The Pharma Innovation Journal 2022; 11(12): 2785-2790

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 2785-2790
© 2022 TPI
www.thepharmajournal.com
Received: 18-09-2022
Accepted: 20-10-2022

Rohit Kumar Yadav
Department of Renewable Energy Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

Dr. Sheen C Moses
Professor and Head, Department of Farm Machinery and Power Engineering, SHUATS, Allahabad, Uttar Pradesh, India

Corresponding Author:
Dr. Sheen C Moses
Professor and Head, Department of Farm Machinery and Power Engineering, SHUATS, Allahabad, Uttar Pradesh, India

Comparative performance study of different types of solar dryers for selected vegetable crops

Rohit Kumar Yadav and Dr. Sheen C Moses

Abstract
Solar drying is becoming a popular option to replace mechanical dryers due to the high cost of energy, and the increased awareness of consumer orientation to clean energy products. In this study, three different low-cost solar dryers, viz. solar tunnel dryer (STD), cabinet solar dryer (CSD), and open sun drying (OSD) were examined, and green peppers drying experiments were carried out on each. In this study, three main topics were determined: (i) to compare the drying rate of each solar drying method (ii) to determine the drying time of each solar drying systems, (iii) to compare the drying efficiency of each solar dryer. For these purposes, 3 experiments were conducted between 10:00am–04:00pm at the department of renewable energy engineering campus in shuats, Prayagraj (u.p.). The average daily solar irradiance was around 890 W/m2. In drying experiments, it was observed that the samples were completely dried out within the experiment period, while the drying process of the green pepper in STD were completed in 14 hr and in CSD and OSD were completed after 28 hrs. The results show that the drying time of STD is less than CSD and OSD. Drying rate and drying efficiency of STD is more than CSD and OSD. Mint leaves have a thermal efficiency of 40.04% in the winter and 44.68% in the summer when dried in a sun tunnel. Slices of potatoes used in a solar tunnel dryer have a thermal efficiency of 78.14% in the winter and 93% in the summer. The thermal efficiency of green chilies for solar tunnel dryers in the winter and summer, respectively, is 49.34% and 82.94%. For the cabinet type solar dryer, mint leaves have a thermal efficiency of 34.46% in the winter and 40.38% in the summer. For cabinet-style solar dryers, the thermal efficiency of potato slices is 74.44% in the winter and 84.45% in the summer. Last but not least, the thermal efficiency of green chilies for a cabinet type solar dryer is 43.38% and 69.31% in the winter and summer, respectively. Mint leaves may be dried in a solar tunnel dryer with an efficiency of 21.84% in the winter and 34.14% in the summer. In the winter and the summer, the solar tunnel dryer's effectiveness for drying potato slices is 44.99% and 49.69%, respectively. Last but not least, the solar tunnel dryer's drying efficiency for green chilies in the winter and summer, respectively, is 36.72% and 42.29%. Mint plants can be dried with an efficiency of 20.92% in the winter and 32.60% in the summer using the cabinet type solar drier. Potato slices may be dried using cabinet-style solar dryers with an efficiency of 43.55% in the summer and 39.47% in the winter. Last but not least, a cabinet-style solar drier can dry green chilies with an efficiency of 30.11% or 37.39% depending on the season.

Keywords: Vegetable crops, cabinet-style solar drier**,** green chilies, mint plants, potato slices

Introduction

Fruits, vegetables, and meals should always be preserved if they are to be kept for an extended period of time without additional deterioration in the product's quality. Drying among them is particularly suitable for underdeveloped nations with inadequate low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce post-harvest losses and offset the shortages in supply. Drying is an energy-consuming procedure that removes moisture from a product so that it has the correct moisture content. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind. Drying involves the application of heat to vaporize moisture and some means of removing water vapor after its separation from the food products. It is thus a combined and simultaneous heat and mass transfer operation for which energy must be supplied. The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage, and transportation costs and enables storability of the product under ambient temperatures (Asnaz & Dolcek, 2021) [1].

The major application of solar energy is its use for drying of agricultural products. Sun drying is the oldest method for drying product with the direct utilization of sun radiation. This method improves heat transfer both inside the product and at its surface. While drying proceeds the thermal conductivity of the crops is also important, particularly if the drying layer is deep enough to require heat conduction between particles. Crop is placed on the ground or concrete floors, which can reach higher temperatures in open sun, and left there for a number of days to dry. On the basis of capacity, and easy or simple nature of the process, natural drying remains the most common method of solar drying. During the process of drying energy requirements, which come from solar radiation and the air enthalpy, are readily available in the ambient environment and no capital investment in equipment is required. This process has some serious boundations. There are some major problems such as the agricultural products bear the unwanted effects of dust, dirt atmospheric pollution, and insect and rodent attacks. Because of these limitations, the quality of the resulting product can be reduced, sometimes beyond eatable.

Solar drying is most suitable for use in developing countries. Drying process plays a crucial role in post-harvest technology for preservation of agricultural products. Due to the increasing cost of electricity and fossil fuels, application of solar energy for drying of various agricultural products has become the need of the time. It is not only economical but also ceases the gas emissions. By solar drying, huge amount of national revenue can be saved by avoiding the spoilage of agricultural products due to non-availability of conventional processing facilities. Solar drying is a clean and hygienic way to process the products according to international standards without any expenditure on energy costs. Although solar energy occupies larger area comparatively yet it also Improves product quality like conventional high tech. dryers and saves time and money for drying. In the present scenario, solar energy is successfully being utilized for complete drying of agricultural products (Visavale, 2012) [1].

Solar Tunnel Dryer

Recent efforts to improve on sun drying have led to solar drying. Solar tunnel dryer is simple to construct, affordable in cost, and more efficient. A hemi-cylindrical metallic frame structure is covered with a UV-stabilized semi-transparent polythene sheet with a thickness of 200 microns in the tunnel drier. The tunnel dryer's floor and other objects are usually painted black to absorb the sunlight that enters the tunnel. The long wave thermal radiation emitted by the objects inside the tunnel dryer is retained inside the tunnel, raising the temperature of the air and speeding up the evaporation of moisture in the product kept inside the tunnel dryer. Natural and artificial convection currents can be used to remove damp air. The microclimate inside the tunnel dryer can be regulated by adjusting the exhaust fan's air flow rate through the dryer (Bala & Mondol, 2001) [2].

Cabinet Solar Dryer

The cabinet solar dryer is a more advanced version of the direct sun dryer. Fruit, vegetables, fish, and meat, for example, are typically used in modest amounts to preserve. Single or double-glazed insulated hot boxes with apertures at the base and upper parts of the cabinet's wall are typical of this type of dryer (Sreekumar et al., 2008) [8]. The necessary solar energy for the drying process passes through the cover and is absorbed both on the blackened interior surfaces and on the product. Warm damp air escapes through the upper section due to buoyancy forces, while utilized fresh air is collected from the base. The dryer was stated to have a drying temperature of over 80 °C (Singh and Mishra, 2022) [7].

Chavan *et al.* (2011) [3] was conducted in each solar tunnel dryer (STD) and compared with open sun drying (OSD). The drying behavior of mackerel drying in STD was studied by comparing eleven different drying models. The Midilli model provided the highest R2 (0.9928), lowest χ 2 (0.000406) and RMSE (0.0164). The drying time required for STD and OSD were 27 and 48 h, respectively. The overall drying efficiency of the STD and OSD was about 19.87 and 12%, respectively. STD significantly influenced the biochemical properties such as Free fatty acid (FFA), Peroxide value (PV), Thiobarbituric acid (TBA), total volatile bases nitrogen (TVB-N), Trim ethylamine nitrogen (TMA-N) and histamine of dried mackerel. There was a significant positive relationship between drying temperature and time (R2>0.85). No microbial growth on dried product was found in STD dried fish.

Munir *et al.* (2013) [5] develop a portable solar tunnel dryer (STD) for the drying of fruits, vegetables and medicinal plants. The system was designed as a portable system for decentralized applications at various sites to satisfy the drying requirements of small farmers and co-operatives. It has been observed that the drying air temperature was easily raised by some 8-14°C above the ambient temperature at air velocity ranges 0-1 m s-1. The efficiency of the solar tunnel dryer was found to be 40-45%. Psychometric analysis was also carried out within the dryer and the process curves were drawn. The process curves were found similar to a conventional dryer showing that this dryer can be successfully utilized for the drying of agricultural products using solar energy.

Kaur et al. (2015) [4] carried out on tomato slices, green chilli and potato slices in natural convection mode. The aperture area of all types of collectors, cabinet sizes, numbers of trays (4 no.) in each cabinet and mass flow rate of air through collector were kept same. The moisture content of chilli from an initial value of 78% (w.b) to a final value 9% (w.b.) reduced by natural convection mode in 24 hours, 23 hours, 23 hours in dryers integrated with flat plate, V-shape and fin type collector respectively. The fin type collector has highest average collector efficiency, drying rates and collector outlet temperature among all tested collector types in both natural and force convection mode.

Naing & Soe (2021) [6] designed calculation of cabinet solar dryer for 1kg of banana slices and the comparative investigation of cabinet solar dryer and open sun drying. The thickness of a banana slice is taken 4mm. After 14 hours of drying time in two days experiment, moisture content of banana slices inside of the cabinet dryer is 14% meanwhile open sun drying is still 40%. As a result, the desired moisture content of banana slice can be received quickly in cabinet solar dryer. And then, it can easily construct with locally cheap and environmentally acceptable, non-hazard materials. Cabinet solar dryer can also reduce the loss of food due to high temperature, insects, and birds. Hence, it is more effective than open sun drying.

Materials and Methods

The experimental studies were carried out at the Department of Renewable Energy Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higgionbottom University of Agriculture, Technology and Sciences, Allahabad. The study was conducted with a view to obtain the drying characteristics of different vegetables and the parameters suitable for the different type of solar dryer for drying selected vegetable crops. The methodology used for the Comparative performance study of different type of solar dryer for drying selected vegetable crops has been discussed under the following heads:

1. To compare the thermal efficiency of each solar drying method.
2. To compare the drying efficiency of each solar dryer.

Thermal Efficiency

Sr. No.	Crop	Solar Tunnel Dryer			Cabinet Type Solar Dryer		
		Winter Season	Summer Season		Winter Season	Summer Season	
1	Mint Leaves	40.04	44.68		34.46	40.38	
2	Potato Slices	78.14	93		74.44	84.45	
3	Green Chili	49.34	82.94		43.38	69.31	
		Result	S. Ed. (±)	C.D. at 5%	**Result**	S. Ed. (±)	C.D. at 5%
Due to crop		S	3.285	6.650	S	2.366	4.788
Due to season		S	2.121	4.292	S	1.527	3.091

For solar tunnel dryer, mint leaves have a thermal efficiency of 40.04% in winter season and 44.68% in summer season. The thermal efficiency of potato slices for solar tunnel dryer is 78.14% in winter season and 93% in summer season. And lastly, the green chilies have 49.34% and 82.94% thermal efficiency for solar tunnel dryer in winter season and summer season respectively.

Mint leaves have a thermal efficiency of 34.46% in the winter and 40.38% in the summer for the cabinet type solar drier. In the winter and the summer, potato slices' thermal efficiency for cabinet-style solar dryers is 74.44% and 84.45%, respectively. Finally, the thermal efficiency of green chilies for a cabinet type solar drier in the winter and summer, respectively, is 43.38% and 69.31%.

Solar Tunnel Dryer

Anova:					**T5%**	**2.024**
Source	**d. f.**	**S.S.**	**M.S.S.**	**F. Cal.**	**F. Tab. 5%**	**Result**
Due to replicate	2	11.7556	5.8778	0.109	3.89	**NS**
Due to crop	2	5620.2348	2810.1174	52.067	3.89	**S**
Due to season	1	1372.8800	1372.8800	25.4375	2.52	**S**
Error	12	647.6488	53.9707	-	-	-
TOTAL	17	7652.52	-	-	-	-

The aforementioned ANOVA tables demonstrate that, at the 5% level of significance, the F. Cal. Value is greater than the F. Tab. Value for their respective d.f. due to crop and due to season. The aforementioned tables also demonstrate a statistically significant difference ($p \leq 0.05$) between various treatments. The thermal efficiency of solar tunnel dryer is higher than cabinet type solar dryer for all of the chosen vegetable crops (Mint Leaves, Potato Slices, and Green Chili) in both the winter and summer.

Cabinet Type Solar Dryer

Anova:					**T5%**	**2.024**
Source	**d. f.**	**S.S.**	**M.S.S.**	**F. Cal.**	**F. Tab. 5%**	**Result**
Due to replicate	2	11.7556	5.8778	0.210	3.89	NS
Due to crop	2	5315.7325	2657.8663	94.987	3.89	S
Due to season	1	847.0728	847.0728	30.2727	2.52	S
Error	12	335.7773	27.9814	-	-	-
Total	17	6510.34	-	-	-	-

The aforementioned ANOVA tables show that for their respective d.f. owing to crop and due to season, the F. Cal. Value is bigger than the F. Tab. Value at the 5% level of significance. Additionally, a statistically significant difference ($p \leq 0.05$) between various therapies is shown in the aforementioned tables. For all of the selected vegetable crops (Mint Leaves, Potato Slices, and Green Chili), the thermal efficiency of solar tunnel dryer is greater than cabinet type solar dryer in both the winter and the summer.

The above ANOVA tables are showing that, in both the solar drying method, F. Cal. Value is higher than the F. Tab. value at 5% significant level on their respective d.f. due to crop and due to season. The above tables are also showing significant difference ($p \leq 0.05$) between different treatments. For the all-selected vegetable crops (Mint Leaves, Potato Slices & Green Chili) the thermal efficiency of solar tunnel dryer is greater than cabinet type solar dryer for both winter and summer seasons. In the case of both solar drying methods, all the selected vegetable crops has higher thermal efficiency in summer season than winter season.

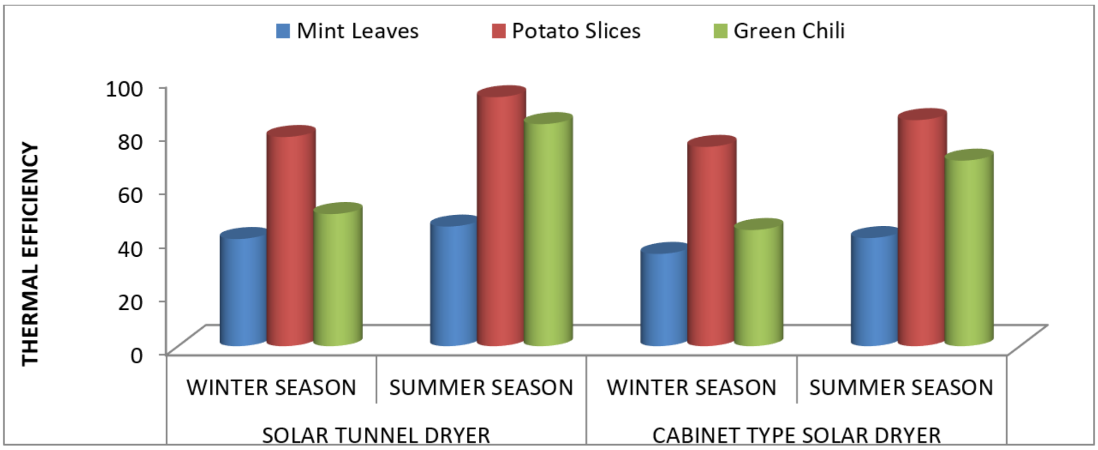

Fig 1: Thermal efficiency of mint leaves, potato slice and green chili in solar tunnel dryer and cabinet type solar dryer

Drying Efficiency

Sr. No.	Crop	Solar Tunnel Dryer			Cabinet Type Solar Dryer		
		Winter Season	Summer Season		Winter Season	Summer Season	
1	Mint Leaves	21.84	34.14		20.92	32.60	
2	Potato Slices	44.99	49.69		39.47	43.55	
3	Green Chili	36.72	42.29		30.11	37.39	
		Result	S. Ed. (±)	C.D. At 5%	Result	S. Ed. (±)	C.D. At 5%
Due To Crop		S	0.934	1.891	S	0.858	1.737
Due To Season		S	0.603	1.221	S	0.554	1.121

Mint leaves can be dried using a cabinet-style sun drier with an efficiency of 20.92% in the winter and 32.60% in the summer. For drying potato slices, cabinet-style solar dryers had an efficiency of 39.47% in the winter and 43.55% in the summer. Not to mention, a cabinet-style solar drier has a drying efficiency for green chilies in the winter and summer of 30.11% and 37.39%, respectively.

Mint plants can be dried with an efficiency of 20.92% in the winter and 32.60% in the summer using the cabinet type solar drier. Potato slices may be dried using cabinet-style solar dryers with an efficiency of 43.55% in the summer and 39.47% in the winter. Last but not least, a cabinet-style solar drier can dry green chilies with an efficiency of 30.11% or 37.39% depending on the season.

Solar Tunnel Dryer

ANOVA:					**T5%**	**2.024**
Source	**d. f.**	**S.S.**	**M.S.S.**	**F. Cal.**	**F. Tab. 5%**	**Result**
Due to replicate	2	11.7556	5.8778	1.346	3.89	**NS**
Due to crop	2	1136.8099	568.4049	130.182	3.89	**S**
Due to season	1	239.1485	239.1485	54.7722	2.52	**S**
Error	12	52.3949	4.3662	-	-	-
TOTAL	17	1440.11	-	-	-	-

The aforementioned ANOVA tables demonstrate that, at the 5% level of significance, the F. Cal. Value is greater than the F. Tab. Value for their respective d.f. due to crop and due to season. The aforementioned tables also demonstrate a statistically significant difference ($p \leq 0.05$) between various treatments. The drying efficiency of a sun tunnel dryer is superior to a cabinet type solar dryer for all of the vegetables that were chosen (Mint Leaves, Potato Slices, and Green Chili) in both the winter and summer.

Cabinet Type Solar Dryer

ANOVA:					**T5%**	**2.024**
Source	**d. f.**	**S.S.**	**M.S.S.**	**F. Cal.**	**F. Tab. 5%**	**Result**
Due to replicate	2	11.7556	5.8778	1.597	3.89	**NS**
Due to crop	2	653.2804	326.6402	88.741	3.89	**S**
Due to season	1	249.5378	249.5378	67.7938	2.52	**S**
Error	12	44.1700	3.6808	-	-	-
TOTAL	17	958.74	-	-	-	-

The aforementioned ANOVA tables show that for their respective d.f. owing to crop and due to season, the F. Cal. Value is bigger than the F. Tab. Value at the 5% level of significance. Additionally, a statistically significant difference ($p \leq 0.05$) between various therapies is shown in the aforementioned tables. For all of the veggies selected (Mint Leaves, Potato Slices, and Green Chili), the drying efficiency of a sun tunnel dryer is superior to a cabinet type solar dryer in both the winter and summer.

The above ANOVA tables are showing that, in both the solar drying method, F. Cal. Value is higher than the F. Tab. value at 5% significant level on their respective d.f. due to crop and due to season. The above tables are also showing significant difference ($p \le 0.05$) between different treatments. For the all-selected vegetable crops (Mint Leaves, Potato Slices & Green Chili) the drying efficiency of solar tunnel dryer is greater than cabinet type solar dryer for both winter and summer seasons. For the both solar drying methods, all the selected vegetable crops has higher thermal efficiency in summer season than winter season.

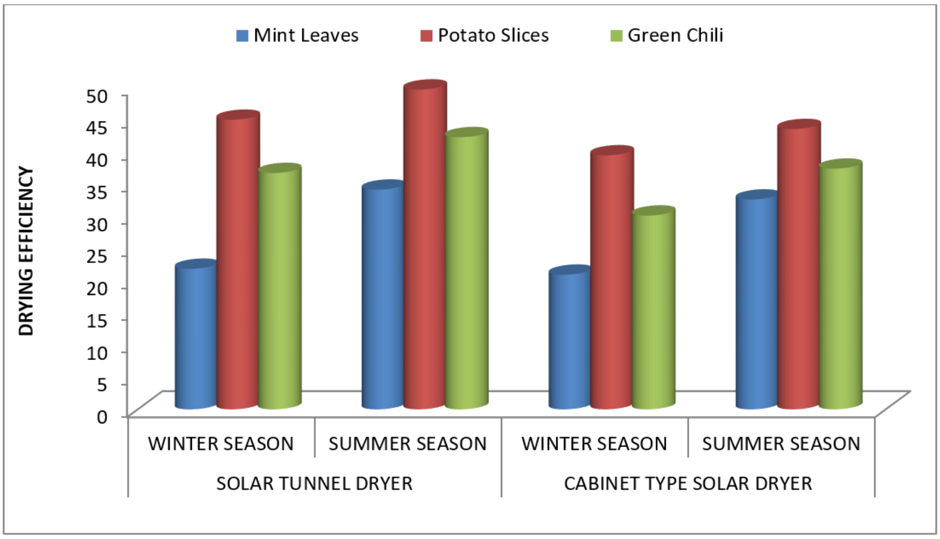

Fig 2: Drying efficiency of mint leaves, potato slice and green chili in solar tunnel dryer and cabinet type solar dryer

Conclusion

The aforementioned ANOVA tables show that for their respective d.f. owing to crop and due to season, the F. Cal. Value is bigger than the F. Tab. Value at the 5% level of significance. Additionally, a statistically significant difference ($p \le 0.05$) between various therapies is shown in the aforementioned tables. For all of the selected vegetable crops (Mint Leaves, Potato Slices, and Green Chili), the thermal efficiency of solar tunnel dryer is greater than cabinet type solar dryer in both the winter and the summer. The above ANOVA tables are showing that, in both the solar drying method, F. Cal. Value is higher than the F. Tab. value at 5% significant level on their respective d.f. due to crop and due to season. The tables are also showing significant difference ($p \le 0.05$) between different treatments. For the all-selected vegetable crops (Mint Leaves, Potato Slices & Green Chili) the thermal efficiency of solar tunnel dryer is greater than cabinet type solar dryer for both winter and summer seasons. In the case of both solar drying methods, all the selected vegetable crops have higher thermal efficiency in summer season than winter season. The aforementioned ANOVA tables demonstrate that, at the 5% level of significance, the F. Cal. Value is greater than the F. Tab. Value for their respective d.f. due to crop and due to season. The aforementioned tables also demonstrate a statistically significant difference ($p \le 0.05$) between various treatments. The drying efficiency of a sun tunnel dryer is superior to a cabinet type solar dryer for all of the vegetables that were chosen (Mint Leaves, Potato Slices, and Green Chili) in both the winter and summer. The aforementioned ANOVA tables show that for their respective d.f. owing to crop and due to season, the F. Cal. Value is bigger than the F. Tab. Value at the 5% level of significance. Additionally, a statistically significant difference ($p \le 0.05$) between various therapies is shown in the aforementioned tables. For all of the veggies selected (Mint Leaves, Potato Slices, and Green Chili), the drying efficiency of a sun tunnel dryer is superior to a cabinet type solar dryer in both the winter and summer. The ANOVA tables are showing that, in both the solar drying method, F. Cal. Value is higher than the F. Tab. value at 5% significant level on their respective d.f. due to crop and due to season. The tables are also showing significant difference ($P \le 0.05$) between different treatments. For the all-selected vegetable crops (Mint Leaves, Potato Slices & Green Chili) the drying efficiency of solar tunnel dryer is greater than cabinet type solar dryer for both winter and summer seasons. For the both solar drying methods, all the selected vegetable crops have higher thermal efficiency in summer season than winter season.

References

1. Asnaz MSK, Dolcek AO. Comparative performance study of different types of solar dryers towards sustainable agriculture. Energy Reports. 2021;7:6107-6118.
2. Bala BK, Mondol MRA. Experimental investigation on solar drying of fish using solar tunnel dryer. Drying technology. 2001;19(2):427-436.
3. Chavan BR, Yakupitiyage A, Kumar S. Drying performance, quality characteristics, and financial evaluation of Indian Mackerel (Rastrilliger kangurta) dried by a solar tunnel dryer. Science & Technology Asia; c2011. p. 11-25.
4. Kaur S, Kumar S, Bhat ZF, Kumar A. Effect of pomegranate seed powder, grape seed extract and tomato powder on the quality characteristics of chicken nuggets. Nutrition & Food Science; c2015.
5. Munir A, Sultan U, Iqbal M. Development and performance evaluation of a locally fabricated portable solar tunnel dryer for drying of fruits, vegetables and medicinal plants. Pakistan Journal of Agricultural Sciences, 2013, 50(3).

6. Naing TT, Soe CT. Comparative analysis of the performance of cabinet solar dryer and open sun drying for Banana slices. In IOP Conference Series: Materials Science and Engineering 2021;1127(1):012015. IOP Publishing.
7. Singh D, Mishra S, Shankar R. Experimental investigation and drying kinetics of mixed type solar dryer with thermal energy storage material for drying of apple slices. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 2022;44(2):4763-4782.
8. Sreekumar A, Manikantan PE, Vijayakumar KP. Performance of indirect solar cabinet dryer. Energy Conversion and Management. 2008;49(6):1388-1395.
9. Visavale GL. Principles, classification and selection of solar dryers. Solar drying: Fundamentals, Applications and Innovations, Ed. Hii, CL, Ong, SP, Jangam, SV and Mujumdar, AS, Published in Singapore; c2012. p.1-50.