The Pharma Innovation Journal 2022; 11(7): 2381-2387

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 2381-2387

www.thepharmajournal.com
Received: 01-05-2022
Accepted: 07-06-2022

Sachin SB
M.Tech., Department of Agricultural Engineering, University of Agricultural Sciences, Bangalore, Karnataka, India

Darshan MB
Assistant Professor, College of Agricultural Engineering, GKVK Campus, University of Agricultural Sciences, Bangalore, Karnataka, India

Palanimuthu V
Professor, College of Agricultural Engineering, GKVK Campus, University of Agricultural Sciences, Bangalore, Karnataka, India

Mohan Kumar TL
Assistant Professor, College of Agriculture, GKVK Campus, University of Agricultural Sciences, Bangalore, Karnataka, India

Jayashree GC
Assistant Professor, College of Agricultural Engineering, GKVK Campus, University of Agricultural Sciences, Bangalore, Karnataka, India

Corresponding Author:
Sachin SB
M.Tech., Department of Agricultural Engineering, University of Agricultural Sciences, Bangalore, Karnataka, India

An experimental study on hybrid drying of *Simarouba glauca* leaves

Sachin SB, Darshan MB, Palanimuthu V, Mohan Kumar TL and Jayashree GC

Abstract
Antibacterial, anticancer, antifungal, antimicrobial, antioxidant and other properties of *Simarouba glauca* leaves were well interested in the research area. An attempt to dry the leaves of *Simarouba* with the conventional resources have not been reported well. The experiment was carried out with six different drying methods; shade, sun, tray, solar, biomass and hybrid drying of pharmaceutically important *Simarouba glauca* leaves. The results showed that product was dried under falling rate period. Temperature affected the drying time, final moisture content and colour value of dried product. Time of solar radiation exposed to the product affected total phenolics and total flavonoids. Tray, Solar, biomass and hybrid drying methods resulted with significantly lower drying time as compared to shade and sun drying. Hybrid mode of drying resulted with 20 h of total drying time including 8 h of solar energy based drying and remaining with the help of biomass energy. Around 60% of moisture was removed by biomass energy drying during hybrid drying. Hybrid drying also retained colour and phytochemicals (Phenolics and flavonoids) as well. Thus, hybrid drying would be the promising method for drying of temperature sensitive materials with conventional energies as a heat source for drying air.

Keywords: *Simarouba glauca*, hybrid drying and drying characteristics

1. Introduction
Simarouba glauca (Family: Simaroubaceae), also known as 'Paradise Tree' or 'Laxmitaru' in India is receiving great interest due to its pharmaceutically importance. A promising medicinal herb contains alkaloids, flavonoids, phenolic compounds and saponins (Sharanya *et al*., 2016) [30]. The leaves of *Simarouba glauca* possesses antibacterial, anticancer, antifungal, antimicrobial and antioxidant properties (Jangale *et al*., 2012; Osagie-Eweka *et al*., 2016; Rajurkar, 2011; Santhosh *et al*., 2016; Umesh, 2015) [14, 24, 26, 28, 33].

Importance of extracted bioactive compounds is been increased by the consumers. Since, it is to be dried prior to extract, the essentiality to study the drying characteristics is increased. Akpinar (2010) [2] investigated solar cabinet and open sun thin-layer drying characteristics of mint leaves. The effect of different drying methods on the quality charcateristics of curry leaves were investigated by Kenghe *et al*. (2015) [17]. Kaya and Aydin (2009) [1] studied the drying kinetics of nettle and mint leaves for thin layer drying characteristics in a convective dryer.

The leaves of *Simarouba glauca* were reported to be dried prior to extraction in Gurupriya *et al*. (2017), Jangale *et al*. (2012), Manasa *et al*. (2019), Mikawlrawng *et al*. (2014), Osagie-Eweka *et al*. (2016) and Santhosh *et al*. (2015) [10, 14, 19, 21, 24, 28]. There is no such an evidence on investigation of drying characteristics of *Simarouba glauca* leaves. Therefore, the recent experiment has been conducted on thin-layer and bulk drying of *Simarouba glauca* leaves. Three different thin-layer drying; sun drying, shade drying and tray drying were performed. The unpublished solar-cum-biomass energy hybrid dryer developed at ICAR - AICRP on PHET, UAS-Bangalore were used to facilitate the bulk drying of leaves. The study observed different drying characteristics as well as physico-chemical properties of *Simarouba glauca* leaves.

2. Materials and Methods
2.1 Raw Materials
Diseases free healthy leaves of *Simarouba glauca* were harvested from the campus of UAS-B, GKVK, Bengaluru. Well matured leaves were washed with normal tap water and drained well before drying. Parameters were measured with the help of analytical grade chemicals and reagents.

2.2 Drying of *Simarouba glauca* leaves

Thin layer drying of leaves were performed with sun drying, shade drying and tray drying. Sun drying was performed by exposing 15 trays, each having 500 g sample to direct solar radiation in open plot. Shade drying was carried at shaded open area by spreading thin layer of leaves in trays. Tray drying of leaves was carried out in tray dryer (Make: Macro Scientific Works Pvt. Ltd., Delhi, India). All the three thin layer drying were maintained with 10 mm thickness of sample. Temperature for tray drying was set 55 ℃. Weight of the sample was taken until constant weight achieved.

About 7.5 kg of sample was treated in solar-cum-biomass energy hybrid dryer for solar, biomass and hybrid drying. The loaded sample was exposed to solar radiation during day time for solar drying. For biomass drying, the biomass was fuelled to heat the drying air. Briquettes were used as a firing biomass at feed rate of 2 kg/h. In hybrid drying, solar and biomass, both the energies were used to heat the drying air. During bright sun-shine hours, the dryer with sample was exposed to solar radiation. During bad weather or night, biomass was fired as similar in biomass drying.

Drying performance was evaluated based on drying rate (DR) and moisture ratio (MR) for different drying methods. Air properties, such as temperature and relative humidity were measured for ambient air, drying air and exhaust air.

2.2.1 Drying rate

Drying rate was expressed as kg of water removed per kg of dry matter per hour. Quantity of evaporated water from leaves was measured and plotted against drying time. Drying rate (DR) was calculated using following equation (Kamble and Dombale, 2015) [16].

2.2.2 Moisture ratio

As described by Kamble and Dombale (2015) [16], moisture ratio (MR) was calculated with the help of following equation. Moisture content, M was measured at definite interval of time from initial, M_o to until product reached equilibrium moisture content, M_e.

2.3 Quality Parameters of *Simarouba glauca* Leaves

2.3.1 Colour

Colour of the leaves was measured with the help of spectrophotometer (Make: Konica Minolta Instrument, Osaka, Japan; Model - CM5). Instrument was calibrated prior to measurement. Piece of the leaf was measured in L* a* b* coordinate system and replicated for higher accuracy. L*, a* and b* values indicates lightness, greenness (-) or redness (+) and blueness (-) or yellowness (+), respectively. Colour of the leaves after drying was compared with fresh leaves. Total colour difference (ΔE*) was calculated using Hunter-Scotield equation (Spada *et al*., 2012) [32].

2.3.2 Total Phenols

Total phenol content of leaves were measured in terms of mg Gallic Acid Equivalents per 100 g of sample (Singleton and Rossi, 1965). One gram of sample was crushed and extracted using 20 ml of 80% methanol and repeated twice. The volume of the extract was made up to 50 ml from pooled extract. 0.5 ml of extract and 0.2 ml of Folin Ciocalteu Reagent (FCR) were added in test tube. The solution was mixed thoroughly after adding 3.3 ml of distilled water. One ml of sodium carbonate solution was added after 2 minutes. Incubate the solution at room temperature for 30 minutes. The blue colour intensity was measured at 700 nm with the help of spectrophotometer (Make: Systronics, Model: UV-VIS 118). Standards were prepared using gallic acid.

2.3.3 Total flavonoids

Total flavonoids (mg Quercetin equivalents /100 g) present in *simarouba* leaves were estimated by Chun *et al*. (2003) [8]. Quercetin was taken as a standard. The samples were extracted using methanol. One ml of extract was taken and diluted with 80% methanol. In extract, 0.3 ml of $NaNO_2$ (5%) was added twice at 2 minutes interval. 3.4 ml of 4 N NaOH was added after 2 minutes and incubated the mixture for 10 minutes at room temperature. Absorbance of brick red colour solution was taken at 510 nm.

2.4 Statistical analysis

One-way Analysis of Variance (ANOVA) was used to analyse the effect of drying methods on draying rate and quality parameters; colour, total phenols and total flavonoids of dried product. Parameters were analysed at 5% of significance and data are represented as the mean value of thrice.

3. Results and Discussion

3.1 Drying of *Simarouba glauca* leaves

3.1.1 Shade drying

Drying rate for shade drying of *Simarouba glauca* leaves was observed at an interval of 2 h and presented in Figure 1 (A). Rate of drying was decreased from first day to consecutive days. The drying time was observed 56 h. Moisture ratio was decreased with time (Figure 2 (A)). Drying was observed at higher rate during the noon hours as the temperature of ambient air was higher. Temperature of drying air was 3.3 ºC lower than the ambient air temperature. The average temperature and relative humidity was observed 28.5 ºC and 33.7%, respectively. The time required to dry the *Vernonia amygdalina* leaves under the shade drying was observed 58 h at an ambient air temperature of maximum 30.07 ºC at 14:00 h noon (Alara *et al*., 2018) [3]. The moisture ratio was decreased from the initial stage indicated that there was no constant rate of drying. Mishra *et al.* (2012) [22] studied the drying of *Moringa* leaves under shade, which resulted drying time of 96 h at a room temperature.

3.1.2 Sun drying

Sun drying was carried out under bright sun-shine hours. The exposer period for the sample was from 09:00 a.m. to 05:00 p.m. during a day. The drying time was observed 32 hours included 16 h of lack of bright sunshine hours. Decrease in drying rate and moisture ratio was observed higher during the initial stage. At night, moisture loss was almost zero. The average ambient temperature was observed 30.2 ºC with lower relative humidity of 29.2% during recoding time. Drying rate and moisture ratio for sun drying of *Simarouba glauca* leaves were presented in Figure 1 (B) and Figure 2 (B), respectively. As the drying temperature was higher in sun drying as compared to shade drying, drying time was reduced by 24 h. The maximum temperature was observed 35.7 ºC at 01:00 p.m. noon. Arslan and Ozcan, 2008 [5] reported that the moisture content at initial stage was higher which resulted in higher drying rate due to higher moisture diffusion. Rosemary leaves were dried in 12 h for final moisture of 11.86% w.b.

under the sun drying.

3.1.3 Tray drying

The drying temperature for tray drying was set 55 ºC for *Simarouba glauca* leaves. Drying rate was decreasing uniformly due to constant drying temperature (Figure 1 (C)). The total drying time was observed 14 h to reduce the moisture up to the desired level. Figure 2 (C) showed the decrease in moisture ratio for different time intervals during the drying. Kenghe *et al.*, 2015 [17] reported that the curry leaves dried at 55 ºC in tray dryer resulted with 27% less time as compared to shade and sun drying. It resulted with higher retention of green colour and good consumer preference. The moisture ratio reduced exponentially with the increase in drying time. Continuous decrease in moisture ratio shows the diffusion has governed by internal mass transfer. The similar results were reported by Premi *et al*. (2012) [25].

3.1.4 Solar drying

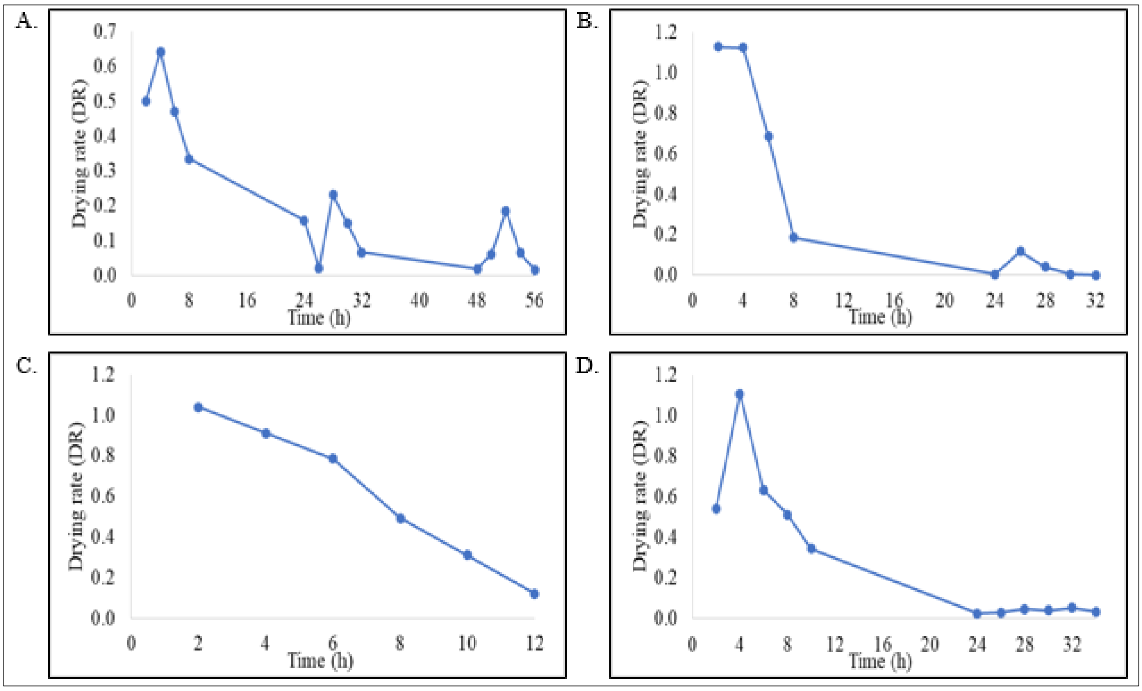
Solar-cum-biomass energy hybrid dryer was used for solar drying of *Simarouba glauca* leaves during 09:00 a.m. to 07: 00 p.m. for a day and drying rate and moisture ratio was observed (Figure 1 (D) and Figure 2 (D)). From the total drying time 32 h, 14 h of night were non-recording hours during the experiment. The maximum temperature was achieved 41.1 °C with an average drying temperature 34.8 °C during recording time. The difference between ambient air and drying air temperature was observed 5.9 °C. There was 3.2 °C decrease in temperature of drying air at the exhaust. Sengar *et al.* (2018) [29] reported that the temperature of 46.6 °C was observed in solar dryer with an ambient temperature of 28.5 °C. It was observed around 17 h of time for drying of sargava, henna, tulsi and neem leaves for final moisture content of around 10%. The drying rate was observed in similar manner.

3.1.5 Biomass drying

Briquettes were used as a firing fuel in dryer to heat the drying air. The feed rate was 2 kg/h maintained for 18 h of drying. The temperature of drying air (45.8 °C) was observed constant after initial lag period of 30 minutes. The temperature gradient between ambient air and drying air was 11.4 °C that lower drying time as compared to other pervious methods. The moisture loss was observed higher due to higher drying air temperature (Figure 1 (E)). Figure 2 (E) showed the uniformity in decrease of moisture ratio as the constant drying air temperature. Geramitchioski *et al.* (2011) [9] reported that around 60 °C of drying air temperature could be achieved with the feed rate of 4 kg wood briquettes per hour. Decrease in the moisture content in biomass drying was similar to tray drying operation due to the constant temperature. Similar trend of temperature with biomass drying of fish was observed by Yuwana and Sidebang (2016) [36] during performance evaluation of solar-biomass dryer.

3.1.6 Solar-cum-biomass (Hybrid) drying

Drying of *Simarouba glauca* leaves was ensured continuously for 20 h with solar drying and biomass drying. The average temperature during experiment was observed 43.2 °C. The temperature difference between drying and ambient air was 17.9 °C. As showed in Figure 1 (F), the drying rate was not uniform with time as the two energies were used alternatively during an experiment. Figure 2 (F) showed the moisture ratio during hybrid drying. Approximately, 30.7% of total moisture was removed in 8 h by solar drying and remaining 69.3% was removed in 12 h with the help of biomass energy. Andrew *et al*. (2013) reported that additional biomass burner with solar dryer allowed continuous drying process at night and during wet seasons. It shortened the drying time to a single day drying. Bena and Fuller (2002) [7] reported that 53% of moisture of total removed moisture was removed by biomass energy. The drying time was observed 24 to 32 h to complete empty fruit bench (EFB) drying under hybrid drying mode (Al-Kayiem and Yunus, 2013) [4]. It resulted combined resources were effectively enhanced the drying performance.



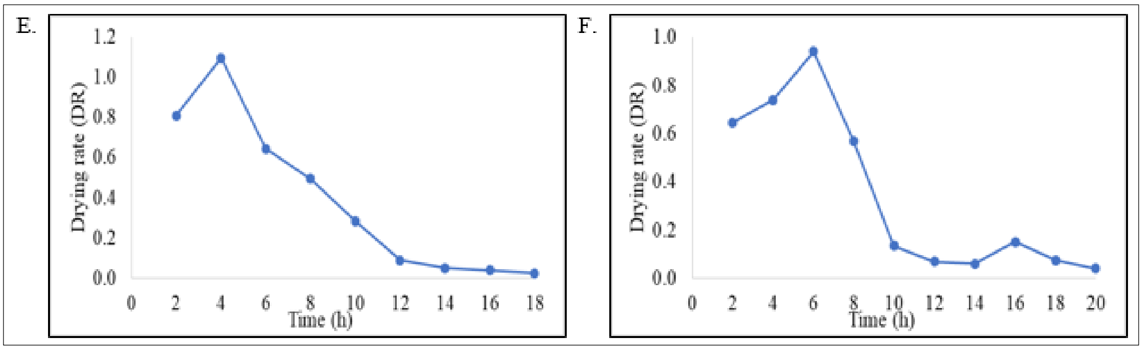
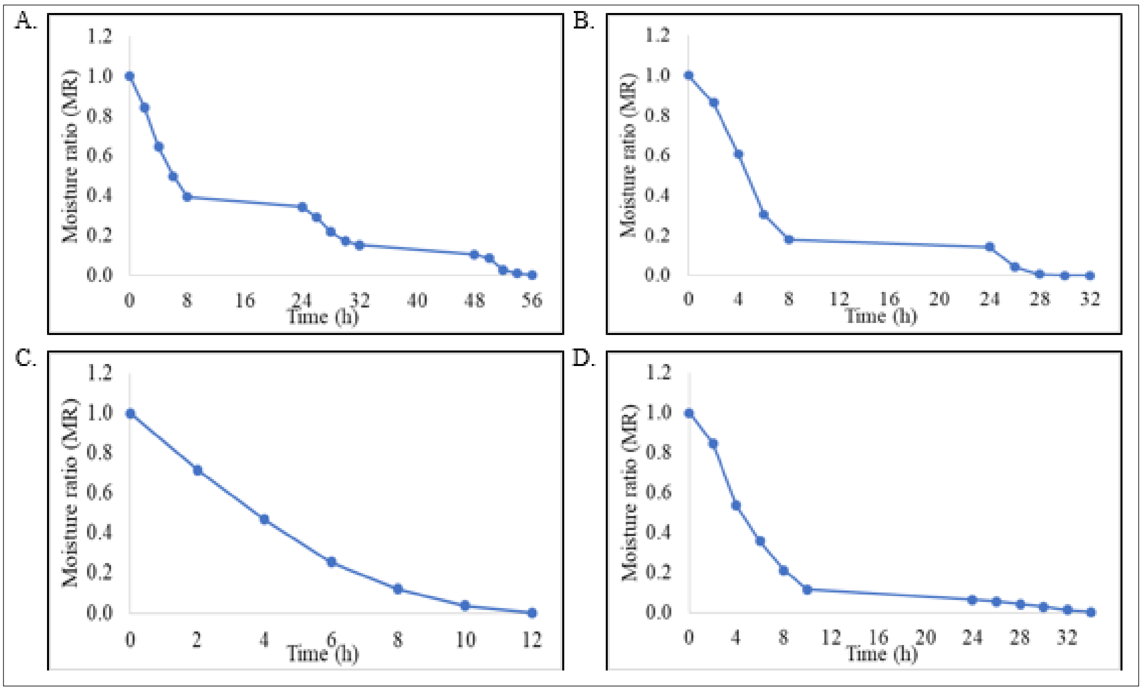


Fig 1: Drying rate (DR) of simarouba leaves; A: Shade drying; B: Sun drying; C: Tray drying; D: Solar drying; E: Biomass drying; F: Hybrid drying3.2 Drying parameters for thin-layer and bulk drying of simarouba leaves

Average drying air temperature for recording hours during different drying methods was presented in Table 3.1 along with total drying time, average drying rate and final moisture content. The dying air temperature was significantly different in all the methods except sun and shade drying. Shade drying temperature was 1.7 ℃ lower than sun drying method. The temperature in the dryer was higher than the ambient air temperature. Solar drying and biomass drying method resulted with temperature difference of 11 °C, whereas hybrid drying method resulted with 2.6 ℃ higher than biomass drying method. The results were compatible with drying time. Total drying time (14 h) was lowest in tray drying as it resulted with highest drying air temperature (55 °C). Lower drying time was 18 h in biomass drying resulted due to the higher temperature of drying air as compared to solar and hybrid drying. As hybrid drying method performed with the combination of solar and biomass drying, total time of drying was not significantly different from biomass drying. The drying time in hybrid drying was reduced by 41% as compared to solar drying which is highly significant. A difference in drying time was observed with different drying methods as the temperature of the drying was different (Bahloul *et al*., 2009; Akpinar, 2010; Janjai, 2012; Kenghe *et al.*, 2015; Yahya, 2016, Vaghela *et al*., 2018) [6, 2, 15, 17, 35].

Drying rate was highest in tray drying (0.3307 kg/kg$_d$.h), followed by biomass drying (0.2536 kg/kg$_d$.h), hybrid drying (0.2254 kg/kg$_d$.h) and sun drying (0.1457 kg/kg$_d$.h). The lowest drying rate was observed in shade drying (0.0810 kg/kg$_d$.h). The results were compatible with drying time and drying air temperature. As the temperature of drying increased, the drying rate was also increased. Okoroigwe *et al.* (2013) [23] reported 0.0142 kg/h and 0.000732 kg/h for drying of yam chips under hybrid and solar drying. The rate of drying was increased with increase in drying temperature (Lakshmi *et al*., 2019) [18]. The final moisture content of product was statistically same in all the drying methods. Approximately 10% of final moisture content was achieved. Mint leaves were observed with 8.33% moisture content at the end of 10 h under solar drying (Hunashikatti *et al.*, 2022) [12]. Imbabi *et al.* (2016) [13] reported that the final moisture content of basil leaves were reached 1.032% to 12.72% depending upon the temperature of solar dryer. Briquettes used in hybrid drying and biomass drying was 24 kg and 36 kg, respectively. Fuel requirement for hybrid drying was 33% lower than biomass drying.



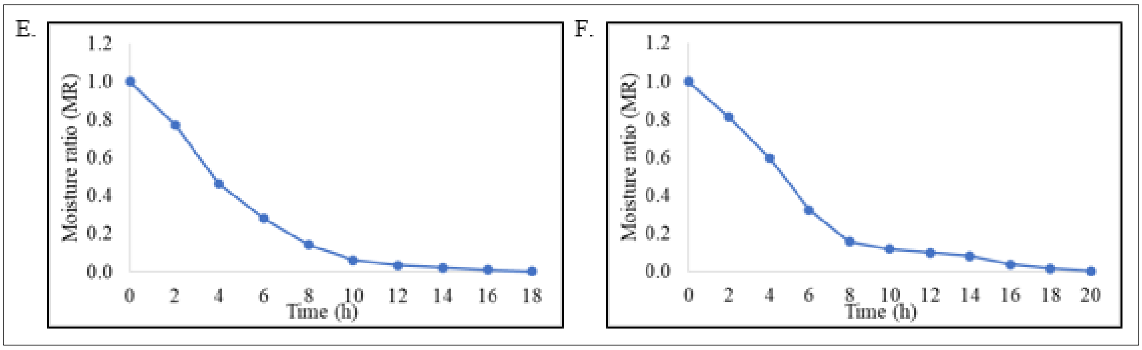


Fig 2: Moisture ratio (MR) during drying of simarouba leaves; A: Shade drying; B: Sun drying; C: Tray drying; D: Solar drying; E: Biomass drying; F: Hybrid drying

Table 1: Drying parameters for thin-layer and bulk drying of simarouba leaves

Treatment	Drying air temperature (℃)	Time (h)	Drying Rate (kg/kg$_d$.h)	Final MC (% w.b.)
Shade drying	28.5^e	56^a	0.0810^f	10.38^a
Sun drying	30.2^e	32^b	0.1457^d	9.06^a
Tray drying	55.0^a	14^d	0.3307^a	7.56^a
Solar Drying	34.8^d	34^b	0.1318^e	10.57^a
Biomass Drying	45.8^b	18^{cd}	0.2536^b	9.83^a
Hybrid drying	43.2^c	20^c	0.2254^c	10.71^a
SEM	0.59	1.33	0.003	0.505
CD at 5%	1.83	4.11	0.008	1.557
C.V. (%)	2.61	7.96	2.242	9.035

3.3 Effect on colour, total phenols and total flavonoids of *simarouba* leaves

The ΔE* colour value varied with the different drying methods as the temperature was different (Table 3.2). As the temperature of drying was higher, it resulted in degradation of green colour and imparted yellow colour for the leaves. Lower temperature difference between drying air and ambient air was observed with lower change in the colour value of dried leaves as compared to fresh *simarouba* leaves. The change in colour was also affect by direct exposure of solar radiation to the product. Colour was more affected by solar radiation than temperature. Sun and solar drying methods were observed with higher effect on ΔE* value, 29.97 and 29.04, respectively as compared to other methods. The change in colour is related to degradation of chlorophyll pigment degradation and browning reactions. The open sun drying was observed with higher ΔE* value than solar drying (Rehman and Rubab, 2020) [27].

Total phenols was observed highest in shade drying (306.20 mg GAE/g), followed by hybrid drying (282.10 mg GAE/g). The lowest total phenol content was observed 206.81 mg GAE/g for sun drying. However, the change in total phenol was not significantly different in all the methods. Total phenolic content was affected by time of drying and light exposure. Higher drying time and light exposure led to oxidation of phenolic compounds (Bahloul *et al*., 2009) [6]. Total phenolic content was observed higher in fresh leaves as compared to shade dried leaves (Manasa *et al*., 2019) [19].

Total flavonoids were observed in range of 139.39 to 198.14 mg Quercetin/g in all the drying methods. The data was not significantly different. However, the change in total flavonoid content was observed due to temperature of drying and oxidation of compounds due to air and light exposure time. Hybrid drying retained about 74.65% and 76.84% of total phenols and total flavonoids, respectively as compared to fresh leaves. Higher temperature with lower time of drying in biomass drying resulted with higher total flavonoids. Higher exposure of solar radiation and higher time of drying observed with higher degradation of flavonoids. Similar trend was found in change of flavonoid content by Mansour (2016) [20]. Hidar *et al*. (2020) [11] observed that the retention of total flavonoid content was lower with increase in temperature of drying and air flow rate for solar convection drying of stevia leaves.

Table 2: Quality parameters of dried simarouba leaves

Treatment	Colour difference (ΔE*)	Total phenols (mg GAE/g)	Total flavonoids (mg Quercetin/g)
Shade drying	23.00^b	306.20^a	198.14^a
Sun drying	29.97^a	206.81^a	139.39^a
Tray drying	24.35^b	231.56^a	140.79^a
Solar drying	29.04^a	254.97^a	152.91^a
Biomass drying	24.04^b	275.48^a	193.01^a
Hybrid drying	27.03^a	282.10^a	194.87^a
SEM	0.74	17.133	14.132
CD at 5%	2.29	52.792	43.544
C.V. (%)	4.193	11.435	14.411

4. Conclusion

Simarouba glauca leaves, having specific properties, are important to dry in a manner to preserve its properties. Renewable resources like solar radiation and biomass are prominent energy sources for drying with preservation of phytochemicals and other components. Total drying time for the bulk drying with the help of hybrid dryer was lower than drying under conventional methods. Drying time was inversely proportional to drying temperature. Highest drying temperature was recorded in tray drying (55 ℃), which resulted with lowest drying time of 14 h followed by biomass drying (18 h). Colour and phytochemicals; total phenol and flavonoid content was well retained with lower drying temperature as well as less or no direct exposure of solar radiation. *Simarouba* leaves were dried in 20 h at 43.2 ℃ of average drying air temperature obtained by solar and biomass energy as a heating sources. Hybrid drying mode would be effective in terms of retaining the quality of the product and increase in the performance of drying operation. It consumed 33% less fuel for biomass energy, which was replaced by solar energy during bright sun-shine hours. Hybrid drying would be promising method that overcomes the shortcomings of mechanical drying and conventional drying.

5. References

1. Kaya A, Aydın O. An experimental study on drying kinetics of some herbal leaves. Energy Conversion and Management. 2009;50(1):118-124.
2. Akpinar EK. Drying of mint leaves in a solar dryer and under open sun: Modelling, performance analyses. Energy conversion and management. 2010;51(12):2407-2418.
3. Alara OR, Abdurahman NH, Mudalip SK, Olalere OA. Mathematical modeling of thin layer drying using open sun and shade of *Vernonia amygdalina* leaves. Agriculture and Natural Resources. 2018;52(1):53-58.
4. Al-Kayiem HH, Yunus YM. Drying of EFB by hybrid solar/biomass thermal backup. International Conference on Mechanical Engineering Research (ICMER2013), Pahang, Malaysia. 2013.
5. Arslan D, Özcan MM. Evaluation of drying methods with respect to drying kinetics, mineral content and colour characteristics of rosemary leaves. Energy Conversion and Management. 2008;49(5):1258-1264.
6. Bahloul N, Boudhrioua N, Kouhila M, Kechaou N. Effect of convective solar drying on colour, total phenols and radical scavenging activity of olive leaves (*Olea europaea* L.). International journal of food science & technology. 2009;44(12):2561-2567.
7. Bena B, Fuller RJ. Natural convection solar dryer with biomass back-up heater. Solar energy. 2002;72(1):75-83.
8. Chun OK, Kim DO, Moon HY, Kang HG, Lee CY. Contribution of individual polyphenolics to total antioxidant capacity of plums. Journal of Agricultural and Food Chemistry. 2003;51(25):7240-7245.
9. Geramitchioski T, Mitrevski V, Vilos I, Trajcevski L. A new construction of a mobile combine dryer. Scientific proceedings xix international scientific-technical conference trans & MOTAUTO, 2011, 11.
10. Gurupriya S, Cathrine L, Ramesh J. Qualitative and quantitative phytochemical analysis of *Simarouba glauca* leaf extract. International Journal for Research in Applied Science and Engineering Technolog. 2017;5(11):475-479.
11. Hidar N, Ouhammou M, Mghazli S, Idlimam A, Hajjaj A, Bouchdoug M *et al*.. The impact of solar convective drying on kinetics, bioactive compounds and microstructure of stevia leaves. Renewable Energy. 2020;161:1176-1183.
12. Hunashikatti PT, Ramaswwamyreddy S, Sethia PM, Goyal S, Rohan SK, Raj S. Experimental studies on thin-layer drying of mint leaves in a solar dryer and under open sun. Current Science, 2022, 122(9).
13. Imbabi AT, Abdel-Galil HS, Abdel-Kader T. Design, construction and performance evaluation of a solar drying unit of basil leaves. Misr Journal of Agricultural Engineering. 2016;33(1):75-100.
14. Jangale BL, Ugale TB, Aher PS, Toke NR, Shivangikar AN, Sanap NT. Antibacterial activity of *Simarouba glauca* leaf extracts against food borne spoilage and pathogenic microorganisms. International Journal of Pharmaceutical Sciences and Research. 2012;3(2):497.
15. Janjai S. A greenhouse type solar dryer for small-scale dried food industries: Development and dissemination. International journal of energy and environment. 2012;3(3):383-398.
16. Kamblea AK, Dombaleb RL. Preparation of ready to use powder from tomato using solar cabinet dryer integrated with heat storage system. Journal of Ready to Eat Food. 2015;2(1):06-17.
17. Kenghe R, Jadhav M, Nimbalkar C, Kamble T. Effect of drying methods on quality characteristics of curry (*Murraya koenigii*) leaves. International Journal of Environmental and Agriculture Research. 2015;1(5):8-12.
18. Lakshmi DV, Muthukumar P, Layek A, Nayak PK. Performance analyses of mixed mode forced convection solar dryer for drying of stevia leaves. Solar Energy. 2019;188:507-518.
19. Manasa M, Palanimuthu V, Darshan MB, Suresha KB, Munishamanna MK. Proximate and phytochemical analysis of an anticancerous *Simarouba glauca* leaves. Journal of Pharmacognosy and Phytochemistry. 2019;8(3):4224-4227.
20. Mansour R. Effects of drying process on total phenolics, and flavonoids content of thyme vulgaris extract. International Journal of Chem Tech Research. 2016;9:632-638.
21. Mikawlrawng K, Kaushik S, Pushker A, Kumar S, Kameshwor M, Sharma G. Comparative *in vitro* antifungal activities of *Simarouba glauca* against *Fusarium oxysporum* and *Aspergillus parasiticus*. Journal of Medicinal Plants Studies. 2014; 2:1-7.
22. Mishra SP, Singh P, Singh S. Processing of *Moringa oleifera* leaves for human consumption. Bulletin of Environment, Pharmacology and life sciences. 2012;2(1):28-31.
23. Okoroigwe EC, Eke MN, Ugwu HU. Design and evaluation of combined solar and biomass dryer for small and medium enterprises for developing countries. International Journal of Physical Sciences. 2013;8(25):1341-1349.
24. Osagie-Eweka SD, Orhue NJ, Ekhaguosa DO. Comparative phytochemical analyses and *in-vitro* antioxidant activity of aqueous and ethanol extracts of *Simarouba glauca* DC (Paradise Tree). European Journal of Medicinal Plants, 2016, 13(3).
25. Premi M, Sharma H, Upadhyay A. Effect of air velocity and temperature on the drying kinetics of drumstick leaves (*Moringa oleifera*). International journal of food engineering, 2012, 8(4).
26. Rajurkar BM. A comparative study on antimicrobial activity of *Clerodendrum infortunatum*, *Simarouba glauca* and *Psoralea corylifolia*. International Journal of Research and Reviews in Pharmacy and Applied Sciences. 2011;1:278-282.
27. Rehman S, Rubab S. Effect of solar radiation on the drying parameters of mint (*Mentha spicata* L.) dried in natural convective solar dryer. 2020. https://www.researchsquare.com/ article/rs-117400/v1
28. Santhosh S, Venugopal A, Radhakrishnan MC. Study on the phytochemical, antibacterial and antioxidant activities of Simarouba glauca. South Indian Journal of Biological Sciences. 2016;2(1):119-124.
29. Sengar SH, Burbade RG, Divyesh B, Parmar A. Evaluation of solar tunnel dryer for green leaves drying. Journal of Postharvest Technology. 2018;6(2):38-48.
30. Sharanya, VK, Gayathiri K, Sangeetha M, Shyam Prakash G, Gopi Sudheer Kumar J, Vimalavathini R *et al*. A pharmacological review on *Simarouba glauca* DC.

International Journal of Pharma Research and Review. 2016;5(6):32-36.
31. Singleton VL, Rossi JA. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American journal of Enology and Viticulture. 1965;16(3):144-158.
32. Spada JC, Noreña CP, Marczak LD, Tessaro IC. Study on the stability of β-carotene microencapsulated with *pinhão* (*Araucaria angustifolia* seeds) starch. Carbohydrate Polymers. 2012;89(4):1166-1173.
33. Umesh TG. In-vitro antioxidant potential, free radical scavenging and cytotoxic activity of *Simarouba gluaca* leaves. International Journal of Pharmacy and Pharmaceutical Sciences. 2015;7(2):411-416.
34. Varghese J, Rajamani S, Daniel B. Antimicrobial effect of *Simarouba glauca* (Lakshmi Taru) on opportunistic pathogens in HIV/AIDS patients. IOSR Journal of Pharmacy and Biological Sciences. 2016;11(6):32-39.
35. Yahya M. Design and performance evaluation of a solar assisted heat pump dryer integrated with biomass furnace for red chilli. International Journal of Photoenergy, 2016.
36. Yuwana Y, Sidebang B. Performance testing of the hybrid solar-biomass dryer for fish drying. International Journal of Modern Engineering Research. 2016;6(11):63-68.