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Review Article

# Recent Progress and Performance of Solar Dryers used for on-Farm Processing: A Review

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**Abstract**

Solar drying is one of the most simple and ancient drying techniques known to mankind. Even, most of the agricultural products like cereals, fruits, vegetables, and spices are processed under sun. However, the direct exposure of these food materials to open sun has many disadvantages due to dust, rain, winds and favorable environmental conditions for animals, insect infestation and animal's interference etc. These factors lead to contamination of food products. The use of solar dryers can be helpful to overcome such problems. So, there is a need to make efficient and cheaper dryer for on-farm processing. Many dryers have been developed depending on crop type, drying type and air circulation. These dryers are forced and natural air circulation dryers, direct solar driers, indirect solar drying driers, mixed mode solar dryer, batch or continuous, etc. In case of direct type solar dryers, the product is exposed directly to solar radiations that cause low quality of food products due to low drying rate. The disadvantages can be reduced using indirect solar dryers. In present study a review has been discussed on different drying techniques, applications, different enhancement techniques applied to improve efficiency and reduce drying time.

## INTRODUCTION

Agriculture is the main source of livelihood for the people living in developing countries. The fruits and vegetables are produced in large quantities and major part of the income is derived from fruits, crops and vegetables. But this income is too low due to inadequate processing, storage and lack of marketing structures [1]. The rural areas in most of the developing countries are deficient in non-renewable energy resources or they are unreliable and too much expensive. Thus, in these areas the crop drying systems use electric fans for drying on farm. The initial running cost of fossil fueled dryers is too high that farmers do not accept it for on farm processing. Furthermore, heating crops by electrical heating system is inappropriate. In industrial drying process, mostly controlled drying is carried out. The air is heated by burning of fossil fuels so large quantities of fuels are used for this purpose worldwide. The consumption of fossil fuels has many constraints like depletion of its reservoirs, high cost, and environmental impacts. According to international Energy outlook 2006 [2], total world marketed energy consumption grows from 421 quadrillion British Thermal Units (BTU) in 2003 to 563 quadrillion BTU in 2015 and 722 quadrillion BTU in 2030 on an average by 2.0% increase per year. The earth receives thousand times more energy from sun than from any other source. Solar energy has too much potential to meet energy demand. Solar drying of crops is one of the major applications of solar energy utilized everywhere [3]. In such conditions the use of solar energy is best alternative and attractive option on the commercial levels and farms for food processing. The climatic conditions for the crop drying have a great influence on crop loss. When there is hot and dry climate the crop can easily be dried in open sun drying. The ambient relative humidity must be low while drying crop to maintain equilibrium moisture content. The crops take long period to reach equilibrium moisture content at the time of drying. The crop deteriorates worse when the climate is hot and humid. The warm weather and high moisture content lead to bacterial, fungal, insects and mites attack on crop during open sun drying. The basic purpose of drying to is to remove the moisture from crop material to prevent deterioration for certain period called "safe storage period" [4, 5].

Drying is the process of moisture removal due to heat and mass transfer. It is the classical method of food preservation, being used since dawn of mankind. It also provides longer shelf life, easy handling of material due to light weight, small space for storage and easy transportation [6]. It is a two-stage process including constant drying rate and falling drying rate. The constant drying rate of materials is just like vaporization of water into the ambient air. The second stage (falling drying rate) of the material is determined by the properties of materials to be dried [7]. There are two types of water present in food items that is chemically and physically bound water. Only physically bound water is removed during drying. The drying process of food products is popular due to longer shelf life, volume reduction and product diversity [8]. The application of the dryers in developing countries can significantly reduce the post-harvest losses. So, drying ensures the availability of food stuff in developing countries. The postharvest losses estimated to be 40% but under adverse conditions losses may be as high as 80%. A significant percentage of these losses in food stuff like cereal grains, pulses, tubers, meat and fish is observed during processing [9,10]. Different types of software's like Computational Fluid Dynamics (CFD) and MATLAB are developed to predict the performance of solar dryers. The application of software is very important to develop and analyze the mathematical models to predict the performance of different dryers. The use of software helps to optimize the design of solar dryers and time can be saved during experiments. It can also be used for predicting crop temperature, drying kinetics, moisture content, drying rate, texture and color of crop. The Computational Fluid Dynamics (CFD) uses heat and momentum transfer equations to investigate air flow rate, humidity, and temperature distribution inside the solar dryer [11]. MATLAB is very useful tool to develop mathematical models to predict the thermal properties of air within the dryer and thermal performance of solar dryer. The software is supportive to test various models for solar dryers [12]. Open sun drying and solar tunnel drying are the most widely used methods in the world. However, in developing countries open sun drying is common practice for preservation of agricultural products like cereals, vegetables and fruits. So, when the weather is hostile for fungal attacks, insects, birds and rodent's encroachment leads to losses in terms of quality and quantity of dried products [13]. The introduction of solar drying technologies can be helpful not only to improve quality but also to reduce quality and quantity losses significantly as compared to traditional drying methods like open sun drying. The solar drying methods are classified into four categories according to heat and mass transfer mechanism to remove moisture from product.

**Open sun or natural dryers:** The drying material is placed for drying directly under ambient air conditions like solar radiations, ambient temperature, wind speed and relative humidity.

**Direct solar dryers:** The drying material is placed in a transparent enclosed body to dry. The heat to dry product is absorbed by the product itself and internal surface of the dryer body. The heat removes the moisture from product by natural convection process.

**Indirect solar dryers:** These dryers consist a solar collector to evaporate moisture. The collector is connected to the duct and air moves through duct to remove moisture from drying product bed.

**Mixed mode solar dryers:** These dryers consist a collector as well as a pre-heater to heat up the air to dry mass in the drying chamber. So, it is a combined action of solar radiation incident on collector and pre-heater to remove moisture [14].

## Open Sun Drying

The most common drying method used in the developing countries involves the spreading of crop materials on bare floor, mates or on trays under shadow or direct exposure to the sun and wind. The open sun drying process depends upon the location of drying, stage of crop to be processed and effect of solar radiations on crop [15]. This process is not suitable to the large amount of crop materials. Some disadvantages of this system are large area requirement, higher labor cost and low quality of food materials. Apart from this, it is a labor-intensive process from drying of products to its storage [16]. It depends on environmental conditions like ambient air temperature, relative humidity, solar radiations and wind speed [17]. The open sun drying process causes deterioration due to many determinants like rainfall, wind, temperature and relative humidity. The crops reabsorb moisture during night or rainfall. The processing in open sun drying is slow that cause considerable losses like reduced weight of crop, enzymatic reactions, insect infestation, and growth of microorganisms. All these factors lead to low quality of produce. Another problem being faced is non-uniform drying that cause germination of some crops during storage. In the humid and subtropical areas, the agricultural products are dried during rainy season that causes a serious problem. So, this drying technique should be replaced by the mechanical dryers [18].

Jain and Tiwari [19], developed a mathematical model to study the thermal behavior of open sun drying on crops. The results showed that moisture transfer from cauliflower and potato was relatively high. The crop temperature, drying rate and the air properties were estimated due to change in ambient conditions. The losses during open sun drying were relatively high as it is a slow process. The products dried in open sun drying did not meet the international quality standard.

Ekechukwu and Norton [20], reported that open sun drying is still a common practice to dry food products despite rudimentary process involved. As the solar radiation, required air enthalpy which is easily available, no capital cost, low operating cost and independence of fuel supply, that is why this method is radially used on commercial scale in developing countries. The quality of the dried products is often seriously degraded and sometimes it is beyond edibility. Thus, at present the large proportion of the world's food supply of dried products like fruits and vegetable are dried by open sun drying.

## Direct Solar Dryers

A simplest type of solar dryer was designed by fudholi et al. [21]. The dryer was constructed using wooden box. The

| Table 1: The solar dryer, product and performance. | | | |
|---|---|---|---|
| **Dryer Type** | **Product dried** | **Performance** | **References** |
| Greenhouse dryer | Cocoa beans | MC 58 % to 7 % in 4 days (drying constant, k = 1.68 /day) | Puello et al., 2017 [39]. |
| Solar tunnel dryer | Aonla (Embilica officianalis) | 16 h from 40 h | Seveda, 2012 [40]. |
| Solar dryer | Banana | 3.1 % decrease in MC per day | Hegde et al., 2015 [41]. |
| Greenhouse dryer (mixed mode) | Red peppers and grapes | Red papers -17 h from 24 h grapes -50 h from 67 h | Khadraoui et al., 2017 [42]. |
| Modified greenhouse dryer | Potato, capsicums and tomato | Transparent polycarbonate covered under forced convection and natural convection | Prakash et al., 2016 [43]. |
| Indirect Type solar dryer | Banana | Initial MC 356% (db) to final MC of 16.329% (Tray1), 19.473% (Tray2), 21.159% (Tray3), 31.158% (Tray4), and 42.3748% (db) for open sun drying | Lingayat et al., 2017 [44]. |
| Direct forced convection solar dryer | Banana | 72% (wet basis, wb) to a final value of 28% (wb) within 4 days | Nabnean and Nimnuan, 2020 [45]. |
| Forced convection solar tunnel dryer | Chilli pepper | MC 589.6% (db) to MC of 12% (db) in 123 h and 193 h dried in the solar dryer and under the open sun, respectively. | Rabha et al., 2017 [32]. |
| Mixed-mode dryer | Grapes | Four days for 3 kg grapes (MC 81.4% to 18.6%) | Pardhi et al., 2013 [46]. |
| Mixed mode forced convection solar tunnel dryer | Turmeric | MC 0.779 (kg water/kg dry matter) to 0.070 (kg water/kg dry matter) in 12 h while it takes 43 h under the open sun drying | Karthikeyan and Murugavelh 2018 [47]. |
| Hybrid solar dryer | Banana slices | 30 kg in 8 h, initial MC of 82% to the final MC of 18% (wb) | Amer et al., 2010 [36]. |
| Abbreviations: MC: Moisture Content, db: dry basis, wb : wet basis. | | | |

dimension of the dryer was 2 m × 1 m whereas the sides and bottom of the dryer were constructed using wooden and metal sheets. The dryer also contained air holes for the circulation of air within the dryer. Ghaba et al. [22] designed and experimentally tested a direct type natural convection solar dryer for drying of mangoes, banana and cassava. The dryer was simple in design and it can be constructed by farmers using locally available materials. The dryer was easy to use and low in cost. The thermal performance of the dryer was found to be high as compared to open sun drying. Mursalim et al. [23] evaluated a modified natural convection cabinet dryer. The dryer consisted a plastic cover and sawdust was used as an insulating material. The walls of drying chamber were made by using plywood and painted black with dimensions 120 cm × 80 cm × 40 cm. The air flow was provided by 12 holes from the bottom of product.

Zomorodian et al. [24] discussed a direct solar dryer, i.e., cabinet dryer, in which solar radiations were main source of drying food products. A collector, blower, and drying chamber made up the dryer. The absorption of solar radiations raised the crop temperature. The discharging of long wave radiations was main working phenomenon to raise the temperature of collector as well as crop. The temperature in the drying temperature was more than ambient temperature. The direct convective losses were reduced by using glass cover. The glass cover also increased the crop as well drying chamber temperature. The dryer had some limitations like discolored crop because of direct solar radiations.

A. Saleh and I. Badran [25] designed, developed and tested the direct domestic dryer with transparent surface. They used thin layer drying method regardless of controlling mechanism. The experimental setup was used to predict the drying period for several products. The performance of the dryer was tested under different experimental conditions and drying characteristics were investigated. They conducted experiments on two local herbs like Jews mellow and mint leaves.

## Indirect Solar Dryers

Indirect solar drying is cost effective and attractive solar energy application used for drying of agricultural and marine products. Two types of indirect dryers like natural convection and forced convection indirect solar dryer are discussed here in present study.

Madhlopa and Ngwalo [26] developed a natural convection solar dryer for pineapple drying. The dryer was integrated with a solar collector and biomass backup heater. The dryer was operated in three modes like solar, biomass and solar biomass. Twelve batches of fresh pineapple (weighing 20 kg each batch) were dried using all three modes. The results of experiments showed that thermal part of the dryer can store heat from both burner and solar energy. The drying time of each batch was one sunny day. The solar biomass mode of drying was proceeded even in unfavorable weather conditions. The moisture content of pineapple was dried up to 11% (db) yielded a nutritious product. The final day moisture pickup efficiencies of solar, biomass and solar biomass were found to be 15%, 11% and 13% respectively.

Bolaji [27] designed an indirect solar dryer with a box type absorber collector. The dryer was made up of a collector with glass cover and black absorber plate, an opaque drying chamber, and an exhaust chimney. The collector was inclined at 20 °C to the horizontal to receive maximum solar radiations. The maximum efficiency of the solar collector was recorded to be 60.5%. The maximum temperature inside the drying chamber and collector was noted to 57 and 64 °C respectively. while the maximum ambient temperature was observed to be 33.5 °C.

Pangavhane et al. [28] designed and developed a multipurpose natural convection indirect solar dryer integrated with solar air heater and drying chamber. The solar air heater was painted black to absorb maximum radiations. It was made up of a glass cover, insulation, and a frame. The air duct to pass air was made up of aluminum sheet. The U-shaped corrugations were placed parallel to the direction of air flow. A 0.15 mm thick aluminum fins were fitted to the back of absorber. The air flow during nighttime was stopped by using (4 mm thick and 0.8 × 0.4 m in size) shutter plates present at the end of collector. The air duct was made leakage proof by using good quality sealing material. The entire unit was placed in a rectangular box made up of 0.9 mm thick galvanized iron sheet. The gap between air duct and box was filled using glass wool insulation material. The experiment on grapes was conducted successfully.

Simate [29] conducted a comparison study of mixed mode and indirect natural convection solar dryer for the drying of maize. The models were operated under variable solar radiations for optimization of dryer and performance comparison. The optimization gave a short collector length for mixed mode than indirect solar dryer for same grain drying capacity. He concluded that initial cost, drying cost, and annual cost of the mixed mode dryer were low than indirect solar dryer. The drying cost of both mixed mode and indirect natural convection dryer were reported to be 12.76 and 16.05 US$/ton respectively.

Singh et al. [30] investigated a small-scale natural convection solar dryer. It had a multi-shelf design with intermediate heating, which resulted in equal drying in all of the trays. The novel feature of the dryer was that the product can be in shade also. The design of the dryer was economically viable and low cost. The maximum temperature in the month of November was recorded to be 75 $^{o}$C in Ludhiana India. Experiments on fenugreek leaves were conducted. The moisture evaporation on first, second and third day of drying was 1.4, 0.9 and 0.4 kg/m$^2$. The problem of efficiency loss was alleviated by using a semi-continuous loading mode on all drying days. The shelf life of dried products was observed more than one year.

Musembia et al. [31] designed and fabricated updraft solar dryer for mid latitude applications. They determined the performance of dryer, analyzed the air properties by using psychrometric chart and assessed the quality of different products. The dryer was fabricated using low cost locally available materials. The zenith angle is dependent on latitude of mid latitude regions. The solar declination angle time of the year of the day were also important parameters to design dryer. The main component of dryer was hinged flexible solar collector, drying chamber consisting of three trays and updraft chimney etc. The experiments on sliced apple of 2.5 mm thickness were conducted by spreading on trays. The experimental data i.e. temperature and relative humidity were taken on collector inlet, drying chamber inlet and outlet by using data logger. The air flow was measured using hot wire anemometer and irradiation was measured by using radiation meter. The drying characteristics such as amount of heat required to evaporate moisture, average drying rate, initial and final moisture contents were determined. The flow was natural convection having an advantage of inducing thermosiphon effect by updraft chimney thus increased efficiency. Fresh apples of 886.64 grams with 86% moisture content were dried to moisture content of 8.12% on wet basis. The drying time and average irradiance were 9 h and 534.45 W/m$^2$. The dryer efficiency was estimated to be 17.89%. The possibility of vapor saturation within the drying chamber was supposed to be minimum which is a challenge while drying. This was based on analysis of dew point of drying chamber, inlet and outlet air properties. The results and performance showed that dryer can be used anywhere in the world. The dryer can be used to retain the color, flavor and nutritional values of products. It can be used on commercial scale owing to its high drying rate.

Rabha et al. [32] conducted a comparative study on drying of chili pepper using indirect forced convection solar tunnel dryer and open sun drying. The dryer was made up of a series of double pass solar air heaters, a semi-continuous type drier, tube heat exchangers, blowers, and trays. The capacity of the dryer was 9 kg of chili pepper. Two samples of 200 g were dried on separate tray to calculate moisture removal rate both in drier and open sun. The chili pepper was dried from initial moisture content of 58.96% (db) to the final moisture content of 12% (db). The drying time for solar tunnel dryer and open sun drying were 123 h and 193 h respectively. They selected the best drying model from previous literature to validate the moisture ratio data during experiment. The page and modified page model for moisture ratio data of open sun drying was used. Whereas for solar tunnel drying moisture ratio data, Midilli and Kucuk model were found to be more suitable.

Stated that post-harvest losses of cereals in developing countries ranged between 10-20% due to improper processing facilities at farm. A new solar assisted solar paddy dryer comprised of 0.5 hp blower, solar collector and perforated drying chamber was developed. The performance of dryer was evaluated for 100 kg freshly harvested paddy at 23.78% moisture content (wb). The results showed suitability of solar dryer as mean drying rate 0.87 kg/hr. in solar dryer and 0.46 kg/hr for open sun drying. The solar dryer took 10 hr for drying 100kg paddy up to 14% moisture content, saving 50% time as compared to open sun drying i.e. 19 hrs per 100 kg. Cost analysis of the dryer showed that dryer was economy and environmentally friendly.

Designed, developed and tested multi pass multi rack solar dryer that comprised of solar collector (75cm long and 45cm wide) oriented 26.25 ºC, drying chamber having 250 g/tray loading capacity, blower and granite absorber covered by aluminum sheet. Experiments on 1 kg Grapes with initial moisture content 81.4% wet basis were conducted on March 2015. The Ambient air temperature was observed 33°C (Average for march) with maximum allowable temperature 64°C in the dryer. The drying time was calculated to be 5 hrs. It was observed that the grapes in the cabinet dryer dried in 32 hr to achieve moisture content of 18.6% and in the open air it took 38 hr to achieve this.

Designed a solar maize dryer with locally available material. It was integrated with simple biomass heater. Air flow system, solar collector, drying chamber, and back-up heater were all incorporated into the dryer. The back-up heater was used for providing heat to product at night or in cloudy conditions. The design of dryer based on climatic conditions of Mau summit in Nakuru country, Kenya. The average ambient temperature was

26 ºC, whereas relative humidity with global solar radiation incident on horizontal surface was about 21.60 MJ/m$^2$/day. The study mainly based on design consideration and calculations of design parameters. The solar collector area of 3.77 m$^2$ was selected for drying of 100 kg of maize in 6 hours. The moisture content on wet basis of maize was reduced from 21% initial moisture content to 13% final moisture content. Another dryer with collector area of 0.6 m$^2$ was fabricated for drying of maize with heat source like solar, biomass and combination of both. The efficiency of solar assisted dryer was estimated about 57.7% and average drying rate of 0.077 kg/hr. The efficiency of dryer with back-up heater was increased by 17.8%.

Reported that for dehydration of food batch type dryers are mostly used. The drying heterogeneity is major problem in such dryers. They developed a batch type dryer and necessary air flow for drying was introduced along the length of dryer (diagonally airflow inlet channel). The drying time of food product was reduced as entire mass was exposed to drying air. A flow simulation software, ANSYS-Fluent was used to predict the homogeneity of incoming drying air. The experiments were conducted using potatoes slices with 4 mm thickness as a drying material to evaluate the performance of dryer. The results of experiments represented by drying curves showed high $R^2$ value. The simulation results of airflow were compared by experimental results. The results revealed a good correlation coefficient of 87.09% for distribution of airflow.

Tonui et al. [33] designed and developed a solar grain dryer coupled with biomass heater using locally available materials. The aim of dryer was to address the limitation of the sun drying, liability to insects and pests and high cost of the mechanical dryers. The dryer was helpful in reducing the post-harvest losses and helping the preservation of agricultural produce. The dryer composed of drying chamber, solar collector, air flow system and backup heater. The design was based on Mau summit in Nakuru county, Kenya. The average ambient conditions like temperature, relative humidity and daily global radiations of the Mau summit was 26 ºC, 70% and 21.6 MJ/m$^2$/day respectively. The minimum collector area required to dry 100 kg of maize in 6 h from initial moisture content of 21%-13% on wet basis was 3.77 m$^2$. A prototype dryer was designed and fabricated for experiments with collector area of 0.6 m$^2$. A blower was used for forced convection to reduce the drying time of the maize to be dried. The thermal efficiency of the solar collector and the dryer were 39.9 and 57.7%, respectively. The backup heater improved the drying efficiency of the dryer about 17.8% and reduced the drying time of the maize.

Misha et al. [34] reported that tray dryer is most extensively used for drying agricultural products because of its simple and economic design. The trays are arranged at different levels and products can be loaded easily. The products of suitable thickness are spread on trays. The problem faced during drying of products is non-uniformity of air flow throughout the bed. So, a computer-based software i.e. Computational Fluid Dynamics (CFD) can be used to reduce flow distribution of air within drying chamber. The software is capable to solve equations for mass, momentum and energy conservation by using numerical methods to predict temperature, velocity and pressure profile in the drying chamber. The research aimed to predict best operating conditions for new tray dryer. The temperature and velocity profile on each tray were analyzed that showed uniformity of drying on each tray. The 3D simulation was done to represent actual model of tray dryer. The temperature throughout the dryer was considered uniform; on the other hand, the air velocity was nonuniform. The average velocity on tray number 1, 7, 8 and 15 were higher than other trays showed nonuniformity whereas other trays showed uniform results. The average velocity above trays were noticed about 0.38 m/s.

## Mixed Mode Solar Dryers

Okoroigwe et al. [35] designed small scale combined solar and biomass cabinet dryer consisted three equally spaced drying trays. The ambient and dryer temperatures observed during experiments were calculated 30°C and 53°C respectively. The drying rates by different combinations like solar drying, biomass drying and combined solar and biomass drying were calculated 0.00732 kg/h, 0.0032 kg/h and 0.0142 kg/hr respectively, showed good result with combinations of both dryers. This implies that results can be improved for sustainable development of developing countries by proper designing and construction. They concluded that by using combined solar and biomass dryer production and process of agricultural produce in developing countries can be increased.

Amer et al. [36] designed and constructed indirect solar energy heat exchanger and drier. The main parts of the solar energy dryer were heat exchanger cum heat storage unit, solar collector, reflector and drying chamber. The drying chamber for product storage located under the collector. The dryer was operated as a solar dryer during normal sunny days and hybrid dryer during cloudy weather. The dryer also consisted a storage unit for water to provide heat energy at night. The water in storage tank was heated up by solar energy and electric heater. The efficiency of the dryer was raised up to 65% by recycling of drying air whereas small amount of it was exhausted outside the dryer. The temperature of the dryer was raised up to 30 to 40 ºC above ambient temperature under mid European summer conditions. The dryer was tested for drying of ripened banana slices. The capacity of the dryer was 30 kg of banana slices in 8 h during sunny days. The slices were dried from initial moisture content of 82% to the final moisture content of 18% (wb). The amount of moisture removed during open sun drying was 62% (wb) moisture content. The aroma, color and texture of the dried solar products were found to be better than open sun drying.

Iwuoha [37] constructed a solar maize dryer for drying of maize seed with a subsidiary heating source. The main parts of solar dryer were collector, drying chamber and heating source. The collector was used as a main heat source and drying chamber for product storage whereas local oil as subsidiary heat source. The plant acquired at a temperature of 60°C and drying chamber was at 50°C. The capacity of drying chamber was 5 kg of maize and the amount of moisture reduction was from 45% to 14%. The plant was provided with rollers so that it should be moved to building for application of heat at night. The maintenance cost was lowered as it did not contain any moving part. The cost of plant was about N 10,000 and it can be used for rice, beans and other agricultural products. The service life of plant was three years.

Irtwange and Adebayo [38] constructed a passive solar dryer and evaluated its performance in Makurdi metropolis, Benue State, Nigeria. The main parts of solar dryer were thermal storage unit, drying chamber and solar collector. The top of the collector surface consisted 4 mm thickness of glass glazed cover. The absorber material was 0.5 mm corrugated thick zinc roofing sheet painted black. The drying chamber i.e. thermal storage was made up of wood owing to its good insulation properties. The experiments were carried out on 10 kg maize at 32% moisture content on wet basis. The results of experiments showed that the drying rate of maize was 0.7 kg/day. The drying rate of solar dried maize was 0.3125 kg/day comparatively. Thus, solar drying proved more beneficial in terms of drying rate and quality. Whereas the quality of solar dried maize was not good, and spoilage occurred due to moisture in grains caused microorganism. The time for maize drying in passive solar dryer was 4 days to dry corn to 13% moisture on wet basis. So, such type of solar dryer was more beneficial for farmers in rural areas.

## DISCUSSION & CONCLUSION

In this review commonly used solar dryer with their performance have been presented. The results of different studies presented showed that the solar dryers have the potential to minimize the energy required environmental impacts of drying agricultural products. Currently different type of materials such as rock, sand, paraffin wax, pebbles and oil are being used for energy storage. The development of dryer using locally available cheaper materials with energy storage facility can be a viable solution to fossil fuel operated dryers for developing countries.

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