Optimization of Infrared Radiation Heating in Disinfestations of Organic Hom Mali Rice

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Abstract

There is a difficulty in using chemical in disinfestations process in organic rice products therefore, this research was aimed to study the optimal setting of infrared radiation heating for disinfestations in Organic Hom Mali Rice. Disinfestations process and rice storage were collected by surveying coupled with interviewing the rice milling enterprise. The infrared radiation heating used in this experiment was belt type with lamp power of 1000 watt. In this study, Design of experimental technique was applied to generate the optimum setting of the infrared heating process. The experiments generated by Box Behnken design were 15 experiments and 2 replicate times, therefore the total experiments were 30 times. The 3 factors include heating temperature, gap between rice and infrared lamp and rice layer thickness. The result from statistical data analysis at reliability level of 95 % shown that the optimization value were heating temperature of 70 ^{o}C, height of lamp above rice of 10 cm. and rice thickness of 0.5 cm, insects mortality rate within 2-3 minutes. Rice after heating were subjected to naturally slow cooling by air, therefore rice quality in a good condition without broken or cracking.

Key words: Infrared radiation heating, rice weevil, design of experiment

1. Introduction

Thailand is one of the agricultural countries which the majority of people are farmers. Consumption of rice are throughout the year, therefore rice storage are important [1]. Especially, Organic Hom Mali Rice which is derived from organic production where all chemicals or synthetic products and fertilizers cannot be used in all stages of production. Farmers can only use natural materials or substance from plant that has no toxic residues in the production and the environment to make rice production is good quality[2].

Generally, milled rice has to keep for a period of time before delivery to customer. If rice were not kept nicely, there will be a chance of deteriorate by moisture or insects. There are many types of rice enemy such as, Rhyzopertha dominica F., Red flour beetle, Siamese grain beetle, Angoumois grain moth, Rice weevil and Maize weevil, etc. [3, 4] The main enemy of the Organic Hom Mali Ri ce is Rice Weevil. It is a small insect and has a fast growth rate. Its deteriorate rice by bite both from internal and external rice kernel resulting in damage and weight loss. Problems encountered when applying chemical in pesticide such as toxic in human and environmental from using chemical, etc.

There are many researcher attempt and develop new methods in disinfestations by not using chemicals. For example, using infrared radiation heating is one alternative to return used chemical, decreased humidity rice and temperature increase, until death insect. The radiation will spread to the rice grain within a short period of time, rice structure not crack or broken. [5, 6, 7]

Cost analysis of disinfestations Organic Hom Mali Rice and decision making in selection infrared radiation heating machine has been presented by Insorn W. et al 2009. However, the optimal parameters in operation setting have not been tested. The operation parameters include temperature, space between lamp and rice and thickness of rice. These factors are needed to be controlled in order to control rice quality.

However, competition in the rice market is high due to product quality is necessary to satisfy customers. The one popular and reliable method when cost and production time is critical is design of experimental [8]. Design of experimental (DOE) is a methodology in designing experiments for processes based on statically control [9,10,11]. Design of experiment is technique to use in design of experimental and product development in preliminary processes such as (1) productivity and manufacturing processes developed improvement. (2) reduce losses in the manufacturing process in the experiment. (3) time shortening the manufacturing and (4) low cost. Design of experimental is importance for contribution the productivity development improvement, used production experimental and industry.

Therefore, this paper is aimed to use design of experimental in generating optimum operating parameter of infrared radiation heating for disinfestations in Organic Hom Mali Rice when quality of rice after heating process is necessary.

2. Materials and Methods

2.1 Design of experimental (DOE)

2.1.1 Preliminary design of experimental is screening of main factor to significantly in the disinfestations by infrared radiation heating application for Organic Hom Mali Rice. Minitab R.14 was used for Design of experimental. Table 1 is listed of three Operating parameters include Temperature

50-70 °C, Space between rice and Lamp of 10-20 cm and Thickness of rice layer of 0.5-1.5 cm. By using Design of experimental of Box - Behnken Design, there were 15 possible setting generated and with 2 repeats, therefore total experiments were 30 times as shown in Table 2.

Table 1 Level and limited of factors in the preliminary experimental

Factors	Set level		Symbol
	Low level	High level	
1.Temperature (^oC)	50	70	T
2. Lamp high (cm.)	10	20	H
3.Rice thickness (cm.)	0.5	1.5	Th

Table 2 Experiment model and experiment results from Minitab Release 14

Experiment Sequence	Random Sequence	Parameter levels			
		T (C^o)	H (cm.)	Th (cm.)	Percentage (%)
1	7	50	15	1.5	0
2	2	70	10	1	100
3	9	60	10	0.5	100
4	22	50	15	1.5	0
5	20	50	15	0.5	0
6	10	60	20	0.5	97.5
7	19	70	20	1	100
8	16	50	10	1	0
9	26	60	10	1.5	95
10	3	50	20	1	0
11	18	50	20	1	0
12	1	50	10	1	0
13	14	60	15	1	97.5
14	15	60	15	1	97.5

Table 2 (Cont.) **Experiment model and experiment results from Minitab Release 14**

Experiment Sequence	Random Sequence	Parameter levels			
		T (C^o)	H (cm.)	Th (cm.)	Percentage (%)
15	21	70	15	0.5	100
16	28	60	15	1	97.5
17	4	70	20	1	100
18	25	60	20	0.5	97.5
19	17	70	10	1	100
20	29	60	15	1	97.5
21	30	60	15	1	97.5
22	8	70	15	1.5	100
23	13	60	15	1	97.5
24	12	60	20	1.5	90
25	23	70	15	1.5	97.5
26	11	60	10	1.5	95
27	24	60	10	0.5	100
28	5	50	15	0.5	0
29	6	70	15	0.5	100
30	27	60	20	1.5	92.5

2.2 Infrared radiation heating machine

The infrared radiation heating is used for disinfestations in Organic Hom Mali Rice. Fig. 1 is a schematic showing a prototype machine designed to have size of 0.50 × 4 × 2 meters. Infrared lamp power of 1,000 watt is fitted. The space between lamp and rice is adjustable. Temperature control system is also controllable. During operation, rice was placed on a the conveyor system and flow rack system to separate rice and insects that will flow into the tray support provided.

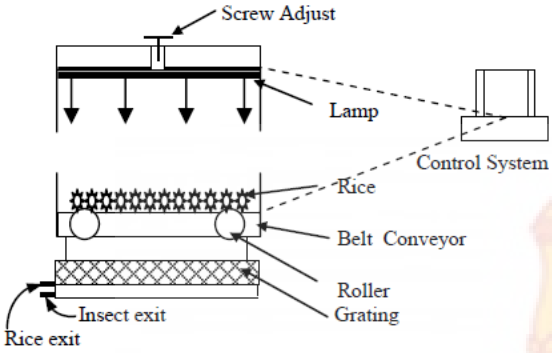
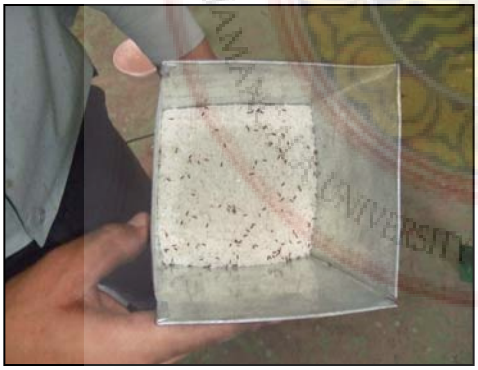


Fig. 1 Simulate of operation mechanism of infrared radiation heating machine (Prototype)

Experimental method sequences are as follows

1. For each experiment, testing rice weight 5 kg per 40 insects (Fig. 2a)
2. Pour rice in the hopper and adjust the thickness of the rice with the level adjust screw. (Fig. 2b)
3. Adjust temperature control system as needed. (Fig. 2c)
4. Rice was released by pass through conveyor belt system to infrared radiation heating for disinfestations. Each experiment was random as listed in Table 1.
5. The rice pan with rice separation grating system and insects flow into the tray support (Fig. 2e).



2a) Rice prepare

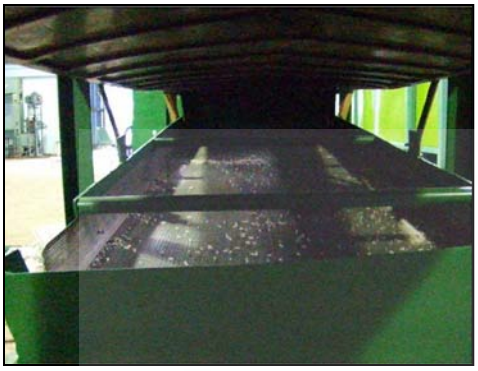
Fig. 2 Experimental process

2b) Rice pour in tray

2c) temperature control

2d) infrared radiation system

Fig. 2 (Cont.) Experimental process



2e) grid system

2f) mortality rate of insect

Fig. 2 (Cont.) Experimental process

3. Result and Discussion

3.1 Verify data by determining the distribution of residuals. A normal distribution of residuals is plotted in Fig. 3. It was showed that the residues from the result of the percentage of insects' dead have normal distribution. This indicated the appropriate of all 30 test results.

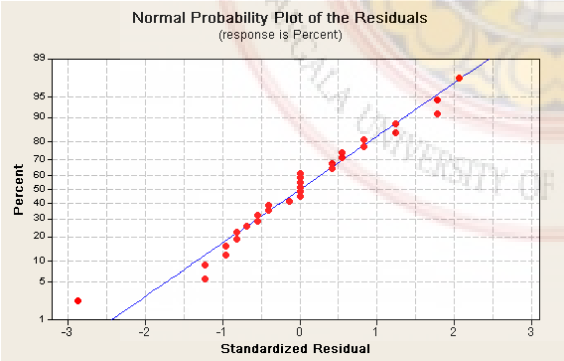


Fig. 3 Normal distribution graph of residuals

3.2 The independence of data was determined by using distribute charts. Fig. 4 is residuals versus the order of the data. It was shown that points are random distributed therefore, the data are independent.

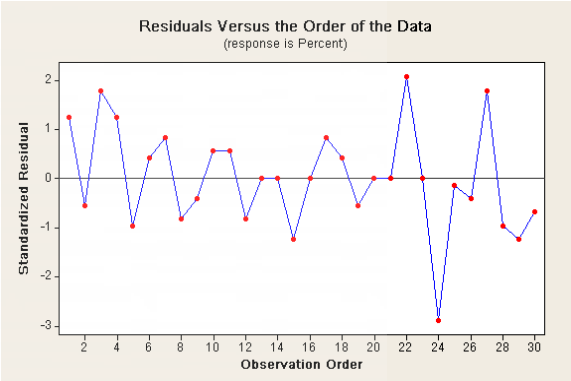


Fig. 4 Residuals versus the order of the data

3.3 The stability of the variance is determined from residuals and the fitted value as shown in Fig. 5. Residues of experimental results are consistently distributed both in positive and negative. This indicated that variance is stable.

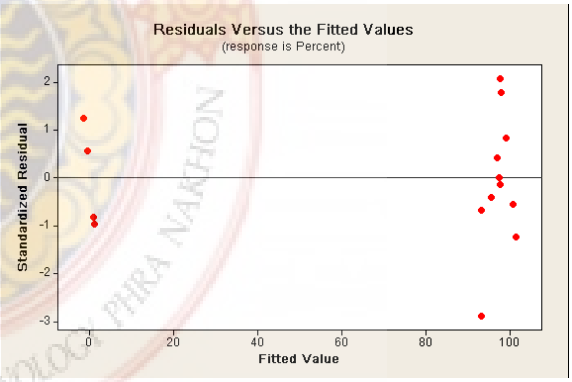


Fig. 5 Residual graphs with priority of data

As shown in Fig. 3-5 that experiment data is suitable, the decision coefficient R^2 was then analyzed. Table 3 shows the analysis coefficient decision (R-

Sq). R-Sq was 99.9% and the R-Sq adjusted equal to 99.9 % which considered satisfactory.

Table 3 P value used in selection the parameters that affecting per mortality of insect by mean of percentage generated by Minitab Release 14.

Response Surface Regression: Percent versus T, H, Th

The analysis was done using uncoded units.

Estimated Regression Coefficients for Percent

Term	Coef	SE Coef	T	P
Constant	-1898.59	23.0755	-82.277	0.000
T	61.30	0.6623	92.551	0.000
H	0.72	0.9072	0.792	0.437
Th	10.00	8.0649	1.240	0.229
T*T	-0.47	0.0053	-88.529	0.000
H*H	-0.03	0.0212	-1.180	0.252
Th*Th	-3.75	2.1179	-1.771	0.092
T*H	0.00	0.0102	0.000	1.000
T*Th	-0.06	0.1017	-0.614	0.546
H*Th	-0.12	0.2035	-0.614	0.546

S = 1.439 R-Sq = 99.9% R-Sq(adj) = 99.9%

Analysis of Variance for Percent

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	56137.8	56137.8	6237.53	3012.84	0.000
Linear	3	39799.2	18746.5	6248.82	3018.30	0.000
Square	3	16337.0	16337.0	5445.66	2630.36	0.000
Interaction	3	1.6	1.6	0.52	0.25	0.859
Residual Error	20	41.4	41.4	2.07		
Lack-of-Fit	3	35.2	35.2	11.72	31.88	0.000
Pure Error	17	6.2	6.2	0.37		
Total	29	56179.2				

3.4 Optimization of the parameter

1. Prediction equation is formed by the coefficient, Coef values from Table 3. This predicted equation will be used for forecast the optimization of parameters when maximize dead of insect is calculated as follow

$$\text{Maximize} = -1898.59 + 61.30(T) + 0.72(H) + 10.00(Th) - 0.47(T*T) - 0.03(H*H) - 3.75(Th*Th) + 0.00(T*H) - 0.06(T*Th) - 0.12(H*Th) \quad \text{(eq.1)}$$

2. The optimization of parameters was analyzed by using Response Optimizer function. The composite desirability (D) of response value was between 0 – 1. If D value is equal to 1, it means parameters were fully desirability. The optimized setting of the infrared radiation heating machine were showed in Table 4 and Fig. 6.

Table 4 The optimization of parameters

Parameters

	Goal	Lower	Target	Upper	Weight	Import
Percentage	Maximum	99.9	100	100	1	1

Global Solution

Temperature [T] = 70.0
High [H] = 10.0
Thickness [Th] = 0.50

Predicted Responses

Percentage = 101.25, desirability = 1
Composite Desirability = 1.00000

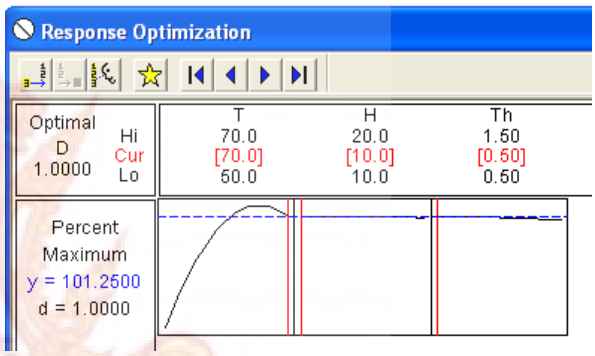


Figure 6 Response graph of the optimization values of experiment

The repeated experiment with the optimum setting confirmed that all insects were deteriorated without rice cracking.

4. Conclusion

Design of experimental was used to generated the optimum setting operating parameters of infrared radiation disinfestations in Organic Hom Mali Rice at 70 ^{o}C, lamp height 10 cm and rice thickness 0.5 cm. the disinfestations was 100%. The slow cooling by air maintained rice quality in a good condition without broken or cracking. Therefore, the entrepreneurs help and administrators of rice mill can used guidelines for decision making and

organizations development to more effectively.

5. Acknowledgement

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6. References

[1] R. Aroonpanichlerd. 2006. The application of infrared radiation for beef drying. Master of engineering Department of energy technology Faculty engineering Mahasarakham University. Thailand.

[2] S. Poupan and S. Chaivimol. 2007. Organic rice production. Department of agriculture Support and services product quality development.

[3] C. Suprakan et al,. 2009. *Study on stored grain in airtight storage in Thailand*. http://pikul.lib.ku.ac.th/cgi-bin/agdb1.exe?rec_id=060525&database=agdb1&search_type=link&table=mona&back_path=/agdb1/mona&lang=thai&format_name=TFMON. March 19, 2009.

[4] N. Mungpaseard et al,. 2009. *Insects of rice enemy*. http://www.brrd.in.th/rkb/data_005/rice_xx2-05_bug_index.html. April 9, 2009.

[5] W. Insorn et al,. 2009. The survey of the Hom Mali Rice disinfestations method in Thailand rice milling industry : Case study of rice milling in surin province. UBU. Engineering journal. Vol. 2 No.1 January–June 2009 : 59-69.

[6] Z. Pan, R Khir and D. Larry. 2007. Feasibility of simultaneous rough rice drying and disinfestations by Infrared radiation heating and rice milling quality. Journal of food engineering. 84 : 469–479.

[7] P. Ramatchima.A study on elimination of paddy insect by infrared radiation. 2009. ThaiLIS is Thailand library integrated system. http://tdc.thailis.or.th/tdc/search_result.php. April 9, 2009.

[8] J. Antony and N. Capon. 1998. Teaching experimental design techniques to industrial engineers. *International journal of engineering education*, 14(5), 335-343.

[9] A. Ampaiboon et al,. 2008. Optimization of MAG-M Welding condition using experiment design technique. Industrial engineering network conference. October 20 - 22, 2008.

[10] P. Chutima. 2002. Design of experimental. 2nd edition. Chulalongkron university publication. Thailand.

[11] D.C Montgomery. 2001. Design and analysis of experiments. 5th edition. Arizona state university.