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Variation of Environmental Parameters during Drying of Tomato under Low Cost Multipurpose Greenhouse (MGH)

Pramod Rai, Augustine Guria, Md. I.A. Ansari, Chhaya, Suman Tigga

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ABSTRACT

The natural ventilated greenhouse is used for cultivation and or nursery growing but multipurpose greenhouse (MGH) can used even for solar drying and or soil solarization during summer season (March–June). This study was conducted to study the variation of environmental parameters (temperature, relative humidity (RH) and air velocity) during drying of tomato under open field and low cost multipurpose greenhouse (MGH). During the drying of tomato (without blanched (WB) and blanched (B)), the temperature, RH and air velocity in open field varied between 28.67°C to 32.67°C, 42.33% to 52% and 1.2 m/s to 4.93 m/s respectively, whereas the temperature, RH and air velocity under MGH varied between 34.67°C to 39.5°C, 31.33% to 45.67% and 0.3 m/s to 1.1 m/s respectively. The drying time of tomato under open field condition was 29 h and 20 h respectively for WB and B, whereas under MGH condition it was 28.5 h and 19.5 h respectively for WB and B tomato.

Keywords Drying, Tomato, Temperature, Relative humidity, Open field, Greenhouse.

INTRODUCTION

A greenhouse (GH) is a framed structure covered with a transparent material in which crops or nursery is grown under controlled or partially controlled conditions. But due to greenhouse effect, the temperature inside the GH is always more than the open field temperature (Baudoin *et al.* 2013). Rai (2009) conducted study to find out its suitability of low cost natural ventilated GH for round the year cultivation of tomato and capsicum. But the major challenge occurred during summer season when temperature and light intensity was very high. In the Jharkhand conditions ambient temperatures during summer season normally exceeds 33^{0}C, so evaporative cooling is the most efficient means for GH cooling, which can lower the GH temperature below the ambient air temperature (Soussi *et al.* 2022). The high fixed and operating cost of evaporative cooling affects the profitability,

Pramod Rai[1]*, Augustine Guria[2], Md. I.A. Ansari[3], Suman Tigga[5]

[1,3,4]Junior Scientist Cum Assistant Professor
[1,2,3,5]Department of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand 834006, India

Chhaya[4]
College of Agricultural Engineering, Birsa Agricultural University, Kanke, Ranchi, Jharkhand 834006, India

Email: pramod_kgp@yahoo.co.uk
*Corresponding author

sustainability and carbon footprint due to higher energy consumption (Ntinas *et al.* 2020, Maraveas *et al.* 2023).

Drying is a method of food preservation which reduces the moisture content of food materials to enhance its shelf life (Tepe and Kadakal 2022). Though sun drying is very commonly used by farmers during summer season to dry excess produce of tomato, cauliflower, cabbage, mahua, leafy vegetables, fish for their future requirement. The comparison between sun and solar drying was studied and found that solar dryer has higher temperature and lower relative humidity and it reduce spoilage by lowering product moisture faster than sun drying (Umogbai and Iorter 2013). Rai (2019) developed low cost natural ventilated multipurpose greenhouse (MGH) for cultivation of tomato/capsicum and or nursery growing during rainy and winter season (July-February) and for solar drying and or soil solarization during summer season (March-June). Rai (2020) concluded that normally standalone solar dryer (active/passive) are used for drying of food materials but the cost of these solar dryer is very high and it depends upon whether solar dryer is active/passive, types of cladding materials and construction materials. The use of these standalone solar dryer is for very limited period and normally used during summer season. The temperature, relative humidity, air velocity are important factors which affect the drying performance of solar dryer (Kumar *et al.* 2023).

Keeping above points in view, this work was conducted to study the variation of environmental parameters during drying of tomato under low cost MGH. The performance was evaluated by studying the variation of environmental parameters (temperature, relative humidity & air velocity) inside the MGH with time and variation of temperature with time at various locations and efficacy of MGH for drying of tomato.

MATERIALS AND METHODS

Low cost multipurpose greenhouse (MGH)

A low cost MGH was used to study the variation of environmental parameters during drying of tomato and details of design, construction method, materials required and working of developed low cost MGH is given by Rai (2019). The low cost MGH was constructed using bamboo, aluminium profile and spring lock, GI wire, coal tar, waste plastic, nail and cladding materials. The cladding materials used were UV stabilized plastic film (200 micron) and UV stabilized insect proof net (40 mesh). The specification of developed MGH was length: 12 m, width: 6 m, side height: 2 m and central height: 3 m. The both side wall of structure is covered by insect proof net accompanied by plastic film to regulate temperature and relative humidity.

Measurement of environmental parameters

The temperature, relative humidity and air velocity were measured during study period from 06^{th} June to 08^{th} 2018 under open field and MGH. The measurement of environmental parameters (temperature, relative humidity and air velocity) and drying of tomato was conducted under full ventilation (area : 48 m^2).

The dry bulb and wet bulb temperature were recorded using a dry bulb (db) and wet bulb (wb) hygrometer (ZEAL: UK, range: -5^{o}C to 50^{o}C, least count: 1^{o}C) and data were recorded from 8.30 AM to 4.30 PM at 1 h interval. The relative humidity (RH) was calculated using the psychometric chart from recorded data of dry bulb (db) and wet bulb (wb) temperatures. The anemometer (Lutron, AM 4201, India) was used to record the air velocity. The dry bulb, wet bulb temperature and anemometer data were recorded above 1.7 m from ground level at center point both for open field and MGH.

The temperature was also recorded at different location under MGH along the length, width and height using thermometer (Dimple, India). The temperature under MGH was recorded 1.7 m from ground level along the length at three points i.e. at center pole, 3 m east of center pole and 3 m west of center pole, along the width at two points i.e. 1.5 m North and 1.5 m South of the center pole and along the height at three points in center pole i.e. 0.7 m, 1.7 m and 2.7 m from ground level.

Raw material and sample preparation

Fresh tomatoes (Variety : Saksham) were procured from the research farm, BAU, Kanke, Ranchi and the sorting process was carried out manually to remove all the undesirable material. It was washed thoroughly in running water to remove the adhering soil and extraneous matter. The tomatoes were cut into four equal parts by using a stainless steel knife and dipped in sodium metabisulphite (6%) solutions for 5 min (Latapi and Barrett 2006). It was mixed continuously during dipping, drained for 2 min and spread in a steel trays for drying. The initial weight of without balanced (WB) and blanched (B) tomatoes used for drying under both for open field & MGH were 941 g and 947 g respectively.

Determination of quality parameters

Moisture content of fresh tomato sample was determined by drying the samples in hot air oven (Acme Instruments Co, India) at 70°C for 24 hrs (AOAC 1980). The rehydration ratio was determined by the regained moisture from the sample weight difference before and after rehydration (Ranganna 1986). The shrinkage ratio was determined by the ratio of mass of raw material to dried product and dehydration ratio by prepared material to dried product (Ranganna 1979).

RESULTS AND DISCUSSION

Variation of microclimate parameters

The Table 1 shows the variation of mean temperature, relative humidity and air velocity at 1 hr interval from 8.30 AM to 4.30 PM under open field and MGH during the drying periods from 06th June to 08th June 2018. During the experimental periods, the ambient temperature, RH and air velocity in open field varied between 28.67°C to 32.67°C, 42.33% to 52% and 1.2 m/s to 4.93 m/s respectively, whereas the temperature, RH and air velocity under MGH varied between 34.67°C to 39.5°C, 31.33% to 45.67% and 0.3 m/s to 1.1 m/s respectively. It is clear from the tables that there is increase in temperature under MGH in comparison to open field and increase in temperature varies between 5.17°C to 8°C. Due to greenhouse effect, the temperature inside the MGH is always more than the open field and it is due to two different effects i.e. (i) A confinement effect, resulting from the decrease in the air exchanges with the outside environment, and (ii) Low transparency of covering to far infrared radiation (emitted by the crop, the soil and the inner greenhouse elements),

Table 1. Mean temperature, RH and air velocity under open field and MGH during drying.

Time	Temperature (°C)		RH (%)		Air velocity (m/s)	
	Open	MGH	Open	MGH	Open	MGH
8.30 AM	31.00	36.67	50.67	40.33	2.50	0.33
9.30 AM	32.67	38.67	42.33	31.33	2.10	0.33
10.30 AM	31.67	39.50	43.33	32.33	1.20	0.30
11.30 AM	28.67	35.83	48.33	42.67	2.20	0.77
12.30 PM	29.33	37.33	49.33	42.00	4.20	1.10
1.30 PM	30.33	38.00	48.67	38.67	3.07	1.03
2.30 PM	29.67	36.00	48.33	40.00	2.50	0.77
3.30 PM	29.50	34.67	51.67	45.67	2.93	0.70
4.30 PM	29.17	35.50	52.00	44.67	4.93	0.80

Table 2. Temperature at center point in open field and at different locations under MGH during drying.

Time	Temperature (°C) at various location (m)							
	Open	MGH						
	Center (1.7 m)	West (1.7 m)	Center (0.7 m)	Center (1.7 m)	Center (2.7 m)	East (1.7 m)	North (1.7 m)	South (1.7 m)
8.30 AM	31.50	34.83	33.50	34.83	37.33	34.67	33.83	33.67
9.30 AM	33.50	36.00	35.17	36.67	40.83	36.50	35.33	35.50
10.30 AM	32.67	36.50	35.33	36.83	40.67	36.83	36.00	35.67
11.30 AM	30.67	33.17	32.67	33.33	36.83	33.67	33.33	32.33
12.30 AM	32.00	35.33	35.00	36.33	38.67	36.33	34.67	35.33
1.30 PM	32.83	34.67	34.67	35.67	38.00	36.00	34.67	35.00
2.30 PM	32.67	33.67	33.83	34.83	36.33	34.33	33.67	33.50
3.30 PM	32.33	33.67	34.17	33.83	35.00	34.00	33.17	33.17
4.30 PM	31.33	32.17	32.67	33.00	33.17	32.67	32.00	32.00

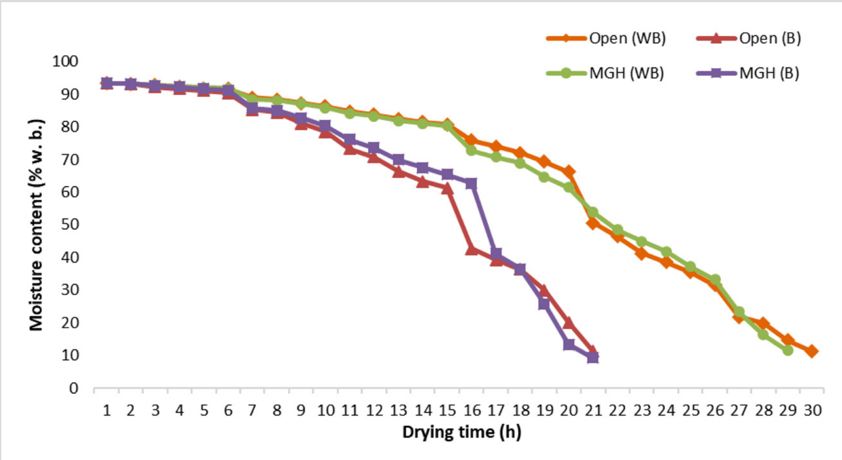

Fig. 1. The variation of moisture content of dried tomatoes during drying.

but its high transparency to sunlight (Baudoin *et al.* 2013). It is reported that increase in temperature under natural ventilated greenhouse varies between 5°C to 10°C in comparison to open field temperature (Badji *et al.* 2022).

It is clear from table that RH under MGH is lower than open field and reduction in RH varies between 5.66% to 11%. The lower RH under MGH is due to increase in temperature under MGH from 5.17°C to 8°C in comparison to open field under constant humidity condition (Korner and Challa 2003).

It is clear from the tables that there is reduction in air velocity under MGH in comparison to open field and air velocity under MGH is 13% to 34% of air velocity recorded under open field. There is substantial reduction in air velocity under MGH in comparison to open field due to insect proof net material (40 mesh) used in covering the side wall of MGH for ventilation (Lopez *et al.* 2022).

Table 3. Final moisture content and drying time of tomato under open field and MGH.

Sl.N0.	Drying methods	Final moisture content (% wb)	Drying time (h)
1	Open field (WB)	11.21	29
2	Open field (B)	11.19	20
3	MGH (WB)	11.54	28.5
4	MGH (B)	9.33	19.5

Variation of temperature with time at various locations

The Table 2 shows the variation of temperature at 1 hr interval from 8.30 AM to 4.30 PM at various locations i.e. along the length, along the width and along the height inside the MGH during the experimental periods (06^{th} June to 08^{th} June 2018).

The variation in temperature along the length for MGH at center pole is between 33°C to 36.83°C, at east of center poleis between 32.67°C to 36.83°C and at west of center pole is between 32.17°C to 36.50°C. The temperature recorded at west pole is 0°C to 1.17°C lower and at East pole it is 0°C to 0.5°C lower than temperature recorded at center pole. But at East pole there is increase

Table 4. Shrinkage ratio, rehydration ratio and dehydration ratio for open field and MGH dried tomato.

Sl.No.	Drying methods	Shrinkage ratio	Rehydration ratio	Dehy-dration ratio
1	Open (WB)	13.5	1.7	13.3
2	Open (B)	14.22	1.8	12.75
3	MGH (WB)	14.48	1.7	12.68
4	MGH(B)	13.99	1.7	12.83

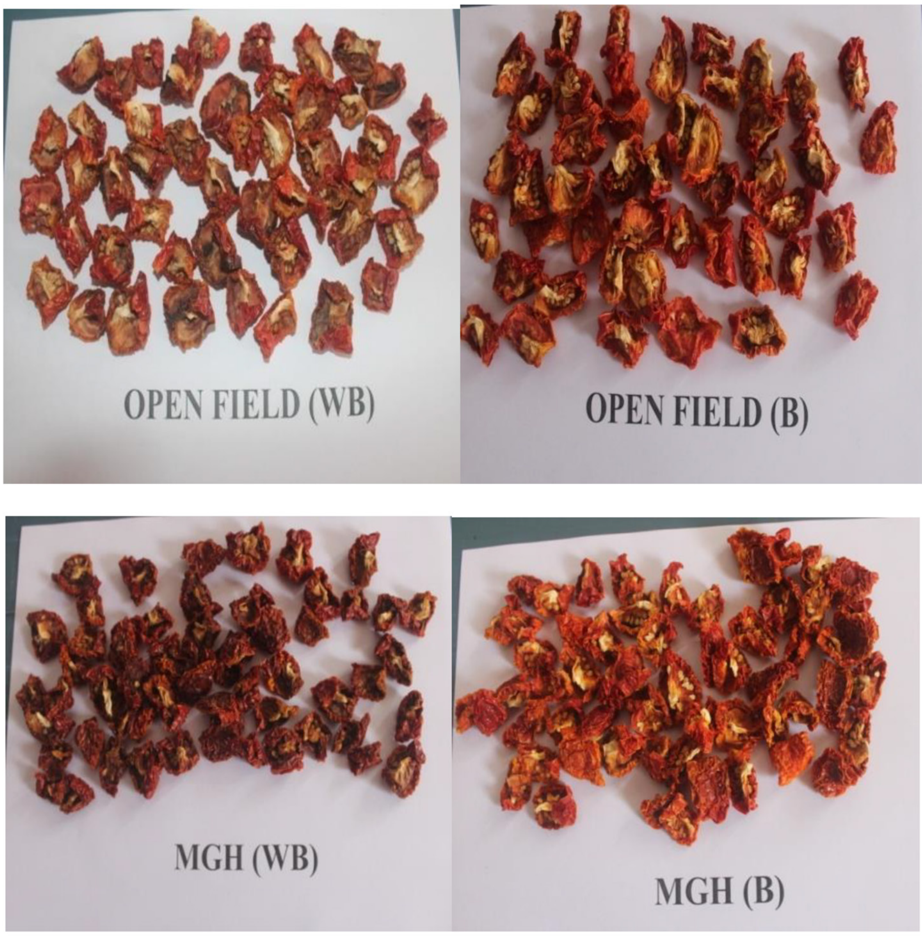

Fig. 2. Dried without blanched and blanched tomato under open field and MGH.

in temperature in comparison to center pole and increase in temperature varies between 0°C to 0.33°C.

The variation in temperature along the width of MGH is found to be between 32°C to 36°C at north point and between 32°C to 35.67°C at south point. There is reduction in temperature recorded both for North and South point in comparison to center pole and reduction in temperature varies between 0°C to 1.67°C at North pole and between 0.67°C to 1.17°C at South pole.

The variation of temperature along the height under MGH is found to be between 32.67°C to 35.33°C at 0.7 m, between 33°C to 36.83°C at 1.7 m and between 33.17°C to 40.83°C at 2.7 m. The highest temperature was recorded at 2.7 m in comparison to temperature recorded at 0.7 m and 1.7 m. There is 0.33°C to 1.5°C increase in temperature at 1.7 m in comparison to temperature recorded at 0.7 m and 0.17°C to 4.1°C increase in temperature at 2.7 m in comparison to temperature recorded at 1.7 m. There is increase in temperature as we move from 0.7 m to 2.7 m. The highest temperature is recorded at 2.7 m at center pole because hot air rose above the cooler air mass due to the density difference and was trapped by the greenhouse roof, resulting in more heat concentration nearer to the roof (Abderrahman *et al.* 2022).

Drying of tomato

The drying of both without balanced (WB) and blanched (B) tomatoes were conducted under both for open field and MGH during the experimental periods (06th June to 08th June 2018). The initial moisture content for all the four tomato samples were 93.33% (wb) and the weights of dried samples were taken at 1 hr interval both for open field and MGH. The variation of moisture content of dried tomato with drying time is shown in Fig. 1 and it is clear that removal of moisture content for blanched tomato is faster than without blanched tomato both for open field and MGH. The drying rate for blanched tomato is higher due to structure softening and celled wall destruction leading to laser resistance to moisture movement during drying (Deng *et al.* 2017).

The variation in moisture content with time during drying is almost constant for initial period of 6 h, which shows the constant drying rate and during this period the removal of moisture from is very fast due to availability of free moisture. The constant drying rate occurs when a film of free water is available at the drying surface for evaporation into the drying medium. After constant drying rate, drying takes place in the falling rate regions and it is indication of an increased resistance to both heat and mass transfer and occur when the surface water no longer exists and water to be evaporated comes from within the structure and must be transported to the surface (Hii *et al.* 2012).

The final moisture content and drying time under both the open field and MGH for without blanched and blanched tomato is shown in Table 3. The final moisture content of tomato for without blanched and blanched under open field condition is 11.21 % (wb) and 11.19 % (wb) respectively, whereas under MGH condition for without blanched and blanched tomato is 11.5 % (wb) and 9.33 % (wb) respectively. Similarly the drying time of tomato for without blanched and blanched under open field condition is 29 h and 20 h respectively, whereas under MGH condition for without blanched and blanched tomato is 28.5 h and 19.5 h respectively. The drying time for blanched tomato is lower than without blanched tomato both under open field and MGH because the drying rate of blanched tomato is higher than without blanched tomato (Deng *et al.* 2017). It is clear from table that though drying time under MGH is lower than open field but reduction in drying time is low due to lower air velocity under MGH condition. Even though temperature under MGH was 5.17°C to 8°C higher than the open field condition and RH under MGH was 6% to 8% lower than open field condition but air velocity dictated the drying rate because the air velocity under MGH was only 13% to 34% of open field condition.

Similar observations was reported during the drying of apple under direct natural convection solar tunnel dryer and open field and final moisture content reduced from 82% to 11 % (wb) in 28 h and 32 h respectively (Elicin and Sacilik 2005). Choudhary and Bala (2011) concluded that the moisture content of jackfruit leather reduced from 76% (wb) to 11.88% (wb) in solar tunnel dryer while it reduced to 13.8% (wb) by open sun drying within 2 days. The Fig. 2 shows the dried without blanched and blanched tomato under open field and MGH.

Quality parameters of dehydrated tomato

The quality parameters i.e. shrinkage ratio, rehydration ratio and dehydration ratio of dehydrated tomato under open field and MGH for without blanched and blanched tomato is given in Table 4. The shrinkage ratio, rehydration ratio and dehydration ratio varied between 13.5 to 14.48, 1.7 to 1.8 and 12.68 to 13.3 respectively for without blanched and blanched dehydrated tomato. The rehydration ratio shows that dehydrated tomato has taken water up to 70% to 80% of their initial weight. However, the rehydration ratio obtained in this study is lower than those reported by Madan *et al.* (2008) and their rehydration ratio was 3.36%. The lower values observed in this study can be partly attributed to the higher initial moisture content. While Joshi *et al.* (2008) reported that the rehydration of dried tomato also gets affected by pre-drying treatments.

The shrinkage ratio is higher than dehydration ratio because in shrinkage ratio initial weight of tomato before preparation of tomato for drying is taken under consideration while for dehydration ratio the final prepared sample is taken.

CONCLUSION

The drying of without blanched (WB) and blanched (B) tomato during summer season was conducted under open field and low cost natural ventilated multipurpose greenhouse (MGH). The temperature, relative humidity (RH) and air velocity are important environmental parameters which affects efficacy of tomato drying both under open field and MGH. The increase in temperature under MGH varied between 5.17°C to 8°C in comparison to open field, reduction in RH varied between 5.66% to 11% under MGH in comparison to open field and air velocity under MGH was 13% to 34% of air velocity recorded under open field. The final moisture content of WB and B dried tomato under open field condition was 11.21% (wb) and 11.19 % (wb) respectively, whereas under MGH for WB and B dried tomato was 11.5 % (wb) and 9.33 % (wb) respectively. The drying time of tomato under open field condition was 29 h and 20 h respectively for WB and B, whereas under MGH condition it was 28.5 h and19.5 h respectively for WB and B tomato. The drying rate of tomato was higher under natural ventilated MGH in comparison to open field but it can be further enhanced under MGH by using forced ventilation during drying process.

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