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Implementation of a Solar – Assisted Dryer for Fish

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ABSTRACT

The Pangasius elongatus (called as Ca Dua in Vietnamese), especially one-sunning Ca Dua is a favourite food and in high value. However, for now, the only solution has been the open sun drying which causes the problems in the dried fish quality.

A 10kg/batch laboratory dryer using solar energy as a heat source was designed and fabricated. Experimental results have shown that the solar collector meets the requirement of drying temperature in range from 40°C to 50°C. Dried Ca Dua satisfied the requirements of the moisture content, whiteness value, and criteria of microorganism. Furthermore, using CCD with JMP software, the optimal drying parameters were found, namely 44°C in drying air temperature and 0.24m/s in air velocity.

A solar – assisted dryer with capacity of 100kg/batch was designed, fabricated, and applied at Kim Yen food enterprise in Can Gio District. The dryer's operation has satisfied all proposed technical requirements. The drying results have shown that the quality of dried Ca Dua is stable, in which, the whiteness value of dried products (57.4%, 57.8%) is higher than that from natural sun-drying product (55.8%, 56.2%). The dryer has also worked well for Croaker, Sole fish, and Spanish mackerel.

Keywords: Pangasius elongatus, Open sun drying, Solar collector, Specific energy, Whiteness value.

1. INTRODUCTION

The one-sunning Ca Dua is a favourite food and in high value. However, for now, the only solution has been the opening sun drying which causes the problems in dried fish quality, and food hygiene and safety. A dryer can solve these problems.

The key objective of the study is to design and fabricate a dryer for Ca Dua and some of other kinds of fish with the capacity range from 50 to 100kg per batch. The dried products have to meet the requirements in quality: moisture content (MC, reduced from 80% ± 3% down to 60% ± 1%, corresponding to one-sunning Ca Dua), the color (56% ± 1% in whiteness value), and the criteria of microorganism.

The reasonable source of energy for drying and the drying principle are the first consideration for designing dryer. Solar energy source is inexhaustible; however, it is "free but not cheap". The solar collector [1] has solved this problem. The solar collector for drying consists the horizontal cylinders, made from heavy PE transparent sheet, with black PE sheet inside as heat absorber and to be easy in fabrication. Its efficiency can up to 40%. Drying tray will be reasonable for thin slice of fish. Furthermore, drying through tray is selected to increase the efficiency of thermal transfer [2]. The dryer is based on the air-reversal principle because of its advantages [3]. The selected dryer model is presented in figure 1.

In which, fish is put on trays (5) in drying chamber (6). Fan (2) sucks heated air from the solar collector (1) through resistor box (3) and blows it through the trays. When valve (4) is closed, drying air blowing from down to up (blue arrow), and opened for reversal direction (red arrow). Besides an air filter is installed on the duct between (2) and (3) to prevent dust and insect from air.

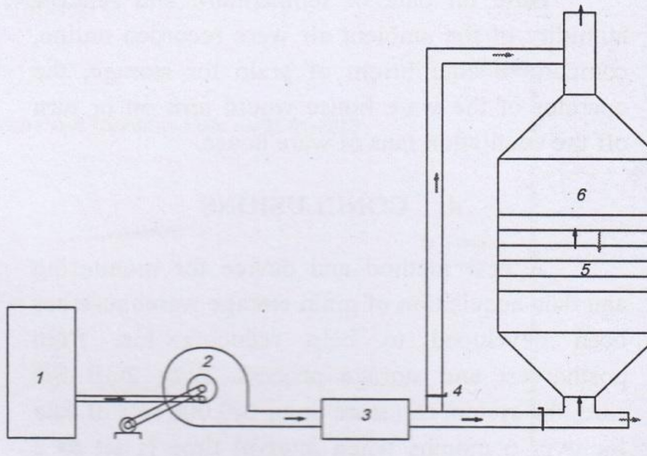

Figure 1: A selected model for designing dryer

2. MATERIALS AND METHODS

A 10kg/batch laboratory dryer was designed and fabricated. The dryer has operated well in temperature range from 40°C to 50°C, with the superficial drying air velocity from 0.21m/s to 0.27m/s. The dryer has been used to find the optimal drying parameters.

An orifice plate was installed to determine superficial air velocity. Temperature were measured with different thermometers (mercury in-glass, infrared and thermal sensor) with about 0.5°C in accuracy. The moisture content was measured by oven method (Daihan101-1). The whiteness value, W (%), was measured by Chroma meter CR-400 Konica Minolta, and the specific energy consumption (A_r) is determined by the rate of the total electric power consumption per batch and the mass of fresh fish.

The Food Hygiene and Safety Standard for the dried aquatic products being applied in Vietnam, TCVN 5649:2006, was used to evaluate the criteria of microorganism.

The experimental design is randomly. The statistical data analysis was made on replicated measurements. The optimal analysis for drying process based on CCD (Central Composite Design) using JMP software 4.0.

3. RESULTS AND DISCUSSIONS

3.1 Optimal drying process for one – sunning Ca Dua

The fresh Ca Dua (80% ± 3% wb) will be dried to become one-sunning Ca Dua (60% ± 1% wb). The quality of dried fish is represented by the requirements in the moisture content, the whiteness value (56% ± 1%) and the criteria of microorganism with low specific energy consumption.

When the whiteness value is an important factor affecting to price of product and saving energy is usually a requirement for drying process. These two factors were chosen to be output parameters of optimization problem. In addition, to meet the required moisture content, the drying air temperature and superficial air velocity decide the two output parameters [4, 5, 6, 7]. The optimization problem is suggested as the following: drying air temperature and superficial air velocity are the two input drying parameters; these are independent parameters while the whiteness value and specific energy consumption are two output factors.

Based on the investigation results for natural sun-drying, the considered drying air temperature was selected in three levels of 40°C, 45°C, and 50°C. The superficial air velocity was investigated in range from 0.21m/s to 0.27m/s [8] and also selected in three levels of 0.21m/s, 0.24m/s, and 0.27m/s.

The encoded matrix of the treatments is presented in table 1.

Table 1: The encoded matrix of the treatments

Treatment	Drying temperature (X_1, °C)	Superficial air velocity (X_2, m/s)	Specific energy consumption (Y_1, kWh/kg)	Whiteness value (Y_2, %)
0a	45	0.197	1.17	59.59
-+	40	0.27	0.84	59.74
00	45	0.24	1.22	57.21
++	50	0.27	1.49	54.2
0A	45	0.282	1.23	53.63
A0	52.07	0.24	1.42	53.91
a0	37.93	0.24	0.81	59.03
--	40	0.21	0.81	60.28
+-	50	0.21	1.47	56.34
00	45	0.24	1.22	55.92

The correction between model and experiment results of the specific energy consumption and the whiteness value is described in figure 2 and 3, respectively.

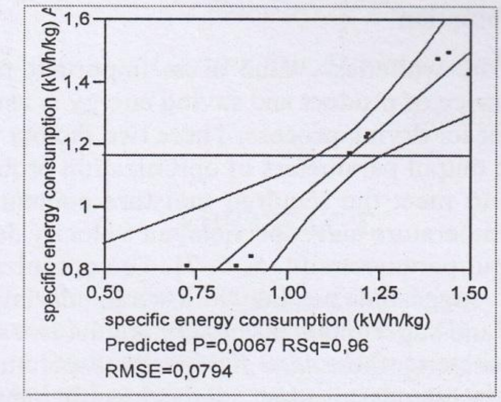

Figure 2: The correction between model and experimental result of specific energy

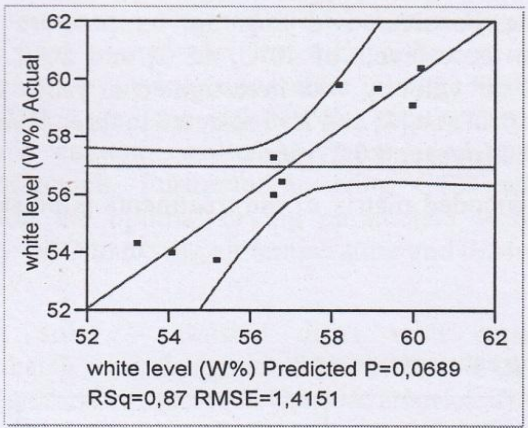

Figure 3: The correction between model and experimental result of whiteness value

Figures 3 and 4 have shown that the correction coefficients (R^2) to be 0.96 and 0.87 respectively; the correction is significant. Based on the coefficient and analysis results for the correction between input parameters and specific energy consumption as well as whiteness value, with 95% in reliability degree, the regression equations were deduced as the following:

$$Y_1 = 1.22 + 0.27X_1$$

$$Y_2 = 56.56 - 2.09X_1 - 1.38X_2$$

As a result, optimal drying process is presented in figure 4.

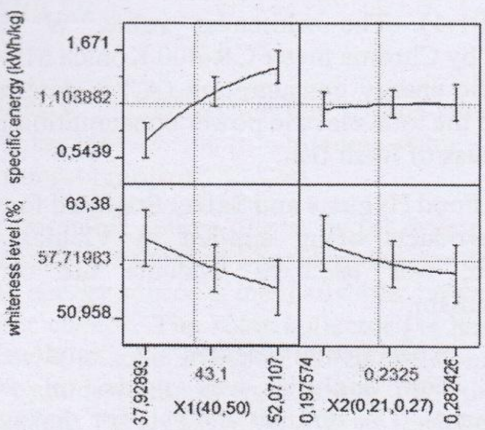

Figure 4: The results of optimal drying process for one-sunning Ca Dua

The optimal drying parameters were found: 43.1°C in drying air temperature and 0.23m/s in superficial air velocity resulting in 57.7% of whiteness value with 1.1kWh/kg in specific energy consumption. Based on the experimental results for optimal drying parameters: 44.2°C in drying air temperature and 0.24m/s in superficial air velocity, resulting in 57.1% of whiteness value corresponding to 262 minutes in time for drying; the optimal drying parameters for one-sunning Ca Dua have been selected to be 44°C in drying air temperature and 0.24m/s in superficial air velocity.

3.2 The criteria of microorganism of the dried Ca Dua

The tests for the criteria of microorganism were also conducted. The results are presented in table 2.

Table 2: The test results for one-sunning Ca Dua

	Criteria	Sample A	Sample B	Sample C	Sample D
1	TPC (cfu/g)	$0.0225x10^6$	$0.128x10^6$	$4.1x10^6$	$< 10^6$
2	Coliform (cfu/g)	$1.5x10^2$	$2.5x10^2$	230.10^2	$< 10^2$
3	E.coli (cfu/g)	Nil	$4.5x10^1$	$590x10^1$	<10
4	Clostridium perfringens (cfu/g)	Nil	Nil	Nil	< 20
5	Salmonella (cfu/25g)	Nil	Nil	Positive	Nil
6	S. aureus (cfu/g)	Nil	Nil	Nil	$< 10^2$
7	V.parahaemolyticus (cfu/g)	Nil	Nil	Negative	$< 10^2$

In the table 2, Sample A, B, and C are the one-sunning Ca Dua from enterprise A, B, and C in Can Gio District. These samples were dried from open sun-drying. Sample D was dried from the dryer.

Based on TCVN 5649:2006, the results have shown that the samples A, B and C did not meet for Coliforms; samples B and C did not meet for E.coli, and sample C was also not satisfied the requirement for Salmonella. The cause can be the contact to the dust, insects and especially flies which could not prevent in open sun drying.

Sample D met all the criteria of microorganism for food hygiene and safety. This result can be from isolating insects by putting fish in drying chamber and drying air was cleaned by an installed air filter.

3.3 A solar – assisted dryer for fish

A solar – assisted dryer for fish, figure 5, with the capacity from 50kg/batch to 100kg/batch was designed, fabricated, and applied at Kim Yen food enterprise.

Dryer consists of the following components: A 1.5HP motor-fan (1) with air volume up to 0.4 m^3/s; drying chamber (4) consists of twelve 1.0m x 1.2m trays with 0.1m in the distance between trays. Solar collector (7) consists of two cylindrical plastic collectors in which each cylinder is 1m in diameter and 12m in length. The collector is quite light and was installed on a rooftop. In fact, to reduce investment cost, the collector can be made from inexpensive materials in local area such as bamboo slats and plastic cords. A 8kW resistor box (2) consisting 4 levels of power (0kW, 2kW, 3kW, 3kW) based on ON-OFF to control the drying temperature. Valve (3) used to change the direction of drying air, and (8) is the drying air filter.

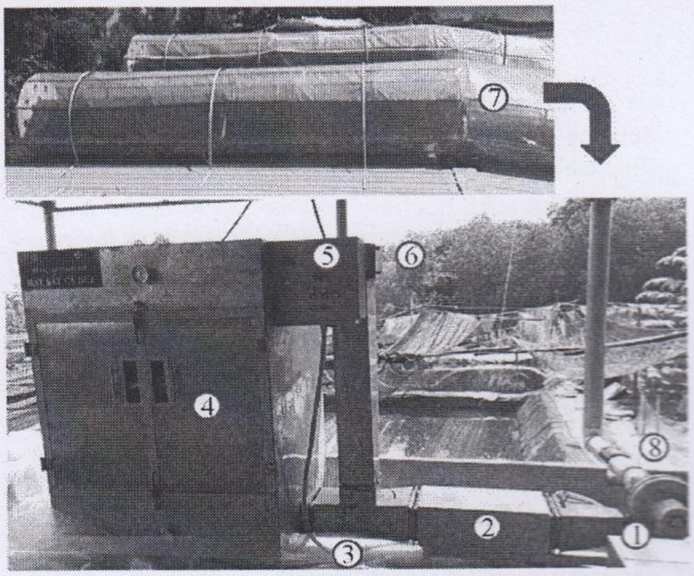

Figure 5: Dryer for fish, 100kg/batch, using solar energy at Kim Yen enterprise

Some initial drying results are presented in table 3:

Table 3: Drying results on the dryer for fish

Batch	Name&mass (kg) of fresh fish	Input MC (%wb)	Drying temperature (°C)	Drying velocity (m/s)	Output MC (%wb)	Whiteness value (%)- using dryer	Whiteness value (%)- sun drying
1	Ca Dua, 58	78.1	44	0.24	59.8	57.4	56.2
2	Ca Dua, 62	77.8	44	0.24	60.5	57.8	55.8
3	Croaker, 60	78.5	45	0.24	60.9	52.3	51.2

The optimal drying parameters for Ca Dua was selected for batch 1 and 2. The results presented that the whiteness value of dried Ca Dua were stable (57% - 58%) and higher than that of sun-drying Ca Dua (57.4% compared to 56.2%, and 57.8% compared to 55.8%).

The objective of batch 3 is to confirm that the dryer can work well for Croaker. The experimental result has presented that the whiteness value of dried product (52.3%) was much better than that (51.2%) of sun-drying product. The recently drying results have presented that the dryer has also worked good for Sole fish and Spanish mackerel.

The dryer is easy for fabricating in small-scale mechanical factories. The drying technology and equipment are ready to transfer to local manufacturers.

4. CONCLUSIONS

A laboratory 10kg/batch dryer for using solar energy as a heat source was designed and fabricated. Experimental results have shown that the solar collector meets the requirement of drying temperature in range from 40°C to 50°C. Dried Ca Dua has satisfied in requirements for the moisture content (60% ± 1% wb), the whiteness value (56% ± 1%), and the criteria of microorganism. Furthermore, the optimal drying parameters were found, namely 44°C in drying air temperature and 0.24m/s in air velocity.

A solar – assisted dryer with the capacity of 100kg/batch was designed, fabricated, and applied at Kim Yen food enterprise. The dryer's operation has satisfied all proposed technical requirements. The drying results have shown that the quality of dried Ca Dua is stable, in which, the whiteness value of dried products (57.4%, 57.8%) is higher than that from natural sun-drying product (55.8%, 56.2%). The drying results on this dryer have also been good for Croaker, Sole fish and Spanish mackerel.

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REFERENCES

[1] Hien P.H., Vinh L.Q., Thuy T.T.T., Tuan T.V., 2009, *Development of solar-assisted dryers for food and farm crops*, American society of agricultural and biological engineers ISSN 0001-2351, Vol. 52(4): 1255-1259

[2] Trần Văn Phú, 2008, *Kỹ thuật sấy*, NXB Giáo Dục.

[3] Hien P.H., Tam N.H., Xuan N.V., 2003, *The reversible air dryer SRA: one step to increase the mechanization of post-harvest operations*. ASEA Paper No. 701P1103e. St. Joseph, Mich.: ASAE

[4] Ortiz J., Lemus-Mondaca R., Vega-Gálvez A., Ah-Hen K., Puente-Diaz L., Zura-Bravo L. and Aubourg S., 2013. *Influence of air-drying temperature on drying kinetics, colour, firmness and biochemical characteristics of Atlantic salmon (Salmosalar L.) fillets*. Food Chemistry 139 (2013) 162 - 169.

[5] Prachayawarakorn S., Soponronnarit S., Wetchacama S. and Jaisut D., 2002. *Desorption isotherms and drying characteristics of shrimp in superheated steam and hot air.* Drying Technology 20: 669-684

[6] Djendoubi N., Boudhrioua N., Bonazzi C. and Kechaou N., 2009. *Drying of Sardine Muscles: Experimental and mathematical investigations.* Food and Bioproducts Processing87: 115-123.

[7] Louka N. , Juhel F., Fazilleau V. and Loonis P., 2004. *A novel colorimetry analysis used to compare different drying fish processes.* Food Control 15 (2004) 327 - 334.)

[8]. Aranda I. D., Casas E. V., Peralta E. K.andElauria J. C., 2010. *Drying Janitor Fish for Feeds in Laguna Lake to Mitigate Pollution Potentials.* Journal of Environmental Science and Management 13 (2): 27 - 43 (December 2010).