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Drying Performance of Beans Using Natural Convective Step Type Solar Dryer

S. Joshua Davidson[1*], J. John Gunasekar[1] and K. Prasanthkumar[2]

[1]Department of Renewable Energy Engineering, Agricultural Engineering College and Research Institute, Kumulur, Trichy, Tamil Nadu, India.
[2]Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Kumulur, Trichy, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author SJD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author JJG managed the analyses of the study. Author KP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Development of appropriate technologies for conversion of solar radiation to thermal energy is essential for fruit and vegetable preservation. A natural convective step type solar dryer with 10 trays was used. The drying parameters such as drying temperature, drying rate and dryer efficiency were studied on bright sunny days from top to bottom of the dryer using unblanched and blanched beans. The maximum and minimum temperatures observed were 84ºC and 50ºC at no load, 59ºC and 75ºC using unblanched beans and 51 and 75ºC using blanched beans. While drying on a sunny day, the moisture content removed was from 72 to 14% for unblanched beans and 76 to 7.32% for blanched beans. On quality evaluation, the high rehydration coefficient was found in blanched beans (0.76) than in unblanched beans (0.52). The collection efficiency was found to be 40.92% and drying efficiency was found to be 15.85% using unblanched beans and 18.75% using blanched beans.

**Corresponding author: E-mail: lyjoe2000@gmail.com;*

Keywords: Solar dryer; blanched; unblanched; drying rate; rehydration coefficient; efficiency.

1. INTRODUCTION

Drying of fruits and vegetables in open sun on ground or on platform is the simplest, cheapest and oldest method followed in most parts of the world [1]. Open sun drying is a conventional low efficient method which gives inferior quality due to uneven drying, contaminants from wind borne dirt and dust and from infestation of insects, rodents and other animals.

The introduction of solar energy in drying system seems to be most promising alternative in reducing post harvest losses and improving the quality of the dried products, compared to traditional open sun drying [2]. Natural or forced convective type solar driers with different modular designs are used in small scale industries [3]. According to Emetere et al. [4], a Double-Pass Solar Dryer (DPSD) for drying of red chili was designed and the performance efficiency was compared with the Cabinet Dryer (CD) with respect to the open air-drying. These solar dryers, a natural convective step type solar dryer has been developed for drying fruits and vegetables. In this paper, the performance study of the natural convective step type solar dryers (NCSSD) has been under taken using blanched and unblanched cluster beans.

2. MATERIALS AND METHODS

The description of the materials, instruments used, and methodology adopted are presented below.

2.1 Details of NCSS Dryer

The experimental setup consisted of a prototype NCSS Dryers with instruments to measure solar intensity, temperature etc. The photographic view of the drier is shown in Fig. 1.

2.2 Processing and Pretreatments of Cluster Bean

Fresh and tender cluster beans brought from market were washed in water. The fiber portions at the sides were removed. They were cut longitudinally into pieces of 2.5 to 3 cm length using a stainless steel knife. The cut pieces were weighted and divided into equal parts and subjected to pretreatment process. The processed cluster beans were treated to steam blanching in order to improve drying characteristics and minimize adverse changes during drying and subsequent storage of the product. Steam was passed into the beans for 5 minutes and then dipped in water [5].

2.3 Methodology

The recommended drying temperature for cluster beans is 60-70ºC [3]. 5 kg beans were processed and spread in 10 trays for dehydration trials. The unblanched (control) and blanched beans were uniformly spread on trays and exposed to sun from morning to evening. The air entering from the bottom of the dryer was exhausted through chimney by natural convective mode. During drying the measurements of time, temperature, solar intensity and weight of the beans were recorded periodically using watch, thermometers, surya mappy (Surya mappy is an instrument used to measure solar intensity) and an electronic weighting machine. The moisture content of the beans was measured by keeping the samples in a hot air oven at $\pm$ 105ºC for 1 h or till to reach constant weight. Trials were conducted with no load, with control (unblanched) and with blanched beans from morning to evening on a bright sunny day.

2.4 Quality Assessment of Dried Products

The quality characteristics of the dried product are affected by drying parameter such as temperature, velocity of drying air and drying time. Rehydration characteristics of the dried beans were evaluated by rehydration co-efficient. Rehydration process of beans was carried out by soaking the bean samples in luke warm water till to regain its original size before drying or size of the fresh beans. Generally rehydration of beans takes about half and hour to 2 hours, depending on the size of dried beans reached to the original size [4]. The rehydration coefficient of the dried product is calculated by the equation [3] as given below.

Re-hydration coefficient (Rc) = $(W_d\ (100 - M)/ Ws – Wr)$ (1)

2.5 Efficiency of NCSS Dryer

Efficiency of the drying system is normally reported as heat collection or collector efficiency and dryer efficiency. Drying efficiency indicates the overall thermal performance of the drying system, including collection efficiency and dryer efficiency [2].

$$E_d = (WL / IA) \quad (2)$$

2.6 Testing

The NCSSD was tested for its performance under no load and load conditions. The control and pretreated beans were used as in load condition. The quality of dried beans was evaluated by rehydration coefficient. The collection efficiency of the collector plate and drying efficiency of the drier were also calculated at load and no load conditions. NCSSD was tested with fresh beans or unbalanched beans for dehydration. The solar intensity, weight reduction of the material, hot air temperature at different tray levels was measured for every half an hour interval.

3. RESULTS AND DISCUSSION

3.1 Drying Performance of NCSSD at No Load

The air entering from the bottom of the dryer became hot and was exhausted through chimneys with natural convection mode. The dryer was tested on a typical sunny day. The hot air temperatures at the top, middle and bottom trays were T_1, T_5 and T_9 along with solar intensity at every 15 minutes interval. The variation of solar intensity and hot air temperature with respect to time is shown in Fig. 2.

Fig. 1. Photographic view of NCSS dryer

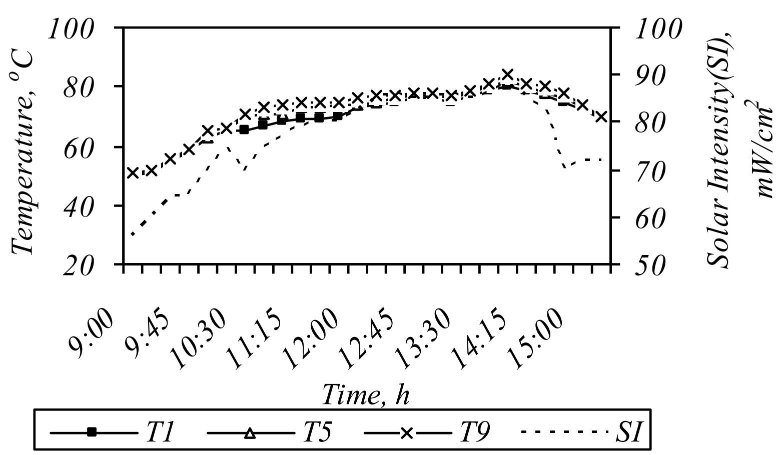

Fig. 2. Temperature variation with time at no load

The maximum and minimum hot air temperatures observed during drying were 84 and 50ºC. The similar temperature rise was observed in all tray levels. The desired temperature required to dry cluster beans was achieved at from 10:00 to 15:15 hours so this prototype NCSSD can be effectively used for drying vegetables. The above results were in close agreement with the findings of Swanson [5] and Emetere et al. [6].

3.2 Performance of NCSSD Using Unblanched Beans

The variation of hot air temperature in different tray levels with respect to time is shown in Fig. 3.

The minimum and maximum temperature during drying was observed to be 59 and 75ºC. The number of hours spent for drying beans was 7 hours. The temperature of about 60 to 75ºC was maintained throughout the drying period. The average variation of hot air temperature from top to bottom of the dryer was found to be 1 to 6ºC. Little temperature difference of about 4ºC between top to bottom of the dryer in the first 4 hours of drying and almost constant temperature was maintained at the 7th hour of drying.

Graphical representation of drying, with product moisture reduction and time as coordinates, indicates drying rate. Fig. 4 shows the variation of weight loss of unblanched beans with respect to time during drying.

The weight loss curve indicated drying rate was faster during the initial hours and then decreases with further increase in time in all tray levels. The drying rate was less during the 7th hour. Emetere et al. [5] reported that maximum moisture reduction was noticed up to 4th hour of drying, i.e., 73 to 80 percent moisture was removed. This is in corroboration with Rathore [7] and Owusu-Kwarteng et al. [8].

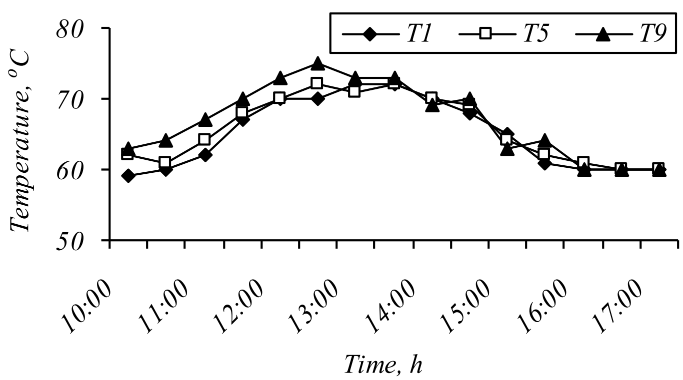

Fig. 3. Variation of temperature with time using unblanched beans

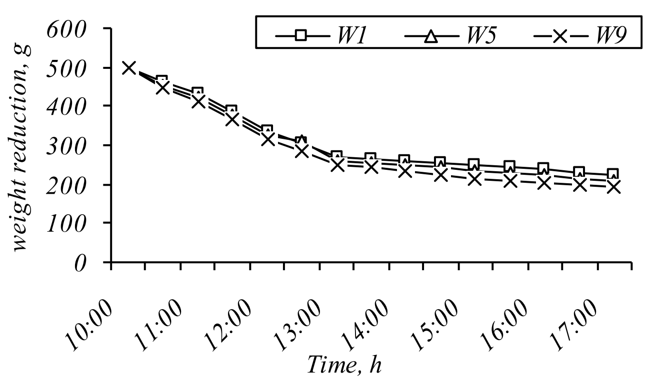

Fig. 4. Weight reduction with time using unblanched beans

3.3 During Performance of NCSSD Using Blanched Beans

The variation of hot air temperature follows the same trend as that of unblanched beans, where as the little variation was observed throughout the period of drying from top to bottom of the dryer.

The final weight of the product from initial loading of 500 g in each tray was found to be 175, 155 and 140 g for bottom, middle and top trays. During drying, high moisture removal was noticed using blanched beans than unblanched beans.

3.4 Comparison of NCSSD Using Unblanched and Blanched Beans

The parameters used to compare the drying process are hot air temperature, and weight reduction during the end of first, fourth and seventh hour of drying. The summary of the observed data for comparison is presented in Table 1.

The difference in hot air temperature during drying blanched and unblanched beans was found to be 16 and 21ºC irrespective of tray levels. The difference of hot air temperature from top to bottom tray was 1 to 3ºC for unblanched beans and 4 to 6ºC for blanched beans. The more temperature difference in blanched beans is because; high hot air temperature is used to increase the vapour pressure there by high drying rate.

The average weight reduced in a tray from 500 g was 210 and 156.6 g for unblanched beans. The more moisture removal in blanched beans is due to the improved elasticity of cell walls and the swelling power of beans. The moisture reduction from 72 to 14% in unblanched beans and 76 to 7.32% in blanched beans resulted NCSSD can be very well suited to dry cluster beans with safe temperature limit [6]. The above results were closely relates to the findings of Srivastava and Jain [9], Singh et al. [10].

3.5 Quality Evaluation of Dried Beans

In this study, the quality of dried products was evaluated by rehydration coefficients. Table 2 gives rehydration characteristics of dried bean.

From Table 2, it is found that the rehydration coefficient was high for blanched beans. The higher rehydration coefficient of blanched beans is due to the increase in water permeability of the skin during pretreatments. The drying rate was significantly improved during drying of blanched beans thereby good quality was obtained. Parmer et al. [11] recommended that for the best drying temperature is 45ºC of basil leaves to retain the various active ingredient.

3.6 Efficiency of NCSS Dryer

The collection efficiency of the NCSS dryer was found to be 40.92%. The drying efficiency was 15.85% for unblanched beans and 18.75% for blanched beans. The observed efficiency values agree well with the results obtained by Ayensu [1] for a solar dryer with convective heat flow of dryer efficiency 21%. The same was observed in oyster mushroom [12] and potato slices [13].

Table 1. Comparison of drying parameters in NCSSD drying using blanched and unblanched beans

Drying parameters	Unblanched beans			Blanched beans		
	Bottom	**Mid**	**Top**	**Bottom**	**Mid**	**Top**
Dryer temperature, ºC						
i) Minimum	59	60	60	54	55	60
ii) Maximum	72	72	75	71	74	75
Weight reduction of beans during drying, g						
i) 1^{st} hour	430	429	410	410	405	395
ii) 4^{th} hour	260	250	235	225	205	185
iii) 7^{th} hour	225	210	195	175	155	140
Final weight after drying, g	210			156.6		
Intial weight of beans, g	500			500		
Initial moisture content, %	72			76		
Final moisture content, %	14			7.32		
Dryer efficiency, %	15.85			18.75		

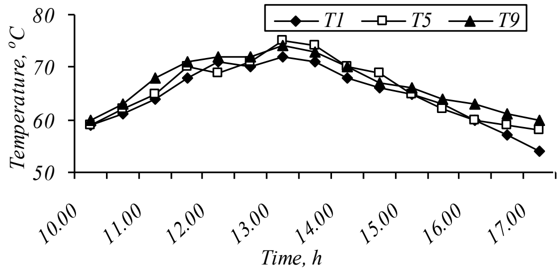

Fig. 5. Variation of temperature with time using blanched beans

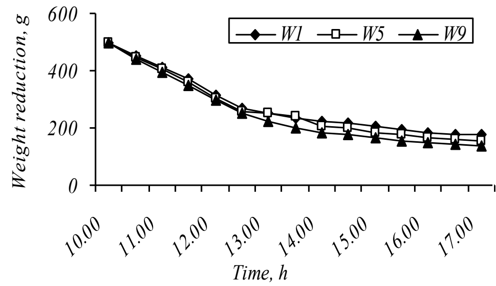

Fig. 6. Weight reduction with time using blanched beans

Table 2. Rehydration characteristics of dried beans

Sl. no	Rehydration parameters	Unblanched	Blanched
1.	Weight of the sample taken for rehydration, g	20	20
2.	Weight of the sample after rehydration, g	38.08	58.7
3.	Rehydration coefficient	0.52	0.76

4. CONCLUSION

The drying performance of unblanched and blanched beans was studied using a natural convective step type solar dryer. The difference of hot air temperature in the dryer from top to bottom trays was ranged from 1ºC to 3ºC using unblanched beans and 4 to 6ºC for blanched beans. The dryer efficiency was found to be 40.92% and drying efficiency was found to be 15.85% using unblanched beans and 18.75% using blanched beans. The drying rate was significantly improved during drying of blanched beans thereby good quality was obtained.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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