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บทความวิจัย

Design and Fabricate an Electric Oven in Combination with Solar Energy to Increase Production of Seasoned Sour Tamarind for Duang Thong Community Enterprise

Thongchai Khrueaphue[1*] and Nisit Ong-art[2]

[1] Program in Production Technology, Faculty of Agricultural and Industrial Technology, Phetchabun Rajabhat University, Thailand

[2] Program in Industrial Electrical Technology, Faculty of Agricultural and Industrial Technology, Phetchabun Rajabhat University, Thailand

[*] Corresponding author, E-mail: Thongchai010426@gmail.com

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Abstract: The purposes of this study were to design and fabricate an electric oven in combination with solar energy. The study compared the efficiency of the former three-phase current oven with variables in temperature, time, dryness percentage, and power consumption. The results of the aspect of transferring knowledge and technology show that 4.31±0.61 total average satisfaction with good level acceptance. The result in the efficiency of an electric oven with solar energy, in using only electricity, was found that the highest temperature 60 degrees Celsius was the best drying temperature with a percentage of dry consistency at 91 percent and consumption rate at 6.51 baht per hour. Compared to the former oven with the electric and solar energy oven by considering the best variables, it was found that the developed oven had the percentage of dry consistency at 94 percent, used average timing in drying at 190 minutes and consumption rate was around 5.62 baht per hour. This was able to reduce cost, time, and consumption rate compared with the former oven that had the dry consistency percentage at 85 percent, use average timing in drying around 240 minutes with consumption rate around 13.77 baht per hour.

Keywords: Electric oven; Solar energy; Seasoned sour tamarind; Duang Thong Community Enterprise

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1. Introduction

The famous tamarind is cultivated in Phetchabun province. The tamarind is usually processed to many products such as dried tamarind, tamarind vinegar and tamarind pie. The dried tamarind is one of the most popular products for consumer. Currently, Duang Thong Community Enterprise, Nong Phai, Phetchabun is a group producing processed products from sour tamarind in the “Sour Tamarind” brand. Since the seasoned sour tamarind products are distributed both internal and export to other countries, they cannot produce as the requirement of consumers, the order of reservation and distribution is more every year. The current producing power is 80-100 kilogram/day. Producing seasoned sour tamarind has many processes; grinding, pressing, drying, cutting, and packing which the most important process is dryness since the essence of tamarind should be keep dry and moisture in the appropriate condition before packing. If the tamarind is too dry, the sour flavor will be decreased [1]. If the tamarind is too moisture, it will be caused fungus on the surface. Currently, Duang Thong Community Enterprise uses the method of drying in the sunlight, switching in the three-phase electric oven and drying with sunlight has the disadvantage in unable controlling the moisture and sometimes the sunlight is not sufficient, it has to take a long time in the sun drying. Drying with only one electric three-phase oven cannot increase production power and it has to merely apply with a three-phase current and the cost is expensive with the budget in setting for a large amount. Another problem with the three-phase oven is that there is no moisture controlling system, which affects tamarind for slower dryness [2].

Consequently, the purposes of the study were to design and fabricate an electric oven in combination with solar energy to increase production of seasoned sour tamarind at a lower cost and apply it to a one-phase electric current for general accommodation. Solar energy is renewable energy that cannot be exhausted [3, 4] and it can generate heat at high and very high level when it is stored in transparent material or room. Due to many advantage factors, it is particularly suitable for heating several products. The drying equipment generally cannot control the humidity and temperature during baking as a result, the roasted tamarind is not of the desired quality. Currently, the production technology has changed rapidly. Increase efficiency and reduce production costs are one of the important components of replacing human labor, reducing waste, and accelerating production. Electric oven with solar energy is the alternative way as the solution to the mentioned problems since the capital of producing oven is low and it can work

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in both sunlight and no light condition [5]. Moreover, the moisture-controlling system with ventilating fan caused the tamarind to easily dry than normal. If there is no sunlight, the heater would increase to the required temperature [6]. Since the oven can work with every household and can be applied to everyone in the enterprise group of sour tamarind, thus, it can increase production power per day.

2. Materials and methods

2.1 Conventional drying equipment.

This study examined the efficiency of the former oven (three-phase), electric oven with solar energy (one-phase) which would examine into 2 functions; using only electric current for heating without sunlight energy and using electric current for heating with solar energy, for comparing information and results. The examination was done in both the former oven and developed oven with drying temperature at 45, 50, 55, 60, 65, and 70 degrees Celsius [6, 7] which is the highest temperature of the ovens. 30 kilograms of tamarind were used in each experiment (The oven can apply 30-50 kilograms per time), timing in tamarind drying from the moisture content of tamarind is 28-30% db. and the moisture control was maintained between at 15-20% db. which was suitable moisture value for consistency drying of tamarind piece in producing seasoned sour tamarind. After that, dryness was measured by random method with tamarind slices [1] and estimated the consumption rate by calculating the electric current with electric meter gauge comparing to each drying time. The study examined three times in each experimental variable. The moisture content of tamarind was determined by method of standard AOAC 1990.

2.2 The design of the electric oven with solar energy.

In the design of the electric oven in combination with solar energy as shown in Fig. 1 (A) it is a modular design with four main components; 1 front cover element, 6 grill elements, 1 top cover element, 1 piece, and 1 set of oven structure parts. Fig. 1 (B) is an illustration of the oven with 6 pieces of 3 tier grills and the front and top covers can be opened 90 degrees to facilitate the loading of 2 tamarind grills in the top and easily taking in and off the 2 middle grills and 2 lower grills. It is also easy to maintenance. Fig. 1 (C) was an assembly design with the solar energy control setting, 4 heater systems, and moisture controlling systems with 2 ventilating fans [5, 8]. The dimensions of the electric oven are approximately 120 centimeters wide, 180 centimeters long and 150 centimeters high.

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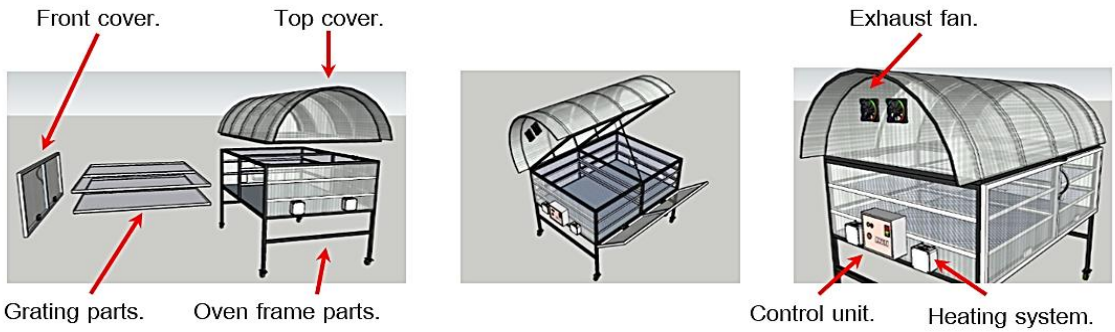

(A) Modular design (B) Assembly of parts (C) Control system design

Fig. 1 Design characteristics of the electric oven with solar energy

2.3 The invention of the electric oven with solar energy.

From Fig. 2, the former three-phase electric oven, the oven structure was rectangular and made of stainless steel. The top of the oven was a 6,000 watt heating unit without a moisture control system. The capacity of tamarind in each drying was 40-50 kilograms. When compared with electric oven with solar energy as shown in Fig. 3, which was a complete oven and ready to work. The installation of 4 heat controls and each unit was 1,000 watt, 1 solar cell with 120 watts was in the top in a compatible with a 12 volt 55 amp renewable battery for working when there was no sunlight. This operation can be continuously worked for 6 to 8 hours after no sunlight condition [4, 6]. When the battery power ran out, the system would be switched to electric power. With this advantage, the electric oven with solar energy used a lower consumption rate than the former one [7]. In the conversion of energy systems to use by a 2,500 watt 12 volt inverter and a 12 volt 10 amp charger. The setting of the heating control system for quick-drying in the oven and a moisture control system with ventilating fans were as follows. For drying processing, 30 kilograms of tamarind was placed in a drying chamber on the two-level trey. The power supply of the heating system was controlled by the control unit. The air velocity during drying of 0.35 meters per second and the temperature of the drying chamber was measured by Thermocouple (Type K) [8]. Perform color measurements with a highly accurate WR10 digital color difference meter. For the early drying period, the drying process operated by using solar energy in a day and the power supply for the drying process was switched to electric power at night.

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Fig. 2 The former three-phase electric oven

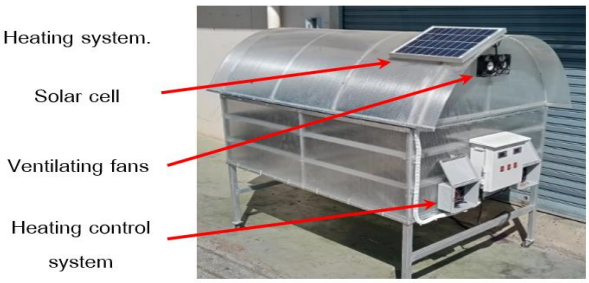

Fig. 3 Electric oven with solar energy

3. Results and Discussions

3.1 The result of transferring knowledge and technology of electric oven with solar energy

Knowledge and technology transfer to Duang Thong Community Enterprise, Phetchabun province in which 20 participants had 3-8 years of working experience in drying tamarind. The evaluation was in 3 aspects which the results of satisfaction as shown in Table 1. It was found that the overall satisfaction was 4.31±0.61 and the score was at a good level. When considering each aspect, the most average score was knowledge transferring with 4.39±0.58 and with a good level. Moreover, when summarizing the overall assessment of knowledge transfer of electric oven with solar energy, there were no points that were below the standard indicators (Key Results: KRs) of the project. It can show that the design and development of an electric oven in combination with solar energy to produce seasoned sour tamarind can meet the needs of the target audiences effectively [9].

3.2 The results of the experimental in drying seasoned sour tamarind.

From the experiment of drying seasoned sour tamarind in an electric oven with solar energy as shown in Fig. 4, the results of the experiment as shown in Fig. 5 (A), the tamarind was too dry and rough, in dull and tasteless color with a color value between L=34.81 a=19.32 b=37.23. The weight is light due to the over and high-temperature drying, causing the surface of tamarind to dried faster than the inner side. When compared to Fig. 5 (B), which was exactly dry with a soft surface and in red and brown color, with color value is between L=28.80 a=15.35 b=25.09. The tamarind pulp was moistured and wet with a good smell from drying, due to the appropriate temperature related to heating and its consistency dry throughout the piece of tamarind [6]. Fig. 5 (C), the tamarind was too moist, sticky together as a lump in dark brown color, the color value is between L=25.20 a=5.07 b=15.99.

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Table 1 Result of transferring knowledge and technology of electric oven with solar energy

Assessment Details	$(\bar{x})$	S.D.	Level
Knowledge transfer process			
Trainers have knowledge and ability to convey	4.48	0.58	Good
Trainers have easy-to-understand techniques and methods for transferring knowledge	4.50	0.52	Very good
Trainers can answer questions covering questions	4.25	0.62	Good
Trainers have a variety of media to transfer knowledge	4.48	0.58	Good
Trainers used the time for training and demonstration appropriately	4.25	0.62	Good
Average	**4.39**	**0.58**	**Good**
Usefulness			
Bring knowledge and technology to apply in daily life	4.38	0.65	Good
The electric oven with solar energy has been used to increase productivity	3.97	0.72	Good
Average	**4.17**	**0.68**	**Good**
Satisfaction			
Satisfaction for electric oven with solar energy	4.50	0.52	Very good
Satisfaction for transfer of knowledge and technology	4.25	0.62	Good
Average	**4.37**	**0.57**	**Good**
Total Average	**4.31**	**0.61**	**Good**

Because it dried at a low temperature for a long time, some part of tamarind was not ready in the transpiration process, causing a lot of moisture to accumulate [7,10].

3.3 The results of the efficiency testing of the former electric oven (3-phase type).

The researchers tested the efficiency of the former electric oven as data in comparison with the designed and developed one. Table 2 shows that the most appropriate temperature was at 65 degrees Celsius. The percentage of drying consistency was 85 percent and the consumption-rate was 13.77 baht per hour. The enterprise group was able to dry twice a day with 80-100 kilograms per day. However, the more or less temperature than 65 degrees Celsius, it was affected to consistency percentage in dryness, too much or too little [6, 11]. Moreover, the timing of drying is more than the developed oven since the former oven did not have an air or moisture absorption system during drying and it caused more accumulated moisture, so it would take more time to dry as well [12].

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Fig. 4 Flavored sour tamarind cooked by the electric oven with solar energy

(A) Tamarind that is too dry. (B) Suitable dry tamarind. (C) Very moist tamarind.

Fig. 5 Characteristics of dried tamarind by the electric oven with solar energy

Table 2 Results of the efficiency testing of the former electric oven.

Experimental Variables	Average Drying time (Minute)	Drying Consistency (Percent)	Consumption Rate (Baht per hour)
Temperature 45 °C	450	71	25.81
Temperature 50 °C	390	79	22.35
Temperature 55 °C	355	76	20.64
Temperature 60 °C	275	85	15.48
Temperature 65 °C	240	85	13.77
Temperature 70 °C	180	87	10.32

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3.4 The results of efficiency testing of an electric oven with solar energy from using only electricity.

From Table 3, the experiment found that the maximum temperature of the oven was 60 degrees Celsius and a slow increase in heating due to it used only one heat setting. Therefore, the suitable variable in dryness was at 60 degrees Celsius, the percentage of the drying consistency was 91 percent and the consumption rate was 6.51 baht per hour. If the temperature was less than 60 degrees Celsius, the consistency in dryness was low [13]. Since the timing for dryness was 245 minutes, the ability in drying was twice a day.

3.5 The results of efficiency testing of an electric oven with solar energy.

Table 4 shows that the most suitable temperature was 65 degrees Celsius, the percentage of drying consistency was 94 percent and the consumption rate was 5.62 baht per hour. The drying time was 190 minutes and it was able to dry 3 times a day. The capacity was increase from around 80-100 kilograms per day to about 120-150 kilograms per day. However, from the analysis, it was found that heat, moisture, and time greatly affected the tamarind drying process. If the temperature was too hot, the tamarind dried unevenly. Some part was dried than other parts [14].

Table 3 Results of efficiency testing of an electric oven with solar energy from using only electricity

Experimental Variables	Average Drying Time (Minute)	Drying Consistency (Percent)	Consumption Rate (Baht per hour)
Temperature 45 °C	425	78	11.38
Temperature 50 °C	350	82	9.48
Temperature 40 °C	315	88	8.52
Temperature 60 °C	245	91	6.51

Table 4 Results of efficiency testing of an electric oven with solar energy

Experimental Variables	Average Drying Time (Minute)	Drying Consistency (Percent)	Consumption Rate (Baht per hour)
Temperature 45 °C	390	82	11.55
Temperature 50 °C	330	86	9.75
Temperature 55 °C	295	88	8.71
Temperature 60 °C	210	91	6.23
Temperature 65 °C	190	94	5.62
Temperature 70 °C	135	96	4.02

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On the other hand, if the temperature was lower, it affected moisture in tamarind to take longer in drying [15]. Hence, moisture-controlling systems with ventilating fans can vent the humidity very well.

In comparison, it was found that the electric oven combined with solar energy is more efficient than conventional ovens. Considering the percentage of tamarind drying at uniform dryness throughout the pods and energy consumption of all variables, when considering the best variable, the baking temperature was 65 ^{o}C, which is the variable that Duangthong Community Enterprise Group has most satisfied and wanted both in terms of dryness, tamarind color, time and energy consumption because the tamarind is not dry and not too moist, and when considering at 70 ^{o}C, the percentage drier was higher than all variables. However, the baked tamarind is dry only on the skin surface. Due to the high temperature, the area dries out too quickly.

4. Conclusion

The objectives of the research were to design and fabricate the electric oven in combination with solar energy for Duang Thong Community Enterprise to increase the production of seasoned sour tamarind comparing the efficiency of the former oven and the developed one. The results of tamarind drying by the electric oven with solar energy in considering to the best variable percentage of drying consistency at 94 percent with drying time average at 190 minutes and approximately consumption rate at 5.62 baht per hour. Compared to the former oven, the best variable of drying consistency percentage was 85 percent, the drying time was around 240 minutes and the consumption rate was approximately 13.77 baht per hour. Compared to the power, it can save money around 8.15 baht per hour and save the time about 50 minutes per time. If considered in 1 day, the former oven can dry twice a day but the electric oven with solar energy can dry 3 times a day. The production can increase by at least 20-50 kilograms per day. Normally, the enterprise group can dry tamarind 80-100 kilograms per day, and if the low-cost ovens were built more and used by the members in this enterprise group, they will be able to increase their production capacity according to the number of machines since the ovens can be applied with the household electricity.

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6. References

[1] N. Chaiyat, Upgrading of Low temperature solar heat with cascade vapor compression and absorption heat pump, International Journal of Modern Engineering Research (IJMER), 2019, 3(4), 1923-1934.

[2] U. Teeboonma and S. Jongjam, Ginger drying using infrared-vacuum technique, Burapha Science Journal, 2010, 15(2), 76-86.

[3] S. Saelee, S. Manoton, W. Maneephan, P. Unturo, S. Sonsaree, E. Boonthum, E. Kaewcharoen, Drying giant sour tamarind preserves with a solar dryer: Giant sour tamarind farmers group Phitsanulok Province, The 6th Pibulsongkram National Conference (PBR 2020), Proceeding, 2020, 18-27. (in Thai)

[4] B.W. Brook and C.J.A. Bradshaw, Key role for nuclear energy in global biodiversity conservation, Conservation Biology, 2015, 29(3), 702-712.

[5] P. Klaimanee, W. Onniam, N. Yaikaew, Three phase inverter driver for three phase induction motor in single-phase electrical system. Project, Sripatum University, 2012. (in Thai)

[6] P. Sa-adchom, P. Supavititpatana and T. Supavititpatana, Effect of drying temperature on foam-mat tamarind drying using far-Infrared radiation, The 18th TSAE National Conference (TSAE 2017), Proceeding, Article No. TFE010, 277-282. (in Thai)

[7] S. Khwan-on, S. Vatcharasukpo, Analysis and simulation of a high step-up DC-DC converter for renewable energy system applications, Applied Mechanics and Materials, 2015, 775, 378-382.

[8] J. Kaewdiao, N. Dussadee, C. Thararux, N. Homdoung and S. Chindaruksa, Air flow simulation and design of a rotary tray solar dryer combined with infrared rays for fish products, The 14th Conference on Energy Network of Thailand (E-NETT), Proceeding, 2018, 6-12. (in Thai)

วารสารวิชาการเทคโนโลยีอุตสาหกรรม (The Journal of Industrial Technology)
ISSN (Print): 1686-9869, ISSN (online): 2697-5548
DOI: 10.14416/j.ind.tech.2021.08.005

[9] S. Srisawad, T. Khrueaphue and S. Theakthum, Design and fabrication of tobacco leaf-stripping machine to enhance economic production of farmers in Phetchabun Province, SNRU Journal of Science and Technology, 2020, 12(3), 198-206. (in Thai)

[10] A. Borah, K. Hazarika and S.M. Khayer, Drying kinetics of whole and sliced turmeric rhizomes (Curcuma longa L.) in a solar conduction dryer, Information Processing in Agriculture, 2015, 2(2), 85–92.

[11] J. Prasad, V.K. Vijay, G.N. Tiwari, and V.P.S. Sorayan, Study on performance evaluation of hybrid drier for turmeric (*Curcuma longa* L.) drying at village scale, Journal of Food Engineering, 2006, 75(4), 497-502.

[12] B.M.A. Amer, M.A. Hossain, and K. Gottschalk, Mathematical modelling of solar assisted hybrid dryer for banana, Energy Conversion and Management, 2010, 51(4), 813–820.

[13] P. Yinkunthod, Drying agricultural product using solar energy, Master Thesis, King Mongkut's University of Technology Thanaburi, Thailand, 2005. (in Thai)

[14] A. Ekpong, W. Phomkong, and E. Onsaard, The effects of maltodextrin as a drying aid and drying temperature on production of tamarind powder and consumer acceptance of the powder, International Food Research Journal, 2016, 23(1), 300-308. (in Thai)

[15] S. Methakhup, N. Chiewchan and S. Devahastin, Effects of drying methods and conditions on drying kinetics and quality of Indian gooseberry flake, LWT - Food Science and Technology, 2005, 38(6), 579-587.