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Drying of Washed Clothing Utilizing Solar Powered Dryer

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***Abstract* - This study made setups that can be used in solar powered drying of wet clothing. This was used to analyze and test the performance. It determined if there is significant difference on the drying rate of set ups related to traditional and experimental method. A solar drying chamber was designed to use local materials in which the frame is made of bamboo with walls made of plastic to trap the heat of the sunlight entering the chamber. There were four set ups that were established in the gathering of data: S-1 is with electric fan, S-2 is with electric fan and electric flat iron, S-3 which did not use the drying chamber, is a traditional method where the garments C-1, C-2, C-3, C-4 & C-5 of different sizes, shapes, width, and weight were dried under the heat of the sun. S-4 is almost similar to S-3 but the difference is that the garments were dried with no sunlight. The drying chamber alone is effective to reduce the moisture content of the garments using sunlight. Electric fan and electric flat iron increased the circulation of the enclosed hot air and boasted the drying capacity. Although it was computed that P value is greater than alpha ($P > \alpha$) in comparison with the results in all set ups, it is insufficient to conclude that there is no significant difference on the experimental and traditional set ups since the data on the traditional set ups are not complete until the garments are totally dried.**

***Index Terms* - garments, solar power, dryer, drying chamber**

I.INTRODUCTION

Drying reduces moisture content which involves the concept of heating. It is the process of removing moisture from the dried materials under the natural or manual conditions using several methods. However, hot air-drying technology obtains the advantages for it is a kind of traditional drying method that uses the heated air as the drying medium and transfers heat to the wet materials thru heat conduction effect [1]. The system which usually consists of the heating element, blower, drying chamber and heating chamber [2] performed better. There are existing studies on drying of washed clothes using solar power that achieve better results than clothes that are dried outside the window [3]. A solar cloth dryer [4] accomplished a normal drying rate of 0.35 kg.h and drying time of 3 hours even at moderate open air wind speed. Clothes lines and other hang drying methods subjected users to a lack of privacy, extremely long drying time and great dependency on weather but with the development of the solar clothes dryer was able to provide a solution through faster drying time, low cost and superior energy efficiency [5]. Sometimes, a mathematical model was derived to represent solar cloth dryer with an analysis of the elements necessary for successful designing of the various components of a solar dryer [6]. Since solar dryer is a closed chamber, dirt from outside can hardly impact the pieces of clothing which will result in a uniform, spotless and gainful drying [7]. There are cases that the solar cloth dryer is designed in which the assumptions and calculation were based on thermodynamics principles and equations [8]. The main objective of this study is to analyze setups that can be used in solar powered drying of washed clothing. Specifically, it aims to design a system by which solar powered dryer may be applied, to analyze and test the performance. It determined if there is significant difference on the drying rate of set ups related to traditional and experimental method of drying.

II. METHODOLOGY

Guided by the natural convection method of drying, a drying chamber and several set ups were made.

A. The experimental set ups

A solar drying chamber was designed to use local materials in which the frame is made of bamboo. The wall of the drying chamber is made of plastic to trap the heat of the sunlight that enter the chamber. The length of the chamber is 1.05 meters, width is 0.50 meters, height of the body is 1.10 meter but with roof included the height is 1.28 meters. It is inside the chamber where wet clothing was dried. On the first set up (S-1), an electric fan with frame made up of bamboo is attached on the chamber with the purpose that the hot air trapped on the chamber would continuously circulate around the wet clothing. The motor of the electric fan is 12 volts and 18 watts (See Figure 1).

Fig. 1: The experimental set up (S-1) showing the drying chamber, electric fan, washed clothes and the solar panel

On the second set up (S-2), an electric flat iron was attached in front of the electric fan to amplify the heat. With the electric fan, hot air would continuously circulate inside the chamber. The electric flat iron is 12 volts and 150 watts. The electric flat iron is connected directly to 200 watts solar panel while the electric fan was connected directly to a 50 watts solar panel (See Figure 2).

Fig. 2: The experimental set up (S-2) showing the drying chamber, electric fan, washed clothes and the solar panel

Set up 3 (S-3) is a control set up in which the clothes were dried in a typical way by drying under the heat of the sun without using the chamber, electric fan, solar panel and electric iron (See Figure 3).

Fig. 3: The experimental set up (S-3) showing the garments dried under the heat of the sun without using of the drying chamber, electric fan, solar panel and electric iron**.**

Set up 4 (S-4) is similar to S-3 except that the garments are not exposed under the heat of the sun without drying chamber, electric fan, solar panel and electric iron. The garments used are composed of the following: The first cloth (C-1) is a rectangular absorbent cloth which was used as rug with size of 36cmX55cmx1mm. The weight of this cloth when dried is 0.01Kg. The second cloth (C-2) is a 30cmX36cmX4mm rectangular rug that when dried is weighing 0.2kg. The third cloth (C-3) is a 36cmX55cmx4mm rectangular rug in which when dried is weighing 0.30kg; the fourth cloth (C-4) is a rug with oval shape and width of 31cm, length of 43cm, thickness of 5mm and dry weight of 0.40kg. The fifth cloth (C-5) is a long jean pant with width of 46cm, length of 51cm, thickness of 3mm and dry weight 0.45kg.

B. The data collection process

The collected data were based on the moisture contents of the washed clothes after they were exposed to drying for several hours. Using the four set ups the moisture of the washed clothes were measured in hourly basis after the set ups were prepared.

C. Treatment of data

Significant difference on the computed data were determined using ANOVA and t-test. The statistical tools were used to prove the following null hypothesis: is there a significant difference on the following: S-1 versus S-2, S-2 versus S-3, S-3 versus S-1, S-4 versus S-2, S-4 versus S-1, S-4 versus S-3, and S-1 versus S-2 versus S-3 versus S-4 versus S-5.

III. RESULTS AND DISCUSSION

A. The designed system

The designed system was based from the idea that direct solar and ventilation gains are two crucial parameters that should be taken to design an enclosed cloth solar dryer [9]. A temperature-controlled chamber is based on the natural chamber principle utilizing pressure, temperature, humidity and moisture [10]. Hence, the design of this solar cloth dryer is an enclosed chamber made of plastic that five to fifteen number of clothes could be dried. The frame of the cloth dryer is made of bamboo.

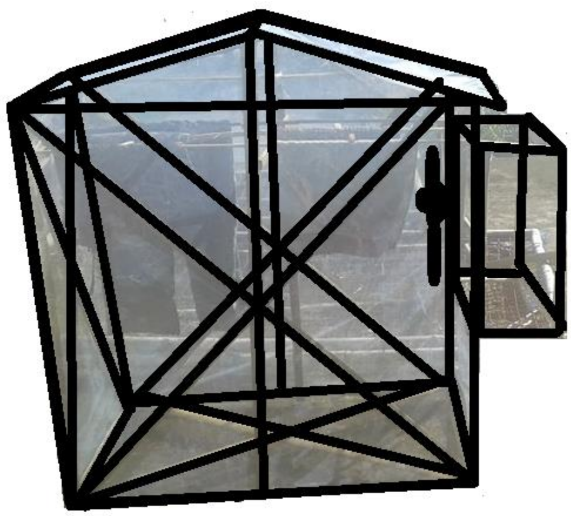

Fig. 4: The designed solar powered dryer

Enclosure of the chamber with plastic does not allow the ray of sunlight to escape making the temperature inside higher as the enclosed sunlight reflect inside. Supplying the chamber with an electric fan increased the circulation of the enclosed hot air and boasted the drying capacity. The electric flat iron was supplied to reinforce the enclosed temperature making the drying capacity higher. Using solar energy makes the operation of the drying chamber free however, it was disclosed [11] that the conventional temperature and humidity chambers comprising of air circulating fans, refrigerator unit, electric heater and humidifier consumes much energy during the operation. Figure 4 shows the designed solar powered dryer.

B. The observed moisture content for S-1

It was observed that C-1 was dried within three hours, C-2, C-4 and C-5 were dried within four hours while C-4 contains 10% of moisture content.

Table 1. Moisture content after hours of drying on S1

Cloth No.	Drying time (Hours)				
	0	1	2	3	4
	Moisture content (%)				
C-1	2000	1000	100	0	0
C-2	250	200	125	50	0
C-3	133.33	100	83.33	50	0
C-4	100	50	37.5	25	10
C-5	100	55.56	44.44	33.33	0
Mean	516.67	281.11	78.05	31.67	2.0

The data reveals that using air circulating fan reduced the moisture content of the garments. The data also reveals that the drying rate on each different kind of garments varies and are increasing. Air circulation through the electric fan may increase airflow that eventually improve drying rate since airflow carry away moisture [12].

C. The observed moisture content for S-2

It was observed that C-1 was dried within three hours, C-2, C-4 and C-5 were dried within four hours while C-4 on that time contains 12.5% of moisture content. The situation is almost similar with S-1.

Table 2. Moisture content after hours of drying on S-2

Cloth No.	Drying time (hours)				
	0	1	2	3	4
	Moisture Content (%)				
C-1	2400	1,400	100	0	0
C-2	225	205	100	90	0
C-3	150	133.33	100	40	0
C-4	87.50	75	50	25	12.5
C-5	144.44	77.78	33.33	11.11	0
Mean	601.34	378.22	76.67	33.22	2.5

The data reveals that using air circulating fan and flat iron as heat pump and temperature enhancer reduced the moisture content of the garments. The data also reveals that the drying time of the different kind of garments varies and are increasing. It supported that using fans inside the greenhouse helps the air to circulate and mix, giving rise to a more homogeneous inside temperature that increased the average value of normalized air velocity by 365 % and increased the average values of kinetic turbulence energy inside the greenhouse by 550 % compared to conditions of natural ventilation [13]. The open and semi-open heat pump dryers could be greatly affected by ambient temperature and humidity while the closed heat pump drying system could be greatly affected by the bypass air rate [14].

D. The observed moisture content for S-3

It was observed that C-1 was dried within three hours while C-5 were dried within five hours while C-2 on that time contains 115% of moisture content, C-3 has 33.33% and C-4 has 5.0%.

Table 3. Drying time and moisture content on S-3

No.	Drying time					
	0	1	2	3	4	5
	Moisture content (%)					
C-1	1900	900	400	100	0	0
C-2	200	195	180	170	125	115
C-3	110.00	93.3	80	73.3	66.7	33.3
C-4	55	50	35	25	12.5	5
C-5	122.2	77.8	68.9	55.6	22.2	0
Mean	477.4	263.2	152.8	84.8	45.3	30.7

The data reveals that the drying rate on each different kind of garments varies and are increasing. The data shows that using the heat of the sun as the conventional method reduced the moisture content, however it takes longer time to dry the garments as compared to the drying chamber with fan and electric flat iron.

E. The observed moisture content for S-4

It was observed that C-1 was dried within seven hours of drying while C-5 are still containing large amount of moisture content.

Table 4. Drying time and moisture content on S-4

No.	Drying time							
	0	1	2	3	4	5	6	7
C-1	240	1900	1800	1700	1400	900	8	0
C-2	290	285	280	270	250	200	190	185
C-3	183	1.67	164	160	133	117	110	107
C-4	112	100	97	95	75	63	55	50
C-5	167	162	144	120	89	78	67	62
M	630	523	497	469	389	271	86	81

The data reveals that the moisture content was reduced in conventional setup with no sunlight but the drying time is delayed compared to the other set ups. Among the disadvantages of the traditional method of sun drying is when it totally depends on good weather conditions [15].

F. Reduction of moisture content

The table shows that S-2 has highest reduction at 151.94, followed by S-1 at 128.67 and S-3 at 89.53 while is the lowest S-4 at 52.03.

Table 5. Reduction of moisture content per hour of drying.

T	Setups			
	S-1	S-2	S-3	S-4
1	235.56	232.12	214.22	107.65
2	203.06	301.45	110.44	25.67
3	46.38	43.45	68	28.11
4	29.67	30.72	39.5	79.56
5	0	0	14.61	118.05
6	0	0	0	185.46
7	0	0	0	5.15
Mean	128.67	151.94	89.35	52.03

The data reveals that using an electric fan with electric flat iron was effective to increase the reduction of the moisture content. Utilizing air velocity of air stream circulation and medium or high temperature in the process may result in a product of superior quality compared to products dried by solar dehydration [16].

G. Significant difference on data of different set ups

The table shows that the null hypotheses cannot be rejected for $P > \alpha$ on the following investigation: S-1 VS S-2, S-2 VS S-3, S-3 VS S-1, S-4 VS S-2, S-4 VS S-1, S-4 VS S-3 and S-1 VS S-2 VS S-3 VS S-4.

Table 6: Significant difference on data of different set ups

Parameters	Computation Result	Decision
S-1 VS S-2	$P = 0.41 > \alpha = 0.05$	Cannot reject the hypothesis
S-2 VS S-3	$P = 0.23 > \alpha = 0.05$	Cannot reject the hypothesis
S-3 VS S-1	$P = 0.28 > \alpha = 0.05$	Cannot reject the hypothesis
S-4 VS S-2	$P = 0.19 > \alpha = 0.05$	Cannot reject the hypothesis
S-4 VS S-1	$P = 0.21 > \alpha = 0.05$	Cannot reject the hypothesis
S-4 VS S3	$P = 0.40 > \alpha = 0.05$	Cannot reject the hypothesis
S-1 VS S-2 VS S3 VS S4	$P = 0.60 > \alpha = 0.05$	Cannot reject the hypothesis

Although the computed data reveals that there are no significant differences on the data of different set ups, the result could not be the bases to prove that there is no significant difference on the performance of drying on set ups where the traditional and the experimental methods were applied. The investigated data are limited only at certain hours that the garments on experimental method were dried and not to the point that all the garments used particularly on the traditional set ups were totally dried.

IV. CONCLUSION

The solar cloth dryer on this study is an enclosed chamber made of plastic and bamboo frame. Enclosing the chamber with plastic prevents the ray of the sunlight to escape. This increased the inside temperature. The drying chamber alone is effective to reduce the moisture content of the garments utilizing the sunlight while with electric fan and electric flat iron, the drying capacity of the enclosed hot air was boasted. Although it was computed that $P > \alpha$ in all the compared data of the set ups, it is insufficient to conclude that there is no significant difference on the experimental and traditional set ups since the traditional set ups of drying are not continued until all the garments are totally dried. The study could be replicated on drying of agricultural and fishery products using the designed chamber.

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