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Application of solar energy in Food processing: An update

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Abstract
Solar dryers are utilised to dehydrate the food items. In modern days, very new framework including proportion of waste energy, sustainability index and upgraded potentiality are inaugurated to define the capability of solar dryers along with preservation capacity. Moreover, besides that, solar dryer utilises solar energy that is amply obtainable from ecology. Besides solar dryer, Indirect Solar Dryer (ISD) is very much prominent along with sustainable wholly with the help of TES and air heat exchanger. Furthermore, recently developed hybrid solar dryer is supplementary origin of energy which is used to heat milk, to cook meats like sausage and salami, and in brewers farming in moderate temperature for washing, cleaning, sterilisation, pasteurisation, drying, cooking hydrolyzation, distillation, evaporation, extraction, and polymerisation. In addition, the dried food items like turmeric are dehydrated from 73.4% to 85% through applying solar dryer within 18.50 hours. The drying kinetics of 200 gm of black turmeric utilising mixed mode forced convection solar dryer in discharge air temperature at 6º to 10 ºC besides paraffin wax are applied as preserving constituent there. An overview of the use of solar energy in food processing will be provided in this article.

Keywords: Solar energy, dried foods, cooking, evaporation, food processing

Introduction
In recent decades, preservation of energy is very much critical because conveniently getting energy is mostly crucial world-wide. Researchers have also pointed out that, decreasing the conventional or non-renewable energy utilisation besides seeking for its replacement. Uplifted renewable energy resources as replaced choices to lesion hydrocarbon concentration along with fallen down another excretion of heavy metals or poisonous substrates. Authors have experimented that, drying is the rigorous methodology that is used in food processing extensively (Mathioudakis *et al*., 2009) [16]. Heating is very much prolonged used to preserve perishable foods especially fruits and vegetable, cereals as moisture deteriorate the quality of foods caused of microbial contamination therefore to decrease moisture content in food items. Drying is very much preferrable because it helps to drop the growth and development of microbes. Thermal energy is especially utilised in drying mechanism. Apart from that, conventional energy sources like fossil fuels and electric energy are extensively applied in drying procedure (Lingayat *et al*., 2021) [14].
Authors have conveyed that, by the procedure of conduction, convection, radiation, infrared rays, dielectric heat origins maximum 96kg moisture foods can be dried in 30º to 200 °C where energy sources are electricity, coal, oil, natural gasses including methane, ethane, butane, propane etc, biomass and solar energy like solar driers, solar water heater etc. Furthermore, fossil fuels are very much eco-friendly as they release toxic gaseous materials. The energy from heat uses at drying is about 12% to 40% of total energy squander in developing countries (Pirasteh *et al*., 2014) [23]. Moreover, natural energy resources like solar energy have extensive function in drying which fallen the utilisation of conventional energy resources at 27% to 80% (Prakash *et al*., 2016) [24]. Precisely, non-renewable energy resources are very much applicable in drying because it is clean, sustainable, economically safe, and eco-friendly energy resources. In very recent times, the conventional energy bares 80% of total global energy production. The essential requirement to alter energy was delayed orient along with seeking nuclear energy in middle of 20th century that is ten to twenty times more efficient rather than fossil fuels (Lingayat *et al*., 2020) [13].

Application of solar drying network

Solar drying and dehydration utilize solar irradiance by only transmission of power to heat the air or as an additional energy source. Authors have revealed that, traditional drying system ignited fossil fuels on the other hand, solar dryers grab benefits of sun irradiation for drying and dehydration (Schnitzer *et al*., 2007) [25]. Moreover, solar dryers are categorised into high and low temperature dryers, high temperature dryers are warmed up with the help of fossil fuels and electric besides low temperature dryers are reheated by fossil fuels and solar energy. Decreased temperature solar thermal energy is good for utilisation in preheating. Furthermore, solar dryers also categorised on the basis of air flow development broadly into 2 classes these are natural convection or passive (Lingayat *et al*., 2020) [13] and forced convection or active (El-Sebaii & Shalaby, 2013) [7] solar dryers. Normally, solar dryer utilises solar energy that is amply obtainable from ecology. The sum of total acceptability of passive dryers differ from depends upon type of material, moisture holding capacity, velocity and clamminess of air. Furthermore, forced convection or active dryers are preferable as it provide good thermal regulation besides share administered drying situation rather than original convection dryers (Mustayen *et al*., 2014) [20]. Solar energy utilised dryers are operated along with thermal energy storage (TES) like latent heat (Singh *et al*., 2018) [27] and rational heat preservation (Ayyappan *et al*., 2016) [3] class to proceed the dehydration until sunset. Apart from that, Direct solar dryers (DSD) supply temperature in estimation from 30 °C to 60 °C that enough to dehydrate fruits from moisture state such as apple, mango, papaya, strawberry, many vegetables, and meat, marine and its products (Mezrhab *et al*., 2010) [18]. Apart from that, Indirect solar dryers (ISD) are much prominent along with sustainable wholly with the help of TES and air heat exchanger. Moreover, recently developed hybrid solar dryers are supplemental origin of energy which is utilised to dehydrate the food items when sunset is continued or in over clouded days or to monitor the temperature, humidity constantly as swing in solar radiation continuously. Additional heating mechanism including electric heater, biomass heater, liquid petroleum gas (LPG) heater, mechanical heat pump and so on are applied for developing thermal energy (Yahya ., 2017) [28]. Moreover, this dryer is utilised for dehydrating highest moisture gaining constituents (Mishra *et al*., 2021) [19]. The thermal preserving system is another essential constituent in solar drying operations that preserve heat at most hours of sunshine that may be applied in post sunset (Esen & Yuksel, 2013) [8]. Authors have experimented that refrigeration or air conditioning system is another approach apart from solar drying, solar freezers do not contain refrigerator Freon which breakdown ozone concentration (Balaras Constantinos *et al*., 2007) [4]. Solar refrigerators are operated into open and closed cycle systems, utilise heat driven pump that is promoted through solar energy. Noteworthy, solar energy is applicable to heat milk, to cook meats like sausage and salami and in brewers farming in moderate temperature for washing, cleaning, sterilisation, pasteurisation, drying, cooking hydrolyzation, distillation, evaporation, extraction, and polymerisation. Authors have documented that, in brewing industry, 80% of total energy is utilised in form of thermal energy, this quantity of energy are segregated into three distinctive methods for example 25 to 50% energy is applied for boiling wort, 25 to 40 % energy is governed for washing the bottles and for pasteurisation. Noteworthy, low-pressure steam is developed at 100° to 110 °C and conservation along with hot air in 60° to 80 °C (Mekhilef *et al*., 2011) [17]. Authors have revealed that, for storing food constituents, applied solar energy for scalding, sterilising fruits and vegetables, fish, after that, cleaning, precooking, concealing, cooling, and refrigeration. Apart from that, dairy industries apply solar energy for pasteurization in 60 to 85 °C. Sterilization have done at 130 °C to 150 °C by using solar thermal energy. Furthermore, milk and whey are dispersed in 120 °C to 180 °C by applied solar energy (Nandi, & De, 2007) [21].

In accordance with International Energy Outlook (IEO), U.S. Energy Information Administration, 2019, has documented that, 50% developed heat is utilised by industries, 46% heat is applied by space mission and for boiling water, rest of 4% are used in heating the agricultural greenhouse farming. Dehydration monitors strictly growth and development of harmful microbes in moisture containing foods besides it is utilised for supressing extensive wide volume and size of the foods. Furthermore, solar energy is applied to dehydrate food items (lamidi *et al*., 2019) [12]. Authors have experimented that, drying kinetics of 200 gm of black turmeric utilising mixed mode forced convection solar dryer merged along with TES in discharge air temperature at 6° to 10°C besides paraffin wax are applied as preserving constituent there. Results have shown that, moisture including turmeric is dehydrated from 73.4% to 85% through applying solar dryer within 18.50 hours. Noteworthy, the organoleptic attributes are present constantly along with phenolic and flavonoid content widely (Lakshmi *et al*., 2018) [11]. Solar drying process are employed upon fruits for dehydration for instance red chilli (Ndukwu *et al*., 2017) [22], bitter guard (Zachariah *et al*., 2021) [29], apricot (Baniasadi *et al*., 2017) [5], garlic (Shringi *et al*., 2014) [26], apple (Atalay *et al*., 2017) [2], orange (Atalay *et al*., 2019) [1] etc. in accordance with Lakshmi *et al*., 2018 [11], by utilising solar energy, most solar drying temperature is 65 °C. in modern days, very new framework including proportion of waste energy, sustainability index and upgraded potentiality are inaugurated to define the capability of solar dryers along with preservation capacity (Atalay, 2019) [1]. Authors have also noted that, forced convection solar dryer (FCSD) along with TES may upgrade the function along with capability of drying system. Very recent terminology “Pick up efficiency” was originated by (Baniasadi *et al*., 2017) [5] to measure the native performing capability of solar dryer based on removing moisture from food constituents. Precisely, authors have noticed that, dairy substances are processed by various applications with help of solar energy like pasteurization at 60-80 °C, sterilization at 100-120 °C, drying at 120-180 °C, concentration at 60-80 °C besides tinned foods are involved into more food processing by thermal energy like sterilization at 110-120 °C, pasteurization at 60-80 °C, cooking and bleaching at 60-90 °C (Kalogirou, 2003) [10].

Conclusion

There are numerous potential advantages to using renewable energy in the food production and processing sector, such as less reliance on fossil fuels, better air quality, greater utilisation of regional resources, and the creation of jobs.

However, before renewable energy can be successfully implemented in this industry, a number of obstacles and constraints must be removed. These include the requirement for a significant initial outlay of funds, consistent power sources, and government incentives and subsidies. However, renewable energy has the potential to play a significant role in the food processing and production sector with the appropriate regulations and financial support.

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