Evaluation of Different Sun Drying Methods in Chilli

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ABSTRACT

Chilli is one of the main cash crops for many farmers in Bhutan, including farmers of Kazhi geog under Wangduephodrang dzongkhag. It is either sold or bartered. However, during the peak chilli production season the price drastically drops forcing farmers to resort to drying. Dried chillies during lean season command a very high price. However, drying is challenging in absence of a more efficient and economic dryer. Further, open sun drying is a laborious job in addition to poor quality and contamination by dusts. Therefore, the main aim of the study was to improvise the present traditional method of open sun drying and compare the drying loss and economics of the existing method with other improvised drying methods. The study conducted in Bjaktey village under Kazhi geog, Wangduephodrang dzongkhag followed RCBD with four treatments and three replications each. The parameters measured were final weight, percent loss, cost benefit, drying duration, and water activity of different treatments. The results indicated that T4 (poly tunnel drier) performed better in six of the seven parameters measured, namely loss percent (least at 0.03%), water activity (least at 0.41), drying duration (11 days), temperature (highest at 41.59°C), relative humidity (lowest at 19.54%) and economics (highest net income at Nu. 728.9/m²). The seventh parameter, the final weight lost, in T4 (at 2.47 kg) was significantly different from the control (T1) (at 2.31 kg), but not from the other two treatments T2 (raised bamboo mat) and T3 (raised bamboo mat with plastic roofing). There was no significant difference between T1 and T2 in five of the seven parameters measured, namely loss percent, water activity, drying duration, temperature attained and relative humidity retained. The high temperature and low relative humidity difference facilitated the produce to dry quickly and lower water activity ($_{aW}$) in T4.

It may be concluded that poly tunnel on raised bamboo mat is comparatively convenient, efficient and economical for drying chillies compared to other methods.

Keywords: *Chilli, Economics, Loss percent, Open sun drying, Poly tunnel dryer.*

1. Introduction

Throughout Bhutan chilli (*Capsicum annuum* L.) is grown either in kitchen gardens for home consumption or in larger areas for sale in local markets. Farmers in major chilli growing areas earn good cash income from the sale of chilli in different forms such as seeds, seedlings, green

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tender chilli, green fresh, red fresh, powdered and dried. Dorji, Dema and Euden (2009) found that the potential return per unit area of chilli was high and was achieved in a relatively short period. Therefore, it is favored by most farmers as a cash crop.

Farmers in Kazhi geog under Wangduephodrang dzongkhag grow chilli in large quantities. The geog has a total area of 70.51 acres under chilli cultivation with an annual production of 405.68 Mt (MoAF, 2012). The geog has warm weather conditions with altitude ranging from 1600 to 2400 masl. Most farmers here plant chillies thrice a year, once in March/April, another crop in May/June and the last in July. The geog is also known widely for its indigenous chilli variety Sha-ema.

With increasing production of chilli, particularly in the same season throughout the country, sale of chilli for income is becoming a difficult business. During the relatively short period of peak production season, the glut of chilli in the local market forces the price to dip (Fuller, Lhendup & Lu, 2005). Despite the low price (about Nu 10 per kg), farmers still sell their produce because the traditional sun drying method to preserve chillies is not viable because the harvest season for the first and second crops coincides with the monsoon rain. Drying perishables such as chilli during continuous heavy rain with low solar radiation results in low quality produce and incurs huge loss (Women and Environment Programme, 2013). However, towards the end of the third harvesting season, autumnal dry and sunny weather replaces monsoon rains. It is at this time of the year that farmers choose to sun-dry their chillies in huge quantities.

Open sun drying is the only method preferred by the farmers of Kazhi because of its convenience and low cost. Open sun drying of agricultural produce is cheap and a popular practice adopted by farmers for a while (Chavan, Yakupitayage & Kumar, 2011; Chavda & Kumar, 2009; Navale, Thorat, Harpale & Mohite, 2013). The vegetable dryer developed by the National Post Harvest Centre (NPHC), Paro, which can also be used for drying chilli is not used by farmers because this dryer cannot dry large volumes of chilli, and also because it involves high electricity cost. Navale et al., (2013) reported that use of dryers heated by coal, gas, fossil fuels, wood and electricity depends on the availability of energy, increases the production cost and is not environment friendly.

Desai, Palled and Anantachar (2009) found that chilli can be dried by solar drying, hot-air, freeze drying or osmotic dehydration. Muhidin and Hensel (2012) defined drying as a process of thermally removing moisture from a product that involves complex process of simultaneous heat and mass transfer. It has been reported that open sun drying is associated with many problems that reduce both the quality and quantity (drying recovery) that ultimately affects the storage life and household income. Browning of chilli was the main problem encountered in sun drying of chilli in major production areas of the world (Chavda & Kumar, 2009; Manjula, Ramachandra & Nidoni, 2013).

Difficulties in drying chilli during monsoon and the use of inappropriate drying methods remains an issue for chilli farmers in Bhutan. On the other hand many success stories of low cost technology such as solar dryer for drying fruits and vegetables elsewhere have been reported (Chavan et al., 2011; Parikh & Agrawal, 2011). Perumal (2007) and Tiwari et al. (2013) found that solar dryer was highly preferred for its many advantages over other drying methods. Solar dryer can generate higher air temperature and lower relative humidity which help to improve both drying rate and quality of the dried product (Amunugoda, Senanayake, Wijeratnam & Kulatunga, 2013; Chavan et al., 2011). It also saves energy, time, occupies less area, improves product quality, makes the process more efficient and protects the environment (Chavan et al., 2011; Fudholi, Ruslan, Othman & Sopian, 2012). Therefore, where sun shine is abundant solar dryer could immensely help marginal farmers (Tiwari et al., 2013).

Given the several advantages of solar dryer, this study aims to investigate and compare the traditional drying method with three other improvised sun drying methods in terms of drying loss, economics and product quality.

2. Materials and Methods

This study was carried out in Bjaktey village in Kazhi geog under Wangduephodrang dzongkhag. It is 30 km south east of the College of Natural Resource, Lobesa. The site at an altitude of 1900 masl has a warm temperate type of climate with frequent rainfall from September to October. The farmers in the village normally dry chillies from October till the end of December. Hence, the experiment for the study was carried out from September to October 2013.

Bamboo mats (1 x 5 m), transparent polyethylene sheet, bamboo basket (for harvesting), data logger (HOBO U-100-003), digital weighing balance (Eagle), measuring tape (Freemans Fibre Glass- 100 m), bamboo pegs and poles were used for the experiment.

The experiment was conducted under ambient conditions adjacent to the chilli production field. There were four treatments with three replications each. To avoid bias and influence of one treatment over the other, the replications were placed 2-3 m apart through drawing lots. Each replication (bamboo mat size) was 1 x 5 m that accommodated 15 kg of fresh chilli in one layer (180 kg of chilli, in total).

Control (T1) was the local method of sun drying, in which chilli was dried on the bamboo mat placed on the ground. In the second treatment (T2) chillies were placed on a bamboo mat that was raised 1.5 feet above the ground. In the third treatment (T3) chillies were placed on a bamboo mat that was raised 1.5 feet above ground with transparent polyethylene roofing placed 2 feet above the mat, and in the fourth treatment (T4) chillies were placed on a bamboo mat that was raised 1.5 feet above ground and a poly tunnel made out of bamboo frame covered by transparent sheet was placed on top of the mat entirely enclosing the chillies. This latter method is similar to the solar tunnel dryer model used by Pattanasethanon (2009) to study hot pepper drying by using solar tunnel dryer.

Fully mature red chillies were harvested during clear day and sorted. Fifteen kilograms of chillies were spread in one layer on each bamboo mat. The chilli in each replication was stirred twice a day as practiced by the farmers for uniform drying except for T4. T4 was kept intact without any disturbance until properly dried. As practiced by farmers, after the first week, everyday at sunset the control (T1) and T2 were covered with bamboo mat leaving some space between the mats to protect chillies from dews.

Data loggers were placed in each treatment in the beginning of the experiment to record relative humidity and temperature within the treatments and under ambient temperatures for comparison. Data recorded were downloaded. In the process of drying, spoiled chillies were collected in a separate basket for each treatment and weighed to determine loss percent. Once all the chillies were dried properly to a safe water activity they were collected, weighed (both good and spoiled) and recorded to compare the effect of treatments.

Water activity was determined using a water activity meter. A mean of three measurements were reported in the report. The duration required for drying in each treatment was also recorded. All the inputs (bamboo mats, poles, plastic sheets) and activities (preparation, displaying, stirring, folding) required for the whole drying process and weather parameters of each day were recorded on daily basis for analysis.

Data were statistically analyzed using analyses of variance (*ANOVA*). Bonferroni *Post hoc* tests were performed at $p<0.05$ to test for significant differences between the main effects and interactions using the SPSS-16.0 software.

3. Results and Discussion

3.1. Final weight and weight loss (%) of chilli

There was significant effect of drying methods on final weight and loss percent of dried chilli ($p< 0.05$. However, paired comparison using Bonferroni *post hoc* test indicated no significant differences amongst T2, T3 and T4, but were all significantly different from control (T1) (Table 1). It was observed that there was higher percentage of spoilage, seed lost and stems detached from chilli in T1 as compared to other treatments, which must have affected the final weight. Similiarly, Tiwari et al. (2013) also found more spoilage and weight loss in open sun drying in comparison to solar dryer.

In terms of loss percent (spoilage), there was no significant difference between T1 and T2, but they were significantly different from T3 and T4 (Table 1). Moreover, T3 and T4 were also significantly different from each other with T3 showing high loss percent at 0.31 compared to 0.03% in T4. There was 21.64% loss in T1 and a comparatively lower loss with 1.21% in T4. The total spoilage in control (T1) was comparatively (93.13%) higher than T4. This was due to short drying time because of high temperature and low relative humidity in T4. T4 was also totally protected from ambient weather, night dew, dust and insects.

Rajeshwari and Ramalingam (2012) also found that open sun drying method leads to more spoilage of product and greater loss due to adverse climatic conditions. This result indicates that T4 (poly tunnel dryer) was a better drying method in terms of quality product, short drying time and lower loss (spoilage) percent compared to open sun drying and modified open sun dryers.

Table 1.Paired comparison of final weight and Loss/spoiled percent of dried chilli

Treatment	Final weight (kg)	Loss/spoiled weight (%)
T1- Traditional open sun drying	2.31 b	0.50 a
T2- Raised bamboo mat	2.59 a	0.43 a
T3- Raised bamboo mat with plastic roofing	2.57 a	0.31 b
T4- Raised bamboo mat with poly tunnel	2.47 a	0.03 c
Significance	**	***
CV%	2.51	7.30

***$p < 0.05$; Means with different letters are significantly different

3.2. Water activity

Table 2.Mean comparison of water activity (a_W) between the treatments

Treatment	Mean
T1- Tradition open sun drying	0.54ab
T2- Raised bamboo mat	0.56a
T3- Raised bamboo mat with plastic roofing	0.44bc
T4- Raised bamboo mat with poly tunnel	0.41c
Significance	**
CV%	8.14

**significant at $p<0.05$, Means with different letter indicates significant difference

There was significant effect of drying methods on water activity $p< 0.05$. Paired comparison test indicated that T4 was significnatly different from the control (T1) and T2, but it was not significantly different from T3 (Table 2). The control was not significantly different from T2 and T3, but T2 and T3 were significantly different from each other. The highest (0.56 a_W) water activity was observed in T2 and lowest (0.41a_W) in T4 (Table 2). Paul and Sing (2013) also found similar result. Higher temperatures and low relative humidity in T4 must have brought down the water activity. Perumal (2007) on the other hand observed that there was no significant difference in the water activity among different drying methods.

To curve microbial spoilage and prolong storage life of dried chilli, the minimum water activity of dried chilli must be below 0.6 a_W (Fellows, 2000). Since the water activity of all the treatments in the study were below 0.6 a_W, those dried products may be assumed to be safe and shelf stable with respect to microbal growth and spoilage.

3.3. Drying Duration (days)

There was comparatively high difference in drying duration among the treatments (Figure 1). T4 took the least duration of 11 days whereas T2 took the longest (22 days). This translated into a net time saving of 50% in T4 compared to T2. This result was similar to the finding of Fudholi et al. (2012) and Palled et al. (2012) where they found 49% and 52.38% time saved respectively in solar dryer over open sun drying due to decrease humidity since solar radiation and air temperature considerably increased inside the tunnel. Similiarly, Wazed, Islam and Uddin (2009) also found considerable reduction of drying time in solar tunnel dryer (simialr to T4) as compared to open sun drying (T1) because in open sun drying significant amount of energy was lost to the environment. In a study conducted by Paul and Singh (2013), solar drier took 10-15 days to dry chillies, which is more efficient than traditional open sun drying.The drying duration (19 days) in control T1 was better than T2. Akarslan (2012) observed that there was a convective heat loss due to the blowing wind over and beneath the product surface,which must have contributed to delayed drying in T2 as compared to T1. On the other hand, ventilation is also necessary for water to escape.

Despite the study period it was observed that drying rate is dependent on drying conditions, which are influenced by factors such as weather conditions during the drying period. Similar observation was made by Perumal (2007). Several researchers found much higher percent reduction in drying time of 68-83% in solar dryer compared to open sun drying (Perumal, 2007; Paul & Sing, 2013; Sacilik, 2004; Nwokoye & Okeke, 2008).

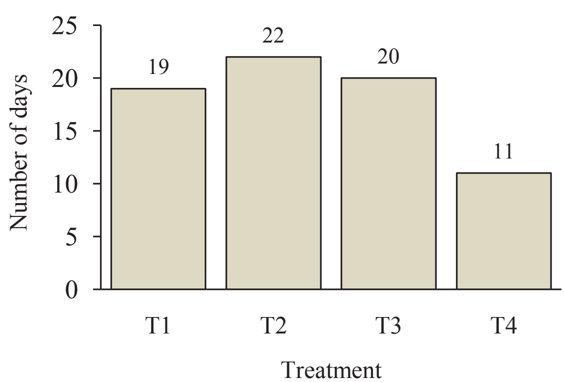

Figure 1.Drying duration (days)

3.4. Temperature and relative humidity variations among treatments

The maximum temperature recorded in each of the treatments (T1, T2, T3 and T4) were 28.20°C, 28.23°C, 28.29°C and 41.59°C, respectively (Fig. 6-A). Perasiriyan, Karthikadevi and Sivakumar (2013) recorded maximum temperature of 43.4°C in solar tunnel dryer and so did Fadhel et al. (n.d.) at 55.1°C. They however worked under different climatic conditions. The final drying temperature was recorded highest in T4 with 38.99°C and lowest in T2 with 23.45°C.The drying rate was comparatively higher in solar dryer due to better absorption of solar energy by the product since the energy is trapped in the structure, facilitating absorption as observed by Perumal, (2007). This difference in temperature must have contributed to faster drying rate of chilli in T4. This result was in line with the findings of Desai et al. (2009).

It was found that drying temperature can be easily raised to 5-30°C under solar dryer, however, raising temperatures above 60°C can be harmful for vegetables, including chillies as this rise in temperature can induce loss of volatile nutrients through the excessive loss of moisture (Basunia et al., 2011).

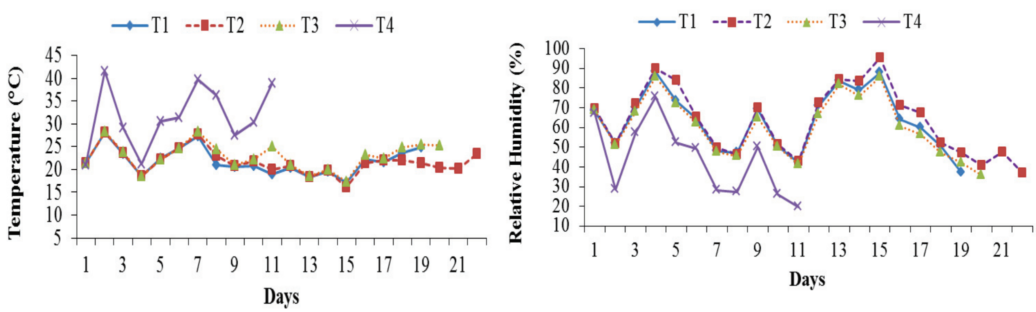

Figure 2.A-Temperature (°c); B-Relative Humidity (%) variations among treatments

The minimum relative humidity for T1, T2, T3 and T4 were 36.87%, 37.21%, 35.87% and 19.54%, respectively (Figure 2-B). It was also similar to the finding of Perumal (2007) where he recorded 16% and 31.9% in solar and open sun dryer respectively. Perasiriyan et al. (2013) recorded much higher relative humidity both in solar tunnel and ambient conditions at 25-40% and 41-54% respectively. The relative humidity difference of 47.49% between the highest (T2) and the lowest (T4) must have been responsible for lower water activity (aw) in T4 and the product under this treatment to dry faster as compared to rest of the drying methods. Fudholi et al. (2012) reported a difference of only 23% between solar and open sun drying methods.

The inside of the solar dryer was observed to be comparatively warmer than outside, clearly indicating that the drying rate in solar tunnel would be higher than open sun drying. Similiarly Fadhe et al. (2013) found that evaporating capacity of the air increases with low relative humidity in solar dryer which favours faster drying. Chavan et al. (2011) reported that energy from solar radiation was trapped inside the poly tunnel, while significant amount of solar energy was lost to the environment in open sun drying. Akarslan (2012) observed that there was a convective heat loss due to wind blowing over the product surface, besides radiation loss due to reflection from the surface.

3.5. Economic

Table 3.Economic comparison between the treatments (Cost per 5 m^2 (area) bamboo mat)

TMT*	Bamboo mat Nu	Bamboo pole Nu	Plastic Sheet	Preparation Nu	Stirring Nu	Folding Nu	Displaying Nu	Total VC* Nu	Gross Income Nu	Net Profit Nu
T1	120	0	0	3.15	6.3	15.75	15.75	160.95	1088	476.9
T2	120	50	0	9.45	9.45	12.6	12.6	214.1	1297	633.1
T3	60	100	53	37.8	5.04	0	0	255.84	1358	652.2
T4	60	100	66	56.7	0	0	0	282.7	1461.6	728.9

*TMT- Treatment; VC-Variable cost, Nu- Ngultrum (Bhutanese currency, 1Nu =72 USD).

Although the variable cost incurred in T4 was much higher (43%) than in T1, the net profit was 34.03% higher in T4 thanT1. This net profit in T4 with an average market price of dried chilli at Nu 600/kg that would translate to Nu 728.9/5m² as compared to Nu 476.9/5m² in T1. The total spoilage in T1 was 93.13% higher than in T4 that must have contributed to the drastic reduction in total net profit in T1. The cost of plastic, bamboo mat and pole contributed 79.94% to the variable cost in T4, whereas bamboo mat and after care (displaying, stirring and folding) involved contributed 98.04% to the variable cost in T1.

Similarly, Chavda and Kumar (2009); Rigit, Jakhrani, Kamboh and Tiong Pe (2013) reported that although the initial cost of solar dryers was high compared to open sun drying, it is more economical than traditional open sun drying and dryers based on conventional fuels. Fadhel, Koolo, Farhat and Belghith (2014) also reported high labor cost in open sun drying over solar drying. Preparation cost was comparatively lower (Nu. 3.15) in T1 as compared to T4, which was Nu. 56.7.

4. Conclusion

The results of this study reveal that chilli dried on a raised bamboo mat with solar tunnel drying method is comparatively better in retaining final weight due to minimum loss/spoiled percent as compared to traditional open sun drying. There was also significant difference in water activity between the treatments with solar tunnel dryer having the lowest at 0.41a_W. Low water activity extends product shelf life as the biological activity that is responsible for accelerating quality deterioration is reduced. In T4, drying time was considerably reduced as compared to all the three methods because of the enclosure that trapped the solar heat and protected against all environmental hazards. The high heat inside the enclosure also significantly reduced the relative humidity as compared to all other methods, which not only led to faster drying of produce, but also maintained the quality of the final product. The solar tunnel drying method also reduced the labor cost as no constant stirring of produce and frequent supervision were required unlike in the traditional open sun drying. Due to lower labor cost and loss percent (spoilage) solar tunnel drying method is more economical.

It can be concluded that raised bamboo mat with solar tunnel made out of polythene/plastic sheet is more economical and efficient in drying chilli as compared to traditional open sun drying and the other two methods involved in the study. However, because the solar tunnel method used in this study was raised, it involves cost and farmers' time. Therefore, similar method, but without raising off the ground may have to be studied in the future to determine whether similar benefits can be derived from the proposed slightly modified method.

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