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Performance Evaluation of Solar Bubble Dryer

Anand Mishra[1*], Sanjeet Kumar Jha[2], Ganga Ram Bhandari[3], Shailendra Khatri[4], Shreemat Shrestha[5], and Pravin Ojha[6]

*Corresponding author's Email: anandhansy@yahoo.com
[1, 2, 3, 4, 5]Agricultural Engineering Division, Khumaltar, Lalitpur, Nepal
[6]Food Research Division, Khumaltar, Lalitpur, Nepal

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Abstract: Rice is an important cereal crop and staple food for more than half of the world's population. Drying and storage are two key post-harvest processes to improve yield in rice production. Farmers mostly perform drying of rice by sun drying. Sun drying has many disadvantages such as: over-drying, animals feeding on the grains, spillage and non-uniform drying. This experiment was conducted at Agricultural Engineering Division for performance evaluation of Solar Bubble Dryer. During experiment paddy was spread on the floor of dryer and was mixed periodically with roller bar. Sun drying was also carried out. The parameters such as moisture content and quality in terms of milling recovery and head rice yield were tested for both methods of drying. Results showed that moisture content of paddy was reduced from about 16% to 12% in six hours of operation. The rice quality was almost similar in both the drying methods. Therefore, we concluded that Solar Bubble Dryer can be one of the options for drying of spring rice. However, the initial cost of Solar Bubble Dryer is high.

Keywords: Paddy rice, Post-harvest handling, Solar Bubble Dryer, Grain moisture content

1. Introduction

Rice (*Oryza sativa L.*) is an important cereal crop and staple food for more than half of the world's population [1]. Rice cultivation covers 42% of total cultivable area under food grains and 51.6% of the total food grain production of Nepal [2]. Rice cultivation in Nepal contributes 7% and 20% of gross domestic product and agricultural gross domestic product, respectively [3]. In Nepal, rice is cultivated under varying topography, climates and altitudes; from 60 to 3050 meters above sea levels [3]. A total of 57 rice varieties have been released and 17 have been registered in the country [4]. About 20% of the total rice production in Nepal is contributed by spring rice. Due to the onset of rainy season during harvesting of spring rice, drying is one of the challenging tasks for the farmers. They can loss from 10 to 30 percent of rice produced due insufficient drying.

About 3-5% of paddy rice losses its quality due to improper drying of wet paddy [5, 6]. At the time of harvesting, the paddy is generally harvested at the moisture content of 20-28% wet basis (MC) depending on wet and dry seasons. The paddy should be dried within 24 hours of harvesting to the safe moisture content of about 14%. Storing paddy at 14% of moisture content prevents losses which occur due to respiration, germination, etc., during storage [6, 7]. About 20% of global rice production is contributed from Southeast Asia [8]. Commonly used mechanical dryers are the Solar Bubble Dryer, the flatbed dryer, the recirculating batch columnar dryer, and the two-stage drying systems (two-stage) described in RKB [9, 10].

Drying and storage are two key post-harvest processes to improve rice production. Farmers mostly perform drying of rice by sun drying. Sun drying has many disadvantages such as: over-drying, animals feeding on the grains, spillage and non-uniform drying. During the rainy season the possible problems in paddy cultivation are: delayed and incomplete drying, yellowing of paddy, fungal propagation, and mycotoxin contamination [11, 12]. The fresh paddy market offers low farm gate prices to the producers [13, 14]. Therefore, farmers are attracted toward drying of paddy and storing them. They sell the paddy when the price becomes higher. The use of Solar Bubble Dryers (SBD) is one of option for drying of paddy. They have low energy consumption and operational costs compared to commercial dryers that use fuels or electricity for heating of the air [15]. The objective of this research was the performance evaluation of Solar Bubble Dryer. We also tested the quality such as milling recovery and head rice yield of dried paddy.

2. Material and Methods

2.1. Introduction on Solar Bubble Dryer (SBD)

In collaboration with International Rice Research Institute (IRRI) and the University of Hohenheim (UOH), the Grain Pro introduced SBD. It is designed in such a way that it can dry grain even during raining season. It is made of transparent polyethylene (LDPE) cover which is UV and water resistant. The SBD safely dries agricultural commodities against unexpected rain and also saves the commodities from contaminants. It acts like a bubble that traps solar radiation to heat the commodities. Moisture is vaporized and pushed out by ventilators. The drying floor is made of a proprietary watertight material to prevent water permeation from below. The top cover and the drying floor are joined together by heavy-duty zippers. They can dry grains and seeds of paddy and corn. During sunny day, the drying rate is faster than conventional sun-drying.

The commercially available SBD are found in market in two sizes. The model SBD25™ has a drying area of $25m^2$ which is of half-ton capacity. The model SBD50™ has a drying area of $50m^2$ which is of one ton capacity. It has both solar and electric models. Solar models use solar energy to run ventilator(s). However, in an electric-powered model, electricity is needed to run the ventilator(s).

2.1.1. Working of Solar Bubble Dryer (SBD)

The SBD uses the solar energy from the sun in two ways. Firstly, the drying tunnel serves as a solar collector to convert energy from the sun's rays which enters through the transparent top of the drying tunnel to heat energy. This helps to increase the temperature of the air and enables the faster drying process. Secondly, the SBD consists of a photovoltaic system which has solar panels for generating electricity. In addition, it also has a rechargeable deep cycle battery for use at night and one or two small blowers to inflate the drying tunnel and move air through it. The hot air helps to remove water evaporating from the grains inside the tunnel. It also has roller with ropes attached on both ends which are periodically moved underneath the tunnel to mix the grains inside the tunnel. For mixing of grain inside the tunnel rake is used.

2.1.2. Benefits of use of Solar Bubble Dryer (SBD)

Solar Bubble Dryer (SBD) protects the agricultural commodities from unpredictable rainfall. It can dry the crops such as paddy, corn, coffee, etc. As it is closed system therefore prevents the commodities from contaminants mixing during drying process. It is portable and have collapsible and detachable components therefore it can easily carried from one place to other and assemble on any flat surface. It can be operated either by solar or electric power. Fig. 1 shows the photographic view of assembling of Solar Bubble dryer (SBD) before start of experiment. Fig. 2 shows photographic view of Solar Bubble dryer (SBD) during experiment.

Fig. 1: Photographic view of assembling of Solar Bubble dryer (SBD) before start of experiment

Fig. 2: Photographic view of Solar Bubble dryer (SBD) during experiment

2.2. Experimental set-up

The Solar Bubble Dryer was assembled on roof of Agricultural Engineering Division, Khumaltar, Lalitpur. Paddy rice purchased from Agronomy Division, Khumaltar, Lalitpur were used for this experiment. Experiment was started at 10:45 am and was completed at 4:45 pm on sunny day. Initial moisture content (wet basis) was about 16%. Fan was operated by electricity during experiment to keep the tunnel inflated. The paddy was mixed with the roller bar at a regular interval of one hour during experiment. One hundred kilograms of paddy was spread on SBD. Additional five kilograms of rice was sun dried for comparing the efficiency of SBD with sun drying methods. The lists of treatment in this experiment are presented in Table 1. We collect the paddy samples from four different locations along the length of SBD. The moisture content of paddy was measured by grain moisture meter.

Table 1: List of treatments

T1	2.0 m away from fan of Solar Bubble Dryer
T2	4.5 m away from fan of Solar Bubble Dryer
T3	7.0 m away from fan of Solar Bubble Dryer
T4	9.5 m away from fan of Solar Bubble Dryer
T5	Sun drying method

2.3. Determination of milling quality of rice

Milling yield of paddy is the estimate of the quantity of the head rice and of the total yield of milled rice that can be produced from a unit of paddy [16].

Milling recovery was calculated as follows:

Milling recovery (%) = (Weight of milled rice (kg)/Weight of paddy (kg)) x 100% ……. (1)

Milling capacity was calculated as follows:

Milling capacity (kg hr^{-1}) = Weight of rice (kg)/ time (hr)

3. Results and Discussion

3.1. Effects of drying methods on grain moisture content before and after drying

The effects of drying methods on grain moisture content before and after drying are shown in Table 2. The moisture content before drying was about 16%. The moisture content after drying was about 12%. No significant difference was found among the treatments for grain moisture content (%) after drying.

Table 2: Effects of drying methods on grain moisture content before and after drying

Treatments	Before drying (%)	After drying (%)
T1	16.30 ± 0.28	12.45 ± 0.21
T2	16.10 ±0.42	12.20 ±0.49
T3	16.35 ± 0.49	12.40 ± 0.28
T4	16.25 ± 0.35	12.55 ± 0.42
T5	16.20 ± 0.42	12.70 ± 0.14

Table 3: Effects of drying methods on grain quality

Treatment	Milling capacity (kg hr^{-1})	Milled rice (%)
T1	115.43	68.69
T2	114.32	67.83
T3	114.78	68.13
T4	115.25	68.47
T5	114.09	67.31

3.2. Effects of drying methods on grain quality of paddy

The effect of drying methods on grain quality is shown in Table 3. The milling capacity (kg hr^{-1}) was 115.43, 114.32, 114.78, 115.25, and 114.09 for treatments T1, T2, T3, T4, and T5, respectively. The milled rice (%) was 68.69, 67.83, 68.13, 68.47, and 67.31 for treatments T1, T2, T3, T4, and T5, respectively. Gagelonia *et al.* (2011) [17] reported similar results for drying of paddy using a flatbed dryer.

4. Conclusions

Drying of spring rice is one of the major problems in Nepal. We did performance evaluation of Solar Bubble Dryer. Results showed that moisture content of paddy was reduced from about 16% to 12% in six hours of operation. The rice quality was almost similar in both the drying methods. Therefore, we concluded that Solar Bubble Dryer can be one of the options for drying of spring rice. However, the initial cost of Solar Bubble Dryer is high.

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