins are mounted on the plate. In this test, dried cocoa beans are fermented cocoa, with two variations in drying capacity of 19.5 kg and 30 kg, or an average of 3.9 kg and 6 kg, on each tray level. Temperature data for drying chamber of cocoa beans during the drying process and outside air conditions, recorded every 20 minutes interval using a digital thermometer. The five temperature sensor locations are installed on one to five level trays and the other two to detect outside air temperatures.

In order for the cocoa bean drying process to be evenly distributed, the cocoa beans are relocated to occupy each level of the tray, as well as a way of reversing the cocoa beans. By turning lever-1 by 90 degrees, the cocoa beans in the first or bottom tray fall into the temporary storage tray. To relocate cocoa beans in tray 2, 3, 4 and 5, it is done by rotating each lever, starting from lever-2 to lever-5, then the cocoa beans fall to the underneath tray-level and then the cocoa beans are slightly flattened so the thickness is close to the same. After the level five tray is empty, then the cocoa beans in the temporary storage tray are taken and transferred to the fifth tray level. During the drying process, the relocation of cocoa beans in this way is carried out every 1 hour interval. By relocating such cocoa beans, the cocoa beans undergo a drying process with the same treatment, so that after the drying process ends, it is hoped that the water content of the cocoa beans will be almost the same (near uniform).

The calculation of the water content in cocoa beans is based on the results of the drying of the cocoa beans with both, wet and cocoa from the results of drying using an oven until the water content reaches zero percent (or the change in sample weight is very small).

III. RESULTS AND DISCUSSION

In testing the dryer with loads, variations in drying capacity of fermented cocoa beans are 19.5 kg and 30 kg, or an average of 3.9 kg and 6 kg, each tray level. It is needed to mention that these dried cocoa beans belong to PT. Pagilaran, Yogyakarta, whose status is loaned, then after being dried and its use is considered to have been completed, the cocoa beans are returned. For that we thank the PT. Pagilaran, Yogyakarta. The company besides engaging in the field of tea planting and processing, it also handles cocoa, so besides having machines to produce tea, there is also a cocoa bean drying machine.

For drying capacity of 19.5 kg of cocoa beans, surrounding air conditions during data collection, the average dry bulb temperature is 30.1 °C and the wet bulb temperature is 26.2 °C. As for the drying capacity of 30 kg of cocoa beans, the average dry bulb temperature is 30.3 °C and the wet bulb temperature is 26.5 °C.

For drying cocoa beans with a capacity of 19.5 kg (wet beans), after drying the mass drops to 7.5 kg, fuel of 3 kg LPG is needed, from the level of dryness (moisture content) 60% to 13%, time required 8 hours, the average temperature of drying room is 49.5 °C. As for drying cocoa beans with a capacity of 30 kg (wet beans), the mass drops to 12.6 kg, fuel is needed 9.1 kg of LPG, from the 60% dryness to become 6.5%, the time required is 20 hours, and the average drying room temperature is 44.5 °C.

The temperature history of the drying process of cocoa beans with a capacity of 19.5 kg is presented in graphs of Figure 1, while for the drying process of cocoa beans with a capacity of 30 kg, are presented in graphs of Figure 2.

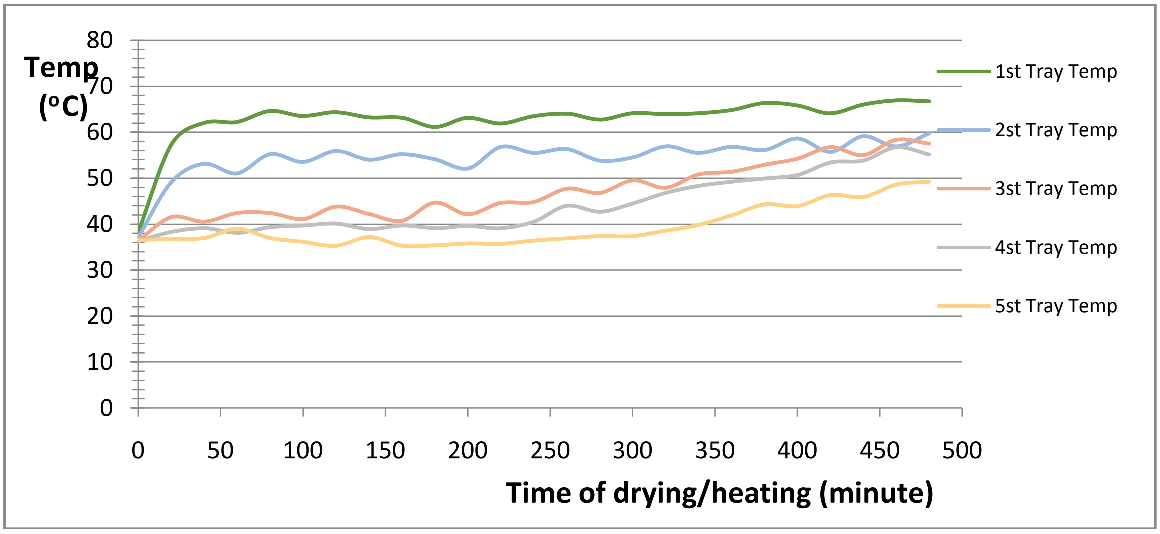


Figure 1. The history of the temperature of the drying process of cacao beans is 19.5 kg.

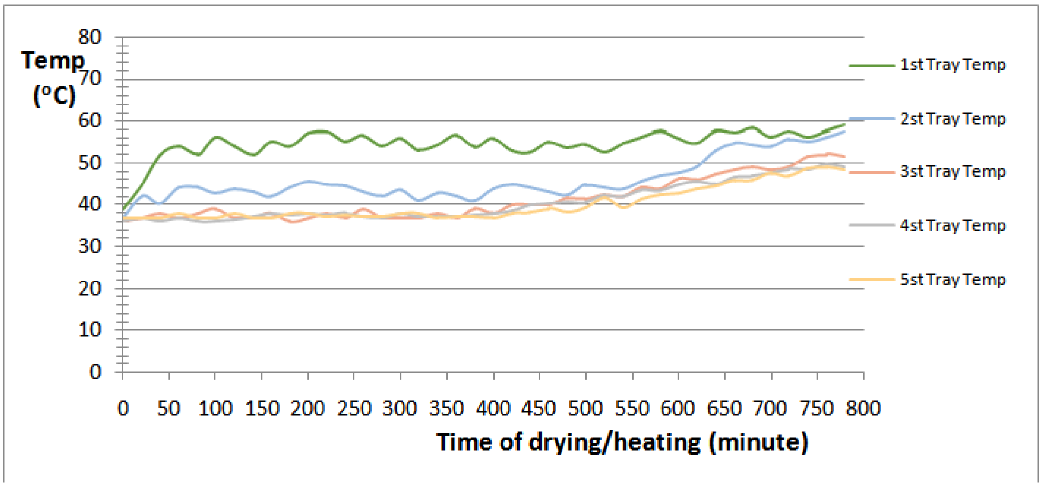


Figure 2. The history of the temperature of the drying process of cacao beans is 30 kg.

From graphs in Figure 1 and 2, it shown that the maximum drying chamber temperature difference between the first and fifth tray, each of which is 23.3 °C and 14.4 °C. Such results are a note that is very concerning for the researchers, thus for the example with recirculating heating air, the magnitude of the temperature difference will at least be reduced (resolved).

From the calculation results show that, for drying cocoa beans with a capacity of 19.5 kg, the dryness decreasing rate is 5.9% every hour, while for the capacity of 30 kg, the rate of decline in the dryness rate is 2.7%. This is understandable because for large capacity, the release of water vapor is more difficult, but more importantly because the average temperature of the drying chamber for drying is 30 kg lower than the drying capacity of 19.5 kg.

For drying of 19.5 kg cocoa beans, the heat needed for heating cocoa and evaporation of the water contained in it is 29,963,730.24 Joules, while the heat from the combustion of LPG fuel is 145,597,452 Joules, then the thermal efficiency of the drying process of cocoa beans use this tool is 19.6%. For drying cocoa beans with a capacity of 30 kg, the heat needed for heating cocoa and evaporation of water contained in it is 42,992,251.69 Joules, while the heat from combustion of LPG fuel is 427,398,972 Joules, then the thermal efficiency of the cocoa beans drying process this tool is 9.7%.

The thermal efficiency of the drying process of cocoa beans for both capacities, shows the difference which is quite far apart between 19.6% and 9.7%. This can be comprehended since the level of dryness or moisture content of the cacao beans produced by the capacity of 19.5 kg is equal to 13%. It has not reached the expected dryness level, which is between 6%-7%. In order to produce cocoa beans with moisture content as wanted, a certain amount of LPG combustion energy is still needed

Qualitative analysis results show that the exhaust gas from combustion of LPG fuel that comes out through the exhaust pipe is still in high temperature, this has been discovered from the observation, which is when the outer wall of the dryer adjacent to the exhaust pipe, the wall has a higher temperature than other location walls. Of course this is a note that must be considered in order to improve the performance of dryers later, or on how we should utilize this wasted heat.

Overall the thermal efficiency of the drying process of cocoa beans using this dryer is still low, one reason is that there is still a lot of heat being wasted, especially the heat contained in the exhaust gas. This is a concern to try improving this dryer, thus resulting in the better performance of the dryer.

On the surface of the cocoa beans produced by drying, there are a number of whitish beans, which raises the suspicion that the white color are fungus. But after consulting with one of the management officer at PT. Pagilaran, they confirmed that they are in fact not fungus. Another encouraging thing was that the cocoa beans which were dryied using a dryer were appreciated by them, this tells that the results of the drying were good. The cocoa beans color were dark brown.

IV. CONCLUSION

The conclusions obtained from the results of this research are as follows;

a. The length of time for drying cocoa beans with a capacity of 19.5 kg is 8 hours, it takes 3 kg LPG fuel, it can reduce the water content of cocoa beans from 60% to 13%. While the drying time of cocoa beans with a capacity of 30 kg is 20 hours, with 9.1 kg of LPG fuel is needed, and the water content of cocoa beans is reduced from 60 percent to 6.5 percent,

b. The rate of decline in the average water content of cocoa beans is 5.9% per hour for the drying capacity of 19.5 kg cocoa beans, while for the drying capacity of 30 kg cocoa beans, the rate of decrease in water content is an average of 2.7%,
c. Thermal efficiency of drying process of cocoa beans for drying capacity of 19.5 kg is 19.6%, while for drying capacity of 30 kg is 9.7%,
d. The maximum temperature difference of the drying chamber is between the first and the fifth tray at 23.3 °C for drying the 19.5 kg cocoa beans, while the drying for 30 kg cocoa beans is 14.4 °C.

Some notes that need to be considered to improve the performance of this cocoa bean dryer are as follows;

a. The size of the combustion waste gas pipe needs to be reduced, so that the gas heat from the combustion does not escape rapidly.
b. The gas temperature from combustion that is wasted through the exhaust pipe is still high, so it is necessary to reconstruct the placement of the exhaust pipe so that the heat can be utilized.
c. It is necessary to consider conducting recirculation of heating air, so that the heating air of cocoa beans is more uniform at each level of the tray.
d. Automatically setting the drying chamber temperature is needed for to get a good dryer.

NOMENCLATURE

cp_C= cocoa beans specific heat, (k Joule/kg.^{o}C),
cp_w = water specific heat, (k Joule/kg.^{o}C),
h_{fg} = latent heat of evaporation, (k Joule/kg),
Q_B = heat (energy)offuel (LPG) combustion,(k Joule),
Q_C = heat for heating solid cocoa beans, (k Joule),
Q_D = heat for heating or drying wet cocoa beans, (k Joule),
Q_{EW} = heat (latent) to evaporate the water content in cocoa beans, (k Joule),
Q_L = lost heat, (k Joule),
Q_W = heat (sensible) for heating water contained in cocoa beans, (k Joule),
T_d = temperature of dried cocoa beans (drying chamber), (^{o}C),
T_f = temperature of initial (wet) cocoa beans, (^{o}C),
W_{Cf} = mass of solid cocoa beans, (kg),
W_{we} = mass of water in cocoa beans at the end of drying process(after drying), (kg),
W_{wf} = mass of water content in wet cocoa beans, (kg),
ΔW_w = mass of water wasted during drying, (kg),
$= W_{wf} - W_{we}$
η = thermal efficiencyof the cocoa bean dryer.

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