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# SOLAR BIOMASS HYBRID DRYING SYSTEM FOR DRYING FRUITS AND VEGETABLES: A REVIEW

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**Abstract:** *Drying is very important process applicable for agricultural and industrial products. Drying is the moisture removing process from the products. Drying reduces the bacterial growth in the products. It will helpful for preserving the products for long time. Solar drying is the oldest method of products drying. Open air solar drying method is used frequently to dry the agricultural products. But this method has some disadvantages. Therefore to avoid disadvantages it is necessary to use the other solar drying methods. Different solar drying methods are direct solar drying, indirect solar drying, and mixed mode solar drying. The device used for drying fruits and vegetables with application combined solar and biomass energy. In this paper, we are studied the solar biomass hybrid drying system for drying fruits and vegetables. The use of solar drying in recent years becomes popular for increasing the quality of agricultural crops especially in developing countries. A wide range of solar dryers is available with various characteristics for drying of crops and food products. A prototype solar dryer with a biomass combustor could be designed and developed for the use of small scale rural farmers to dry their harvested fruits and vegetables.*

**Keywords:** *Template, Algorithm*

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## INTRODUCTION

India is the world's sixth largest energy consumer, consuming about 3 per cent of world's total energy per year. However, the biomass-based energy meets a major fraction of energy demand in rural areas of the most developing countries, including India (Naidu, 1999). Biomass is an organic matter of biological origin as a form of stored solar energy, which is an important source of energy accounting for about one third of the total fuel used in India and in about 90% of the rural households (Sudha *et al*., 2003). Biomass contributes over third of primary energy in India with consumption of fuelwood in domestic sector as 218.5 MT (dry)per year, crop residue, 96 MT and cattle dung cake 36 MT per year (Shukla,1997).

Subabul (*Acacia auriculiformis*) is the prominent tree species available in Maharashtra. It is predominantly found in the seasonally dry tropical lowlands in the humid and sub-humid zones. It is abundantly available in Maharashtra region and popularly used as the major source of firewood due to its density and high energy content and faster rate of growing (Benth, 2009).

Fruits and vegetables constitute a major part of the food crops in developing countries. Drying is one of the seasonal methods which is used for preserving the fruits. Many varieties of fruits are seasonal and most of them are consumed in their dried form to a long time. This has been made possible by the process of drying Grape is world's largest fruit crops in India. The world production of grapes is presently more in India. Drying the grape produces raisins. India receives an enormous amount of solar energy: on average, of the order of 5 $kWh/m^2$day for over 300 days/year. This energy can be used for electrical applications. Drying, which is most commonly used for drying agricultural products, it remove the moisture within the product by heat and its subsequent evaporation from the product. Thus, drying involves simultaneous heat and mass transfer (Bhansali *et al*., 2014).

Drying is a technique of preservation for food by reducing the activity of water to a level consistent with the length of desired shelf life. Drying by artificial heat is more rapid than open air drying and is often necessary in places where humidity is high (Vasanthi *et al*., 2002). Processing of agricultural produce not only contributes to food preservation but also offers better opportunity for expanded product utilization and adds value (Daniel *et al*., 1996).

Solar dryer is the most possible for use in areas where electricity is not available.

Among the different types of natural convection solar dryers, the mixed-mode type has been demonstrated to be superior in the speed of drying (Simate, 2003). In this type of dryer, during day time the heat for drying are from direct solar radiation. For direct mode, the product is allowed to directly absorb heat from solar radiation by applied a transparent cover on drying chamber. Solar dryer is that it can only be used during the daytime when there is adequate solar radiation. it is necessary to provide any form of back-up heating. One exception is a cabinet solar dryer reported by Bena & Fuller (2001) which used a fuelwood burner to provide heat during poor weather and at night. The burner was constructed from a 0.2 $m^3$ steel drum by integrating it with the drying cabinet. An overall efficiency of the burner was reported to be 22%. Another dryer reported by Bassey *et al*. (1987) was used a sawdust burner, constructed as a separate component, to provide a back-up heat. The burner was designed to provide 400 $W/m^2$ of energy to the drying cabinet, and used steam as the heat transfer medium (Tarigan *et al*. 2005).

This paper describes a hybrid drying system of solar dryer integrated with a simple biomass combustor. The biomass combustor is constructed from thin metallic sheet cylinder, and it is surrounded by another metallic sheet cylinder. The gap is provided in between for easy heat transfers. Fuelwood, which is the most common source of energy in rural areas of developing countries, is mainly designated to be the fuel for the burner. The dryer has been evaluated under various conditions to dry fresh fruits and vegetables.

The hybrid biomass combustor and solar dryer will provide the solution for efficient utilization of available biomass. It utilizes the flue gas heat for application like drying of fruit and vegetables with minimum pollution and product degradation. The overall efficiency of biomass utilization can be increased by using heat loss into atmosphere.

**Hybrid Solar Dryers**

The dryer design uses direct solar energy and biomass energy through hot air, produced by a combustor, and circulates. Results of tests, for no load and full load using fruits and vegetables, show that the dryer, operation can dry twice faster than the traditional method.

**Design of Solar Biomass Hybrid Dryer**

The general features of the dryer, consisting of a biomass combustor and cabinet dryer with collector area 3.84 $m^2$, and dimensions of collector are 1.2 × 3.2 m. The combustor is manufacture using galvanized iron sheet, with two concentric cylinders inner cylinder having inverted cone at top with exhaust holes. The sufficient spaced provided in between two cylinders for proper heat exchange to the fresh air which is transfer to dryer for drying purpose. The developed solar dryer took shorter drying time with 10 hours of day time solar radiation and 6 hours of night time with biomass combustor. This hybrid dryer produces a better quality product and can, depending on the heat source, reduce the drying time by up to 50 percent compared to traditional drying.

**Biomass Availability**

Bhattacharya (2001) reported that in the developing countries, biomass fuels were used in a number of commercial applications, e.g. drying/curing/smoking, cooking, baking, pottery etc. There was a great deal of variation in the design of the combustion systems employed in different applications. The environmental considerations was constrained their access to fossil fuels in the future. As a result, the share of renewable energy in general and biomass in particular, in the total energy supply was expected to rise in the future.

Sudha *et al.* (2003) studied the sustainable biomass production for energy in India and reported that, annually 62-310 Mt of wood would be generated from the surplus land, after all the requirements of biomass, such as domestic fuel wood, industrial wood and sawn wood.

Ravindranath *et al.* (2005) reported that in India, fuel wood, crop residues and animal manure were the dominant biomass fuels, which were mostly used in the rural areas, at very low efficiencies. The potential of energy from crop residues, animal manure, MSW, industrial wastewater and biomass fuels that could be conserved for other applications through efficiency improvement was discussed.

Benth (2009) revealed that Subabul (*Acacia auriculiformis*) occurs from near sea level to 400 m, but was most common at elevation less than 80 m. It was predominantly found in the seasonally dry tropical lowlands in the humid and sub-humid zones. It was the major source of firewood; its dense wood and high energy contributed to its popularity

**Drying of agricultural produce (Fruits and Vegetables) on Hybrid Mode**

Daniel *et al.* (1996) studied that processing of agricultural produce not only contributed to food preservation but also offered better opportunity for expanded product utilization and added value. Direct sun drying method was time consuming and it was taken 4-6 days to dry agricultural food products (20 mm thick, loading rate 5 kg/m2) to 14-16 per cent moisture content. Product quality suffered because of prolonged drying, which made the product susceptible to contamination. Solar dryers produced better quality products within a relatively shorter period, but depended mainly on the weather and, therefore, not reliable and attractive during the rainy season or in wet weathers.

Bastin *et al.* (1997) reported the water content of several popular raw fruits and vegetables. Fruits and vegetables contain large quantities of water in proportion to their weight. This was important in development of the dryer.

Singh and Ramana (1999) designed, fabricated and retrofitted the solar dryer for chilly drying in the field with biomass fired hot air generator. The biomass consumption of 7-8 kg per hour, an aspirated type producer gas burner and a shell and tube air gas heat exchanger had been coupled with the dryer. The gasifier based hot air generator produced 750 $m^3$ of hot air at an average temperature of 80 ºC.

Vasanthi (2002) studied the development of biomass based dryer for medicinal plants drying. The drying of medicinal plants was conducted at an average air flow rate of
0.2 - 0.3 m/s. At load condition, the maximum temperature of 50 to 55 ºC was attained inside the unit after 30 minutes of combustion process. The maximum temperature of 50- 55 ºC was maintained by adjusting the airflow rate through the door. The efficiency of the biomass fuel

based drying system was varied from 30.5% to 37.5% for different selected medicinal plants drying. Dryer efficiency significantly depended on the initial moisture content of the drying material and the airflow rate.

Tarigan *el al.* (2005) reported that a mixed mode natural convection solar dryer, designed for small-scale commercial producers of agricultural products in non-electrified locations, has been demonstrated which was combined with a simple biomass burner and bricks heat storage as back-up heating system. The back-up heating system which can be constructed with easily available materials, tools and skills, can improve the viability of the dryer.

Prasad *et al.* (2006) reported the performance evaluation of hybrid drier for turmeric (Curcuma longa L.) drying at village scale. The developed natural convection solar drier with biomass burner was capable of producing the air temperature between 55 and 60 0C, that was optimum for dehydration of turmeric rhizomes as well as other spices, herbs, fruits and vegetables. Drying time for turmeric had been drastically reduced compared to open sun drying by 86%. The efficiency of the whole unit observed was 28.57%. The system was predestined for application on small farms in developing countries due to its low investment.

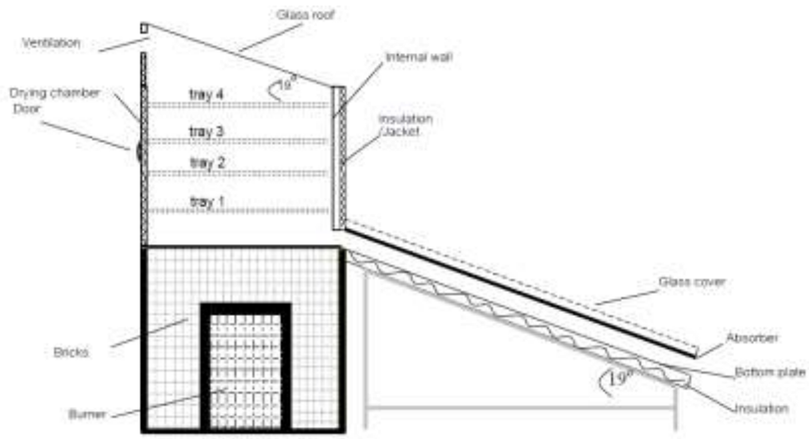


**Fig. A solar biomass hybrid dryer**

Anonymoys (2008) reported that waste heat was heat, which was generated in process by way of fuel combustion or chemical reaction and then dumped into the environment even though it could still be reused for some useful and economic purpose. Large quantity of hot flue gases was generated from boilers, kilns, ovens and furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. If the exhaust gas heat was suitable for equipment in terms of heat quantity, temperature range, operation time etc, the fuel consumption could be greatly reduced.

Adzimah *et al.* (2009) studied that grain drying was very important because it increased the storage life of cereal grains. The common methods of grain drying are included sun drying and the existing cabinet grain dryer. These methods had a lot of deficiencies in terms of drying speed, efficiency, productivity, quality and safety. The right quantity of heat and incorporated fan which, supplies the right quantity of air needed to distribute heat evenly to all grains in the drying chamber should be consider.

Ehiem *et al.* (2009) studied an industrial fruit and vegetable dryer developed using low price materials. The device had a mean thermal efficiency of 82% with average capacity of 258.64 kg/batch. The size, air flow rate and drying time had highly significant effect on weight of the tomato slices being dried. For all the tomato sizes and at all air flow rate levels, weight of the tomato decreased with increase in drying time. Also for all the sizes at all drying time levels, weight decreased with increase in air flow rate.

Bello *et al.* (2010) studied that biomass-furnace dryer had an average thermal efficiency of 59%. This efficiency could be further increased if the heat loss to the environment as conduction and radiation losses through the top cover and outer casing was prevented.

Geramitchioski *et al.* (2011) reported the construction of mobile combine solar – biomass dryer for drying of vegetables and fruits with capacity that was suitable for use in single farm and small cooperatives. The apples were dried at temperature of 60-70 ºC to a final moisture content of 20 % with an average drying rate of 8 sunshine hours.

Belonio *et al.* (2012) reported simple design of an indirect fired flat bed grain dryer using biomass furnace that makes drying of grains possible, even during the wet season. The dryer system consisted of biomass furnace which burns biomass (rice husks, corn cobs, *etc*.) that was available in the farm; an axial fan which moves hot air from the furnace to the drying bin and a drying bin where grains to be dried were held for several hours until the desired level of moisture was reached. The furnace consisted of an inclined grate made of a 10 mm thick mild steel plate which burnt 40 to 60 kg of biomass by direct combustion with excess air.

Gawali (2012) studied the composite biomass based water heater and dryer. At free air supply test, boiler efficiency, dryer efficiency and overall efficiency of composite unit was found to be 31.95 %, 6.78 % and 32.98 %, respectively and at forced circulation test, boiler efficiency, dryer efficiency and overall efficiency of composite unit was found as 31.01 %, 12.27 % and 32.48 %, respectively. It was revealed that the biomass based composite water heater and dryer were more efficient at forced circulation than the natural circulation.

Sanchavat *et al*. (2012) developed system is suitable for curing and drying of 50 kg of turmeric in one batch. The results indicate that solar cabinet drier took lesser time than open drying system. The turmeric sample had higher colour value and higher Curcumin content indicating better quality product. The present net worth of developed system for turmeric processing was found to be Rs. 28800. The system payback period was 1.31 years and benefit cost ratio was found as 1.69. The system was found to be economical for turmeric processing. The system could be good household appliance for processing of turmeric and revenue generation.

Andrew *et al.* (2013) state that a natural convection indirect solar dryer with backup biomass burner for small scale pepper berry farmers was design and implemented. The proposed solar dryer could preserve and protect the pepper berries from rain, dust, insects and animals during whole drying process. It was also portable, cheap and affordable. Therefore, it can easily be handled from one place to another for drying of pepper berries at the required site. The additional biomass backup burner allowed the continuous drying process at nights and during wet seasons. It shortened the drying duration of pepper berries from 5-7 days to a single day with continuous drying. It increased the productivity of small scale rural pepper farmers as they could produce the dried pepper berries in a shorter period of time.

Dhanuskodi. S *et al*. (2013) stated that in present experimental results prove that biomass gasifier supplies more heat when compared with solar flat plate collector. Also drying with solar flat plate collector saves time for drying when compared with open sun drying. Still research has to be continued in the present set up such that efficiency to be improved for solar flat plat collector by optimizing tilt angle, Coating for the surface mirror, installation of booster mirror, supply of air through the collector Using blower, variable speeds for the blower such that heating capacity of the solar flat plate collector to be increased for a best performance by the experimental setup.

Okoroigwe *et al.* (2013) proved that the efficiency of agricultural dryers could be increased through the use of a combination of solar and biomass heating sources, compared to conventional dryers with only solar or only biomass heating sources. Using combined solar and biomass dryers have the potential to increase the productivity and resultant economic viability of small and medium-scale enterprises producing and processing agricultural produce in developing countries.

Sharma (2013) studied the performance evaluation of biomass water heater cum dryer on forced circulation mode. At 100% damper opening, boiler efficiency, dryer efficiency and overall efficiency of composite unit was found as 25.77 %, 27.39 % and 24.99 % respectively, at 75% damper opening, boiler efficiency, dryer efficiency and overall efficiency of composite unit was found as 23.6 %, 26.09 % and 22.68 %, respectively and at 50% damper opening, boiler efficiency, dryer efficiency and overall efficiency of composite unit was found as 22.7 %, 24.89 % and 21.36 %, respectively. It was revealed that performance of composite unit on forced circulation mode at 100 % damper opening was higher as the drying air gets heated and carries the moisture through the sample (bottle gourd) at a faster rate.

Edmund *et al.* (2015) reported that a solar-biomass hybrid dryer was improved upon and its performance evaluated under three heating modes using 3 food samples. The efficiency of the solar collector is 61.42% with average exit temperature of 38.02°C. The average maximum tray temperature of 49°C was recorded on no load test with solar heating only, while the average maximum temperature of 65°C was recorded in a similar test with biomass heating only. When drying groundnut using biomass, only 53°C was the maximum tray temperature while 46°C was recorded when drying okra with solar heating only. The maximum tray temperature of 67°C was obtained on hybrid mode in tray 1. The efficiency of the dryer based on solar, biomass and solar-biomass heating when drying fresh okra, fresh groundnut and fresh cassava chips increased from 5.19 – 16.04%, 0.23 – 3.34% and 1.636 – 8.96% respectively over the initial prototype design.

**CONCLUSION**

This review paper is focused on biomass based hybrid solar dryers. A comprehensive study of how hybrid solar dryers fare compared to other dryers, various design modifications and enhancement techniques applied to them is done. In this paper, various solar, biomass hybrid dryers are also discussed. The Hybrid dryers are the most cost effective type of dryers and are easy to fabricate and use. Hybrid solar dryers do not use any auxiliary equipment and protects the products from external contamination and it can use in unfavourable weather condition and also it is used in night time. These are the simplest form of dryers and are easy to fabricate, use and cost-effective.

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