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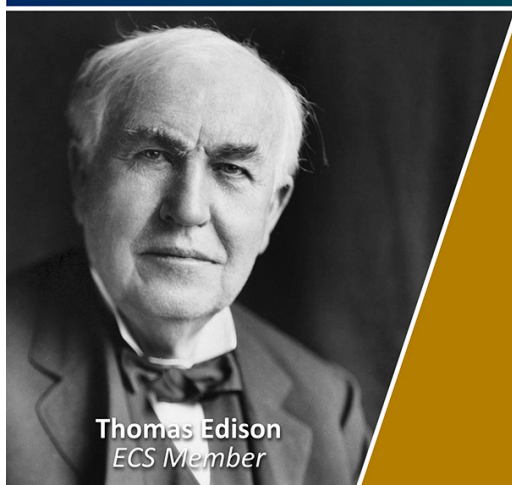
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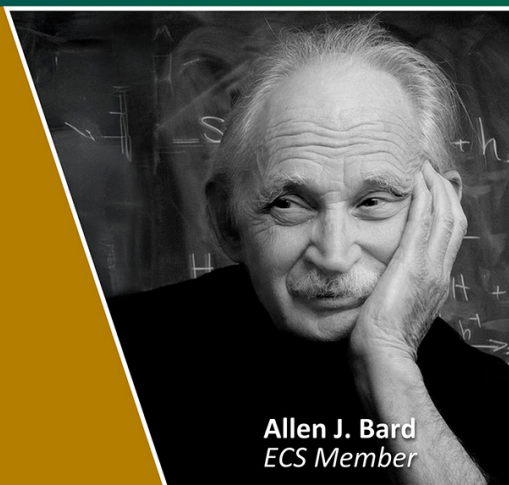
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# Temperature distribution in the planum on the cocoa box dryer in Sidorejo Village, East Lampung Regency

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**Abstract.** One of the factors that influence the quality of the results of cocoa drying using a box dryer is the temperature distribution in the Planum. This study aims to study the distribution pattern of Planum temperature in cocoa box dryers. The study was conducted on a cocoa box dryer with a hot air suction system in Sidorejo village, Sekampung Udik sub-district, East Lampung. The parameters measured are temperatures at several points in the Planum space. Temperature measurements are carried out periodically during the cocoa drying period. The results showed that temperature distribution in the Planum room was quite evenly distributed with the average temperature during the cocoa drying period (12 hours) of  $(75.01 \pm 1.85) ^\circ\text{C}$ . Drying temperature in drying chamber is  $(60.01 \pm 3.92) ^\circ\text{C}$  and moisture content of Cocoa is  $(8.06 \pm 0.65) \%$

## 1. Introduction

Lampung is one of the cocoa producing provinces in Indonesia with an area of 71,192 ha with a production level reaching 33,177 tons in 2015. East Lampung is one of the cocoa producing districts with an area of 14,300 ha with a production level of 8,802 tons [1].

As a commercially valuable commodity, quality is an important factor in seizing world market competition. Therefore it is necessary to do post-harvest processing to maintain optimal quality. The stages of processing cocoa beans are fermentation, washing, drying, sorting, packaging and storing. Drying is the reduction or decrease in the moisture content of the material until it reaches the equilibrium water level with the surrounding normal air, where the decrease in quality due to fungi, enzyme and insect activity can be ignored [2]. Cocoa beans are dried to a moisture content  $\leq 7\%$ , according to SNI quality standards [3].

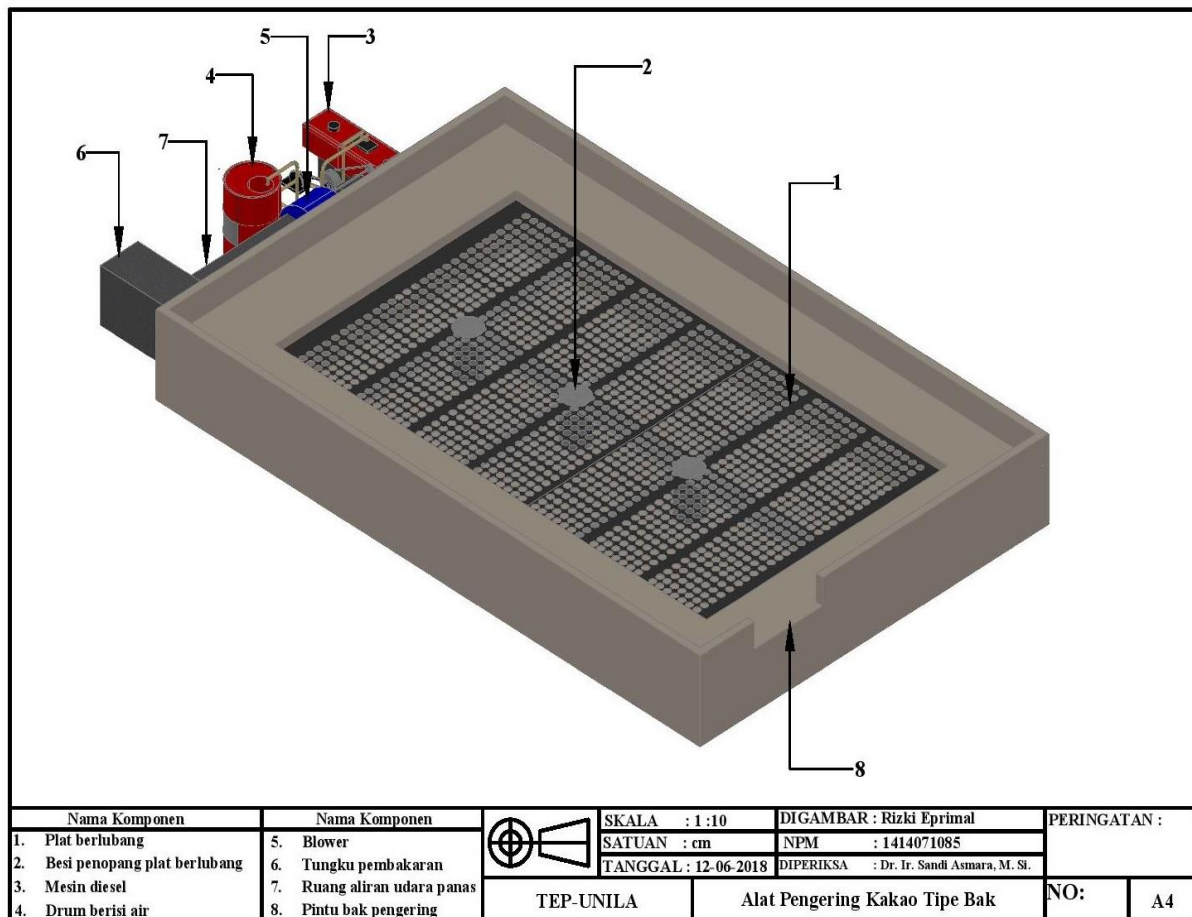
There are various dryers used for drying cocoa beans. One of the dryers used in Sidorejo village, Sekampung Udik sub-district, East Lampung, is cocoa box dryer type, with air suction system type, with wood fuel [4]. The Planum of the dryer is made terrace in order to have more uniform distribution of the drying temperature. They consequently that the moisture content of the cocoa beans after drying is also uniformly distributed. This study aims to study the temperature distribution in the Planum and its effect on temperature uniformity in the drying chamber.



## 2. Materials and Methods

### 2.1. Tools and Materials

The research was carried out in Sidorejo Village, Sekampung Udik Timur Lampung District. The tools and materials used in this study were box type dryers with hot air suction systems (figure 1), thermocouples, scales, shovels, water, wood, diesel, and cocoa beans.



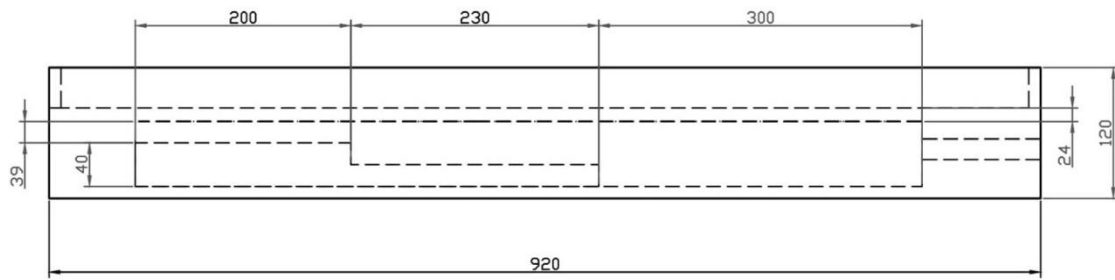
**Figure 1.** Box dryer with hot air suction system

### 2.2. Research Parameters

The parameters observed in this research include:

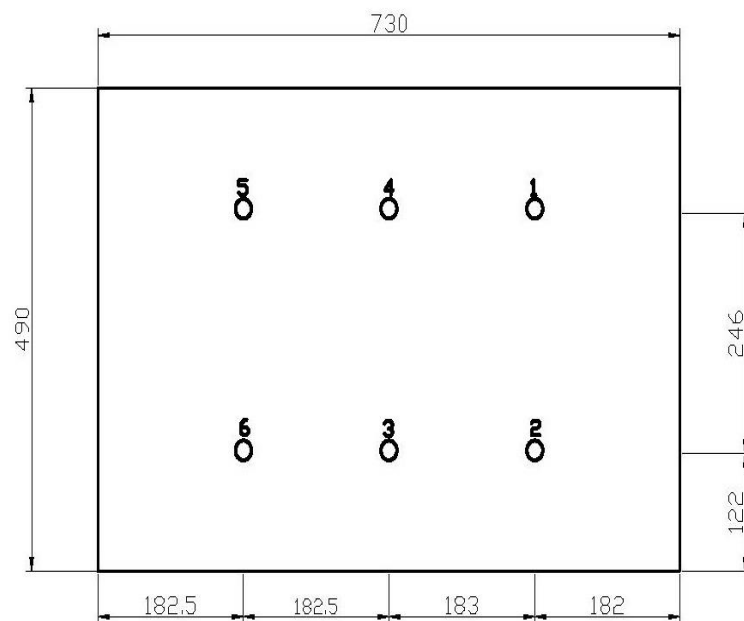
#### a. Planum temperature

The Planum was located under the drying bath with dimensions: 730 cm x 490 cm x 79 cm. The ground floor of the Planum room was made up stairs like with the expectation that the temperature distribution was more evenly distributed (figure 2).



**Figure 2.** Planum, side view

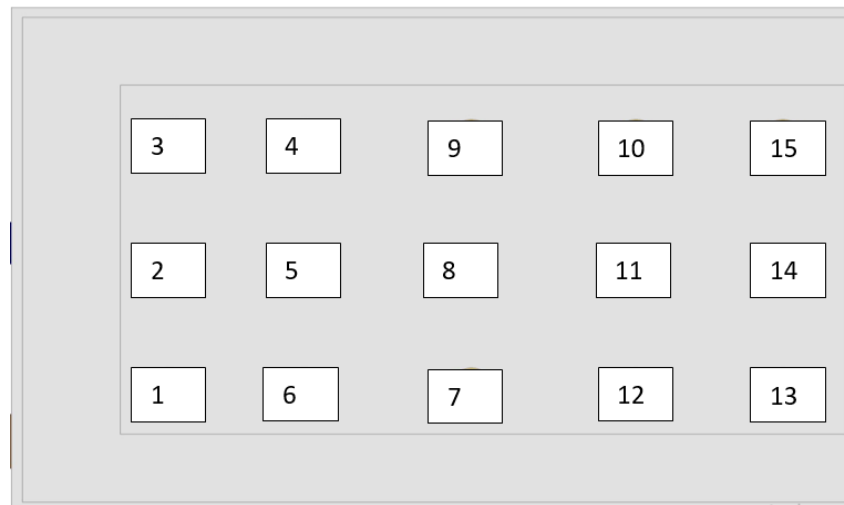
Planum temperature is measured during the cocoa drying period. Measurements were made at 6 points (figure 3).



**Figure 3.** Points measuring planum room temperature

*b. Drying temperature*

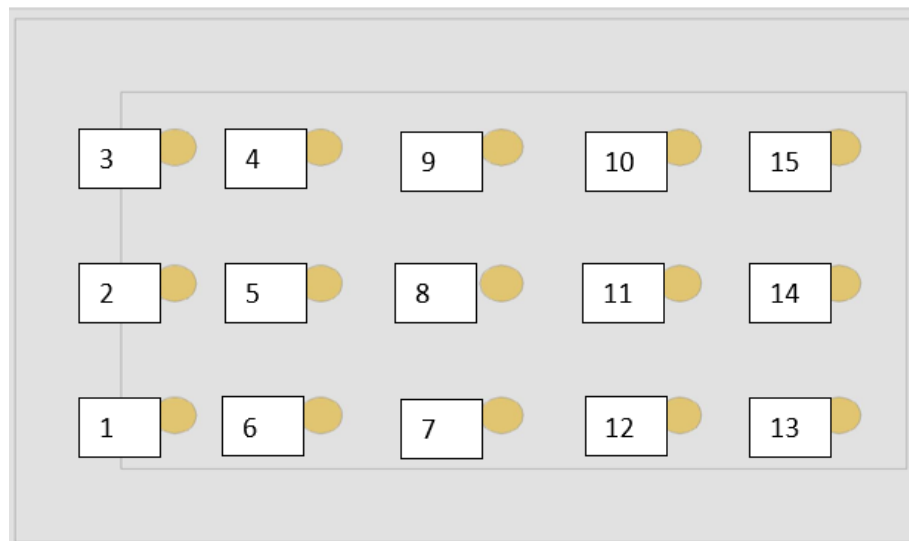
Temperature measurements are taken every one hour during the drying process. Measurements were taken at 12 points in the drying chamber (figure 4).



**Figure 4.** Measuring points for drying temperature

*c. Cocoa water content*

Cocoa water content was measured every 1 hour for up to the drying process. Drying would be stopped if the average water content of the material had reached the range of 6% -8%. Measuring water content was done at 12 points as in figure 5.



**Figure 5.** Measurement point for cocoa content

*d. Drying time*

Drying time was started when the diesel engine and rubber wood fuel were turned on until the material reached the average sample water content of 6-8%.

All parameters were measured with 3 replications, with cocoa weight 2058 kg per drying  $\Rightarrow$  common drying is done using 2058 kg cocoa

### 3. Results and discussion

#### 3.1. Planum Temperature Distribution

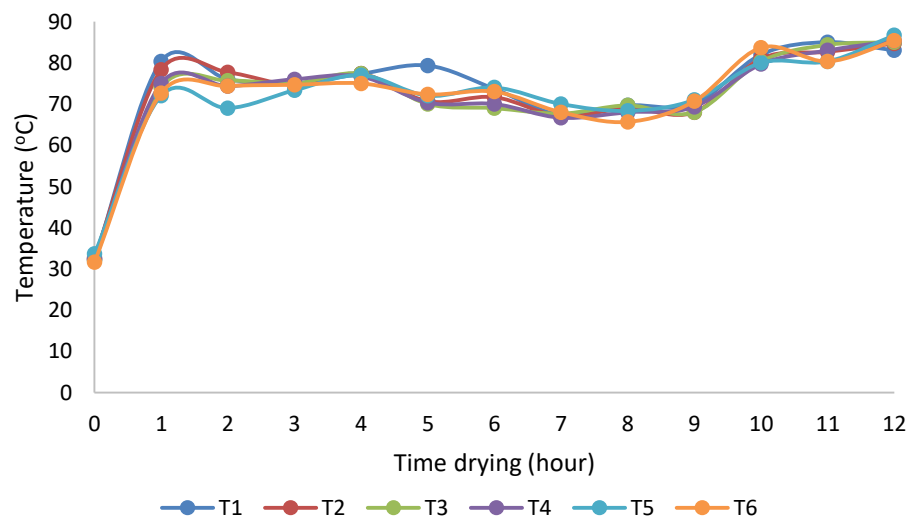
The source of hot air in drying cocoa beans with a box-type dryer is a furnace that uses rubber wood as fuel. Furthermore, hot air is sucked by the blower, flowed into the planum chamber. The bottom of the planum is not flat but made terraced from front to back (figure 2). The results of measuring planum temperatures during the drying period are in Table 1.

**Table 1.** Temperature of planum during the drying period

Position (x,y)	Time drying (hour)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Pp 1	32.33	80.33	76.00	75.00	77.33	79.33	73.67	67.33	69.67	70.00	82.00	85.00	83.00
Pp 2	32.67	78.33	77.67	74.67	77.33	70.67	71.67	67.00	69.00	68.00	81.00	82.67	84.67
Pp 3	32.00	74.00	75.67	75.00	77.33	70.00	69.00	67.67	69.67	68.00	80.33	84.33	85.00
Pp 4	32.33	75.00	74.33	76.00	76.67	70.33	70.00	66.67	68.00	69.33	79.67	83.00	85.33
Pp 5	33.67	72.00	69.00	73.33	77.00	72.00	74.00	70.00	68.33	71.00	80.00	80.33	86.67
Pp 6	31.67	72.67	74.33	74.67	75.00	72.33	73.00	68.00	65.67	70.67	83.67	80.33	85.33
Mean	32.44	75.39	74.50	74.78	76.78	72.44	71.89	67.78	68.39	69.50	81.11	82.61	85.00
STDEV	0.69	3.29	2.96	0.86	0.91	3.50	2.04	1.19	1.50	1.30	1.50	1.96	1.19

Table 1. Shows that the temperature of the Planum during the drying period ranges from 67.75°C - 85.00°C with temperature differences 0.86°C - 3.50°C. The average temperature during the drying period was  $(71.01 \pm 1.85)^\circ\text{C}$ .

The measurement results in Table 1. show that the temperature in the planum is evenly distributed, indicated by the temperature difference between the low measurement points (0.86-3.5). The distribution of Planum temperatures during the drying period can be seen in figure 6.



**Figure 6.** Temperature distribution of planum

The graph in figure 6 shows that the temperature of each observation point is no different significant. Decrease in the temperature of the chart due to the reduction of fuel (rubber wood), which is given periodically every 2 hours.

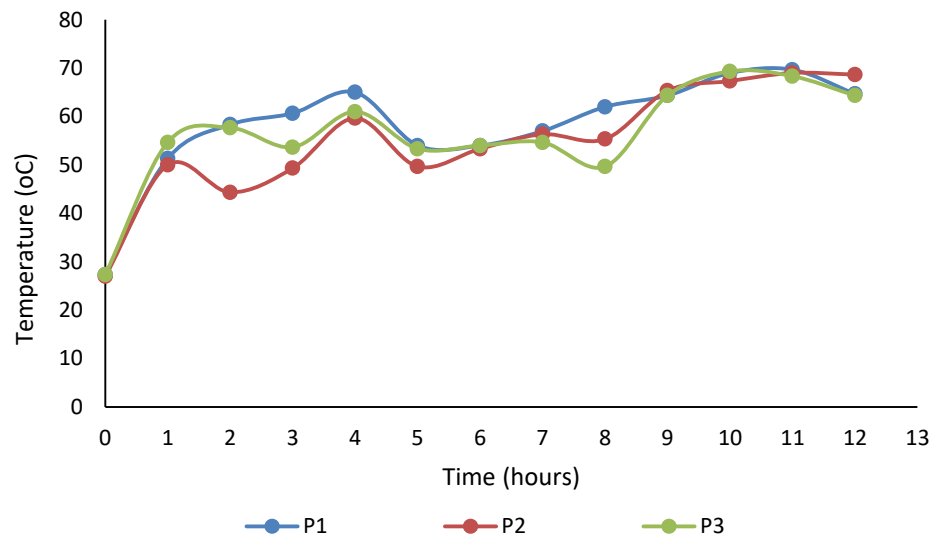
### 3.2. Drying chamber temperature

The drying chamber temperature is measured with the cocoa in it. The results of the drying chamber temperature measurements are presented in Table 2.

**Table 2.** Drying chamber temperature

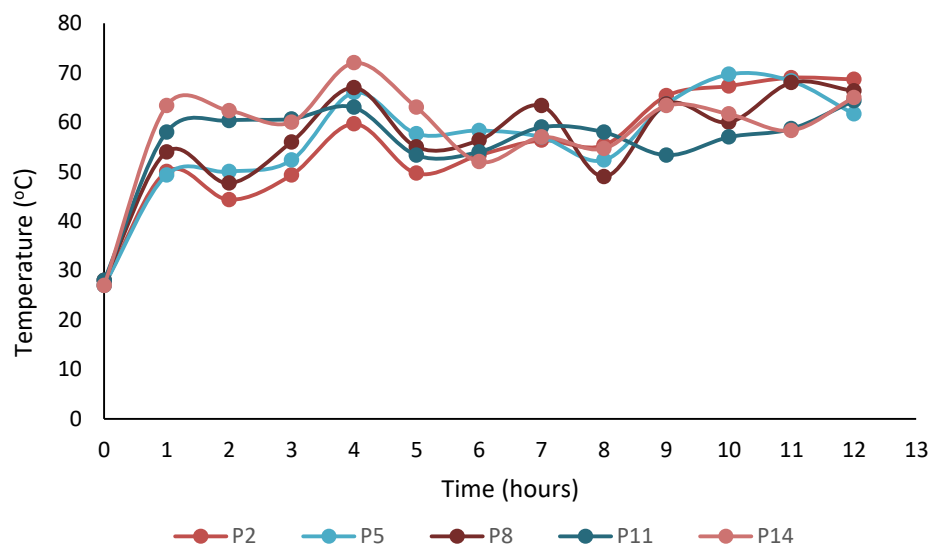
Point	Time (hour)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
1	27.33	51.33	58.33	60.67	65.00	54.00	54.00	57.00	62.00	64.33	69.00	69.67	64.67
2	27.00	50.00	44.33	49.33	59.67	49.67	53.33	56.33	55.33	65.33	67.33	69.00	68.67
3	27.33	54.67	57.67	53.67	61.00	53.33	54.00	54.67	49.67	64.33	69.33	68.33	64.33
4	28.00	53.33	56.33	60.00	67.00	53.33	55.33	59.00	52.00	66.00	70.67	70.67	66.00
5	27.00	49.33	50.00	52.33	66.00	57.67	58.33	57.00	52.33	63.67	69.67	68.33	61.67
6	27.00	54.33	50.33	63.33	61.33	51.33	56.67	60.33	51.33	68.67	67.00	73.33	68.00
7	27.33	55.67	57.67	58.00	63.00	54.67	58.33	60.67	51.67	67.33	65.33	69.67	64.33
8	28.00	54.00	47.67	56.00	67.00	55.00	56.33	63.33	49.00	63.67	60.00	68.00	66.33
9	26.67	59.33	49.67	53.00	62.00	53.67	58.00	63.00	54.00	64.00	61.67	70.00	64.67
10	27.00	53.67	61.33	59.00	67.00	55.67	51.00	59.33	51.33	63.67	62.67	61.00	68.33
11	28.00	58.00	60.33	60.67	63.00	53.33	54.00	59.00	58.00	53.33	57.00	58.67	64.33
12	27.00	58.67	64.67	63.33	65.67	52.67	52.67	62.00	53.33	60.00	66.67	63.33	66.67
13	28.00	50.67	70.67	65.67	64.67	57.67	56.67	57.33	54.67	64.67	65.67	56.67	67.33
14	27.00	63.33	62.33	60.00	72.00	63.00	52.00	57.00	54.67	63.33	61.67	58.33	65.00
15	27.67	65.00	68.67	64.33	71.00	59.33	56.67	59.00	53.00	65.00	69.00	62.33	68.33
Mean	27.36	55.42	57.33	58.62	65.02	54.96	55.16	59.00	53.49	63.82	65.51	65.82	65.91
□	0.46	4.66	7.73	4.84	3.52	3.34	2.35	2.52	3.28	3.49	4.05	5.26	2.00

Average temperature in drying chamber of all observation points during drying period is  $(60.01 \pm 3.92) ^\circ\text{C}$ . This is consistent with the results of the research of Hayati et al. that drying cocoa at  $60^\circ\text{C}$  is very preferred by panelists [5]. Temperature distribution in the drying chamber is relatively uneven than the planum temperature distribution. Table 2 shows that periodical temperature drying chamber during drying period range:  $53.49^\circ\text{C} - 65.91^\circ\text{C}$  and temperature difference range:  $2^\circ\text{C} - 7.73^\circ\text{C}$ . Temperature difference of dryer room is higher than the planum because the influence of dried material (cocoa). The drying chamber temperature during the drying process is presented in figures 7 and 8.



**Figure 7.** Drying chamber temperatures at points with the same distance from the source of hot air flow

Figure 7. shows that at the beginning of measurement (1 hour drying) to 3 points with the same distance from the source of the hot air flow having a relatively uniform temperature point, but at drying 2, 3 4, and 8 hours, there is a difference in temperature at point 1, point 2 and point 3. The temperature difference can be caused by the effect of cocoa reversing which is done every 2 hours. When revering cocoa, the hot air flow is turned off.



**Figure 8.** Drying chamber temperatures at points with the difference distance from the source of hot air flow

Figure 8 shows that the temperature difference at points with different distances from the source of the hot air flow. Temperature differences occur at the beginning of drying (1 hour) to 11 hours of drying. The difference can be caused by the cocoa reversing process, because at the temperature of the planum there is no visible effect of the distance from the air flow source on the temperature distribution.

### 3.3. Moisture content of Cocoa

Decreasing the water content is the most important factor in the success of each dryer to be tested. In this study cocoa bean material samples were taken and measured using the gravimetric method. The

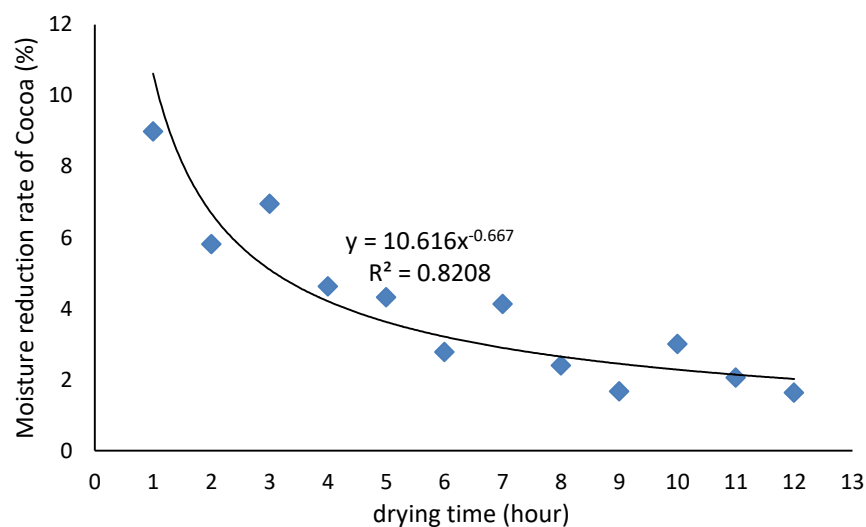


results of measurements of cocoa content are presented in Table 3, while moisture reduction rate of cocoa is presented in figure 9.

**Table 3.** Cocoa moisture content during the drying process

Sample	Time (hours)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
1	59.37	51.13	42.60	33.66	29.80	27.86	23.53	21.75	17.65	14.68	12.24	8.85	7.77
2	57.64	53.83	50.67	44.93	38.58	32.08	27.62	23.17	17.79	14.86	12.53	8.25	6.85
3	53.90	41.73	35.62	28.82	26.04	24.44	22.31	17.45	16.16	13.73	11.74	10.33	9.07
4	55.78	47.76	40.12	32.05	26.05	22.73	20.13	16.05	14.37	12.80	10.32	8.25	7.34
5	56.22	50.90	47.71	37.67	31.09	26.42	23.96	19.61	16.61	14.73	11.67	10.20	7.66
6	57.03	44.72	37.95	30.25	27.20	25.43	21.77	17.91	14.81	12.40	9.97	8.84	8.03
7	55.11	48.43	36.53	29.84	26.36	23.88	21.14	19.44	15.62	13.64	9.84	8.57	7.74
8	57.08	49.72	46.50	38.41	33.56	30.14	22.64	18.48	16.00	18.57	10.39	10.09	7.97
9	56.44	41.93	37.86	30.81	27.47	24.55	23.13	18.41	15.56	13.10	10.01	8.36	7.54
10	55.32	53.08	46.94	40.10	35.40	29.86	26.96	21.40	19.95	18.45	17.83	12.74	8.33
11	60.21	51.44	46.61	41.10	37.33	29.78	27.91	19.53	18.80	18.65	14.63	14.27	9.55
12	52.92	41.40	34.48	30.01	27.15	22.12	21.88	18.81	15.26	14.18	11.57	10.25	8.50
13	60.16	49.13	43.73	36.36	26.81	19.18	17.36	14.20	16.25	14.16	11.36	7.57	8.15
14	53.80	43.35	38.15	34.50	29.56	24.75	22.33	18.46	16.45	14.87	11.76	9.58	8.48
15	54.74	42.47	38.34	31.05	27.88	22.32	21.21	17.39	14.80	12.33	10.33	9.24	8.00
Mean	56.38	47.40	41.59	34.64	30.02	25.70	22.93	18.80	16.40	14.74	11.75	9.69	8.06
S	2.18	4.25	4.94	4.74	4.10	3.49	2.74	2.16	1.51	2.07	2.03	1.73	0.65

Table 3 shows that dried cocoa has initial moisture content 56.38 %. cocoa is dried to 8.06% moisture content during 12 hours. This cocoa water content is higher than SNI, but can already be received by cocoa processing plant [3]. For 2058 kg cocoa, rate of drying: 90.15 kg H<sub>2</sub>O/hour.



**Figure 9.** Moisture reduction rate of cocoa during the drying process

The graph of the rate of decrease in moisture content in figure 9 shows that the rate of soil moisture decreases from the beginning to 6 hours of drying with an average temperature of 22.93%. After 6 hours of drying the rate of decline is slower and is stopped at 12 hours. After 12 hours, the average moisture content of cacao is 8.06%. This is consistent with the study of Sari, et al which states that the rate of decrease in water content increases sharply at the beginning of drying to close to 20% water content, but subsequently the rate of decrease in water content decreases slowly [6].

#### 4. Conclusion

Planum floor produces an uniform temperature distribution during the drying process of cocoa with periodical temperature  $67.75^{\circ}\text{C} - 85^{\circ}\text{C}$  and a temperature difference  $0.86^{\circ}\text{C} - 3.50^{\circ}\text{C}$ . Average temperature Planum during drying period is  $(71.01 \pm 1.85)^{\circ}\text{C}$ .

Temperature distribution in the drying chamber is relatively uninform than the planum temperature distribution with periodical temperature  $53.49^{\circ}\text{C} - 65.91^{\circ}\text{C}$  and temperature difference  $2^{\circ}\text{C} - 7.73^{\circ}\text{C}$ . Average temperature in drying chamber during drying period is  $(60.01 \pm 3.92)^{\circ}\text{C}$ .

Cocoa which is dried for 12 hours can reduce moisture content from 56.38% to 8.6% water content of cocoa obtained after drying evenly with a difference in water content 0.65%.

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