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Drying of *Capsicum annum* (Kashmiri Long 1): Effect of pre-treatments and drying temperatures on quality parameters, colour and drying kinetics

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Abstract
Kashmiri chillies, renowned for their vibrant red hue and distinctive flavor, offer a plethora of health benefits. Rich in capsaicin, the compound responsible for their characteristic heat, Kashmiri chillies possess potent antioxidant and anti-inflammatory properties. Consumption of these chillies has been associated with enhanced metabolism and appetite regulation, making them a valuable addition to weight management regimens. An investigation was conducted about the drying kinetics and physico-chemical composition of Kashmir Long-1 chillies in a cabinet dryer with an air velocity of 1.2 m/s. The study examined temperatures of 45 °C, 55 °C, and 65 °C, revealing a notable decline in drying efficiency as temperatures increased. Among various pre-treatments, T_7 (consisting of 2.5% potassium carbonate, 1% ground nut oil, 0.1% gum acacia, and 0.001% BHA per liter for 15 minutes) proved most effective in preserving capsaicin, capsanthin, and color values (L*, a*, b*, c, h, ΔE). Capsaicin content ranged from 0.615% db at 65 °C to 1.094% db at 45 °C. Notably, capsanthin retention (127.72 ASTA units) was highest when chillies were dried at 45 °C with pre-treatment T_7. A positive correlation between drying air temperature and rate was observed. The decrease in moisture content from 451.572% to 47.82% db during 45 °C drying can be attributed to changes in water molecule availability, orientation, and bonding within the sample. Heat absorption initially facilitates evaporation of surface moisture, followed by diffusion-driven removal of internal moisture. Experimental data for whole chillies were fitted to three drying models, with the Page equation emerging as the most accurate predictor of moisture content.

Keywords: Chilli, capsaicin, capsanthin, drying kinetics, Kashmir long-1, page model

Introduction
Chilli (*Capsicum annum* L.), a member of the Solanaceae family, is a universal spice grown for both domestic and export markets in almost all Indian states. Chilli's native land is Gautemala, a Mexican state of secondary origin. (Sigge *et al.*, 2001) [1]. *Capsicum annum* and *Capsicum frutescens* are the only two species recognized in India, however the majority of the varieties grown are from the *Capsicum annum* species. (Pal *et al.*, 2008) [2]. Chilli contains an alkaloid compound called capsaicin, which has a strong spicy pungent flavor that benefits health (Sadhna` *et al.*, 2006) [4]. Chilli's color is attributed to the presence of red pigmented carotenoids, the most common of which are capsanthin, capsorubin, zeaxanthin, and cryptoxanthin. These pigments are stable when they are in conjunction with plant tissue. It contains a lot of vitamins A, C, and E. Green chillies have also been discovered to contain vitamin P, which is considered essential because it protects against secondary irradiation injury. (Gallardo *et al.*, 2010) [3]. However, auto oxidation occurs as a result of exposure to the sun, light, oxygen, drying, and grinding. (Mangaraj *et al.*, 2001) [5].
Chillies have a high moisture content (300-400 percent db) are extremely perishable both before and after harvest. Chillies with a moisture content of 11% dry base (db) are typically suitable for export, but Indian chillies having moisture content of up to 16 percent dB are often acceptable. Chilli processing and storage is thus crucial for growers, producers, and customers alike. Until processing and storage, the moisture content of chilli must be reduced to a healthy level of 8-9 percent (db). (Famurewa *et al.*, 2006) [6].

Chilli is a temperature-sensitive vegetable. The traditional temperature for hot air drying is kept between 50 and 70 degrees Celsius. Because of the long drying period, there is a problem with color darkening, flavor loss, and reduced rehydration capacity. Longer shelf life, product variety, and significant volume reduction are all factors that have contributed to the popularity of dried fruits and vegetables, and this trend could continue with improvements in product quality and process applications. (Jasim and Shivare, 2001) [7]. To avoid significant quality loss and achieve rapid and efficient dehydration, various drying techniques have been developed. Consumer acceptance of dehydrated foods can improve as a result of these improved techniques. (Arora and Bharti, 2006) [8].

Browning control is one of the most significant food industry issues because color is an important food characteristic that determines consumer preference, and brown foods are viewed as spoiled. To prevent enzymatic browning, a variety of pre-treatments and methods can be used. (Ajaykumar *et al.*, 2012) [9]. The overall colour shift can be minimized while retaining higher drying rates with proper temperature and time variance selection. (William *et al.*, 2008) [10].

Moisture sorption isotherms describe the relationship between water behaviour and the equilibrium moisture content of a food product at constant pressure and temperature. It also aids in the prediction of shelf-life stability in processes such as design, packaging, and processing problems by modelling moisture changes that occur during drying. (Figen and Mustafa, 2001) [11].

Therefore, the current investigation was conducted to compare the effect of pretreatments and the drying temperatures on quality and drying kinetics of the indigenous variety of chilli (Kashmir Long-1).

Materials and Methods

Raw Material

Freshly harvested chillies of variety (Kashmir Long-1) were collected from the research field of the Division of Vegetable Science, SKUAST-K and carried to Food Processing Laboratory, Division of FST, SKUAST-Kashmir after being placed in the shade for 1 hour to eliminate field heat. The bruised, infected and broken chillies were discarded, while the healthy ones were cleaned under running water to eliminate dirt.

Pre-treatment details

The chillies were chemically pretreated to scrutinize the effects of mechanical drying at three standardized drying temperatures 45, 55, and 65 °C. Before drying chillies were subdivided into 500 g per treatment and pretreated with the seven dips in 2500 ml beakers. 1.5 litres of pre- constituted solutions were filled in beakers containing 500 gm chillies. However control samples were not given any dip. (Table 1)

Table 1: Details of the chemical pre-treatments as dips.

Sample	Pre-treatment details.
(T_0)	Control
(T_1)	0.5% citric acid dip (20 min.)
(T_2)	1% Potassium metabilsulphite + 0.5% citric acid (20 min.)
(T_3)	2% Potassium metabilsulphite + 0.5% citric acid (20 min.)
(T_4)	2.5% Potassium carbonate + 2% ethyl oleate (5 min.)
(T_5)	5% Potassium carbonate + 2% ethyl oleate (5 min.)
(T_6)	7.5% Potassium carbonate + 2% ethyl oleate (5 min.)
(T_7)	2.5% Potassium carbonate + 1% ground nut oil+ 0.1% gum acacia +0.001% BHA per liter (15 min.)

Heat Treatment

Pretreated chillies were dried mechanically in a cabinet tray dryer using hot air as the drying medium. Chillies were dried at three different temperatures: 45, 55, and 65 °C with ambient relative humidity and air velocity of 1.2 m/s. The dryer had the ability to control the temperature of the air to ±2 °C. 1.5 kg of chilli were spread in a single layer on aluminium trays (75 x 45 x 6cm) and fed into the drier with set moisture content. To ensure uniform drying, samples were flipped on a regular basis. Weighing samples at hourly intervals on an automated balance (Make Citizen) was used to monitor weight loss. When the chillies reached a moisture level of 10-11 per cent, the drying process was considered complete. The chillies were later packed in re-sealable polythene bags for storage under ambient conditions 27.87±2 °C temperature.

Quality evaluation of dried chillies

Moisture (%)

Weighed 5 g samples were dried for 12 hours in a hot air oven at 60 ±5 °C in pre-weighed dishes until constant weight. The dish containing the dried sample was placed in a desiccator and allowed to cool to room temperature. After that, the dish was weighed, and the moisture content in per cent was measured using the weight loss. (AOAC, 1995) [12].

Capsaicin content (%)

Phosphomolybedic acid was used to assess the capsaicin content of red chillies. (Thimmiah, 2006) [13]. By dissolving 50 mg of capsaicin in 50 ml acetone solution and increasing the volume to 250 ml, 5 test tubes were created by pipetting out 5, 10, 15, 20, 25 ml of this solution in a 100 ml flask and increasing the volume to 100 ml by dry acetone and reading the absorbance at 650 nm. However, 5 ml of 0.4 percent NaOH and 3 ml of 3% phosphomolybdic acid were added to the sample after preparing the standard curve. After being shaken for a few minutes, the samples were filtered and allowed to sit for an hour before being centrifuged at 5000 rpm for 5-10 minutes and the absorbance was calculated at 650 nm using phospho molybedic acid as a blank and dry acetone as a control.

Capsanthin ASTA (Extractable colour)

Using a spectrophotometer, the ASTA colour value was used to determine the capsanthin content of red chilli samples (ASTA, 1986) [14]. Ground chilli (70-100 mg) was added to 100 ml acetone, which was then kept at 0 °C for 4 hours with intermittent stirring. A spectrophotometer was used to measure the absorbance of an aliquot of the transparent extract at 460 nm.

Colour values (L*, a*, b*)

Hunter colorimeter (Model CR-2000, Minolta, Osaka, Japan) with an 8-mm measuring head and c illumination was used to observe the L*, a*, and b* color values (6774 K) (McGuire, 1992) [15].

Mathematical modelling of drying curves and formulation (Drying kinetics)

The drying equations were checked for mathematical modelling to find the best model for representing the chilli drying curve. The STATISTICA computer software was used to perform the regression analysis. The correlation coefficient (r) was the most important factor in deciding which equation to use to describe the drying curve. (Guarte, 1996) [16]. In addition, the best fit was calculated using the reduced chi-square (2) and root mean square error analysis (RMSE). These parameters were calculated as follows:

$$\chi^2 = \Sigma^{n}_{i=1} (MR_{exp} - MR_{pre})^2/N\text{-}n \quad \text{(Eq-1)}$$

$$RMSE = [1/N\ \Sigma^{N}_{i=1} (MR_{pre} - MR_{exp})^2]^{1/2} \quad \text{(Eq-2)}$$

The observed moisture ratio is MRexp, the expected moisture ratio is MRpre, the number of observations is N, and the number of constants is n. (Sarsavadia *et al.,* 1999) [17].

The data was equipped with three models: the Newton model, the Page model, and the Henderson-Pabis model. These models' model equations are as follows:

The Page model:

$$MR= \exp(-kt^{n}) \quad \text{(Eq-3)}$$

The Newton model

$$MR= \exp(-kt) \quad \text{(Eq-4)}$$

The Henderson-Pabis model

$$MR= a\exp(-kt) \quad \text{(Eq-5)}$$

The unaccomplished moisture content or moisture ratio is represented by MR, the drying rate constant is k and the constants n and a are constants.

Experimentally, the empirical constants for thin-layer drying models were calculated from normalized drying curves at various temperatures, which were tested using coefficient of determination (R2).

The form of linearised Page equation is

$$\ln[-\ln(MR)] = \ln(k) + N \ln \quad \text{(Eq-6)}$$

The drying constants k and N are estimated based on the intercept and slope of the ln(-ln (MR) vs ln curve, respectively.

The form of the linearised Newton equation is:

$$\ln(MR) = -kt + 1 \quad \text{(Eq-7)}$$

and of the Henderson-Pabis equation is

$$\ln(MR) = -kt + a \quad \text{(Eq-8)}$$

Where, the drying constants k and a are determined from the slope and intercept, respectively, of the ln (MR) vs. time curve. For the Newton equation, the intercept is set equal to 1.

The goodness of fit for each model was evaluated based on the coefficient of determination R^2, root mean square error (RMSE) and chi-square (χ^2). For the quality fit of the model R^2 (coefficient of determination) should be close to one. As root mean square error (RMSE) and chi-square (χ^2) approach zero, the closer the prediction is to experimental data. The predicted moisture ratio was compared to the experimental moisture ratio using (RMSE) and (χ^2) as shown in the equation above (Akpinar *et al.,* 2003) [18].

Statistical Analysis

Statistical analysis

Experimental data was subjected to the statistical analysis following analytical procedures as described by Gomez and Gomez (1984) [35]. Level of significance used for F; and t; tests were $p \leq 0.05$ from the table given by Fisher (1970) [19] and the data collected was subjected to statistical analysis using statistical software "STATISTICA-AG" from Stat Soft (USA).

Results and Discussion

Capsaicin content (% db)

The amount of capsaicin in the fruit is a key factor in determining the pungency of chillies. The blend of seven homologous branched chain alkyl vanillyl amides named capsiacinoids are responsible for the pungency of chilli, which is an important quality parameter (Hoffman *et al.*, 1983) [20]. Capsaicin content of pretreated samples was significantly higher than non -treated samples under the same drying conditions. The optimum method for retaining capsaicin content throughout drying was to use a temperature of 45 °C and pretreatment of T_7. The capsaicin content of pre-treated samples dried at 45 °C varied significantly from 0.954 to 1.094% (db). The capsaicin level of chilli samples dried at 45 °C (1.094% db) was significantly higher than samples dried at 55 °C (0.775% db) or 65 °C (0.716% db) at the end of the drying process. Higher temperatures manifested a negative impact over the capsaicin retention, hence with the increase in drying temperature to 65 °C, the capsaicin content showed a decline to 0.716% db in samples pretreated with T_7. However, in control samples the capsaicin content was considerably lower (0.615% db) than pre-treated one (Figure 1). Loss of capsaicin and dihydro-capsaicin is a problem during the preparation of dehydrated chilli. Increased temperature showed a detrimental effect on capsaicin content as according to a study, capsaicin and dihydrocapsaicin levels in fruits decrease following cellular disruption, which is thought to be related to temperature-dependent oxidation. (Eleyinmi *et al.* 2002, Ayhan *et al.* 2009, Wiriya *et al.* 2009, Manjula *et al.* 2011 and Kwanhathai *et al.* 2012) [22, 21, 23, 24, 25].

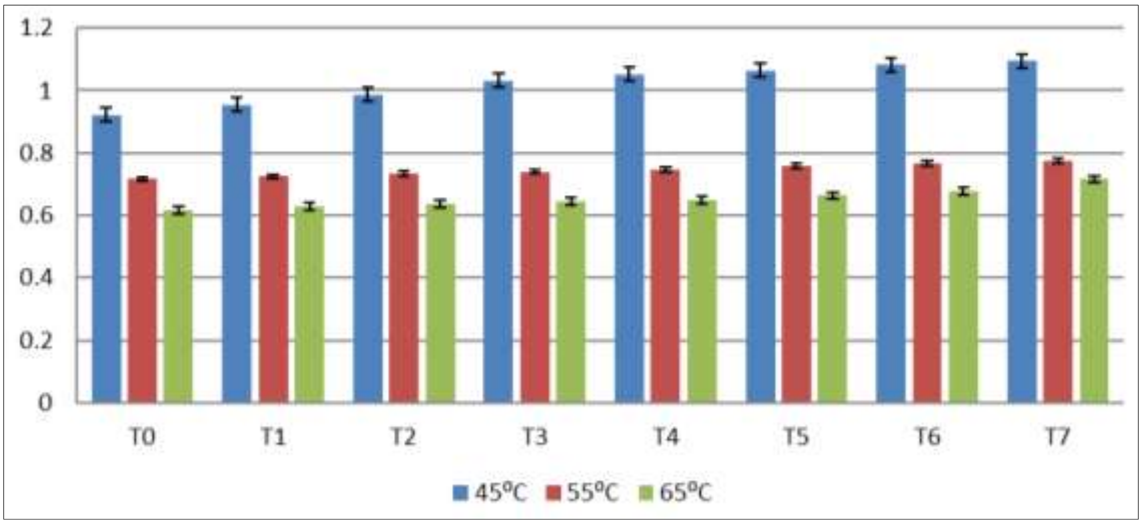

Fig 1: Effect of pretreatments, mechanical drying temperatures on capsaicin (% db) of whole chillies (Kashmir Long-1)

Capsanthin (ASTA units)

The most important pigment in the chilli is capsanthin, which accounts for 30-60% of the total carotenoids (Vega *et al.*, 2008) [26]. The capsanthin concentration of chilli samples after mechanical drying was significantly ($p\leq 0.05$) influenced by pretreatments. Pretreated samples dried at 45 °C showed a varied capsanthin content ranging from 126.93 (T_1) to 127.72 ASTA units (T_7) (Figure 2). Control samples, on the other hand, had a capsanthin content of 126.73 ASTA units. Irrespective of pretreatments the capsanthin concentration of chilli samples dried at 45 °C was considerably higher (127.25 ASTA units) than those dried at 55 °C (127.05 ASTA units) and 65 °C (126.88 ASTA units). However, the samples dried at 55 and 65 °C also showed a significant trend when compared to pretreatments. It is expected that changes in macroscopic properties of materials are caused by their microstructure variation (Xiao *et al.*, 2017) [27]. Observation of the ultrastructure is a powerful method to elucidate the mechanism responsible for changes in the phytochemicals changes in red peppers during thermal process. Meanwhile, thermal treatment causes degradation of cell wall polysaccharides and breakdown of the cell structure particularly the collapse of cell wall and thus increasing the loss of texture and phytochemicals. For example, over-blanching resulted in texture softening and mass loss in red peppers (Wang *et al.*, 2018) [28].

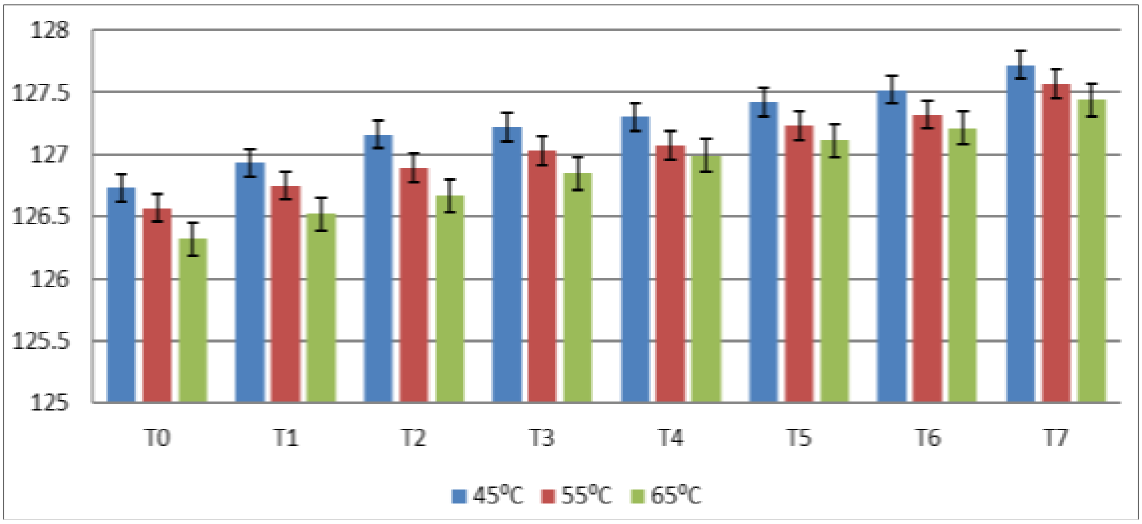

Fig 2: Effect of pretreatments and mechanical drying temperatures on capsanthin (ASTA units db) of whole chillies (Kashmir Long-1)

Colour values (L*, a*, b*, c, h, ΔE)

Color is an essential food quality feature that impacts customer preferences and choices. As depicted in Figure 3 the colour parameters (L*, a*, b*, c, h, ΔE) of chilli samples were significantly influenced after mechanical drying at 45 °C. Dried red pepper was found to have a wide range of lightness levels. After drying at 45 °C the control (T_0) samples had a lightness (L*) value of 28.93, whereas pretreated samples had lightness (L*) values ranging from 29.28 (T_1) to 31.81 (T_7). (Figure 3)The peak lightness (L*) value of 31.81 was recorded in samples pretreated with T_7solution which hence gives a brighter product. Furthermore, as the drying temperature was raised, the lightness of the dried samples dropped (Wiktor *et al.*, 2016) [29]. It paralleled the findings of Rhim and Hong, (2011) [30], who discovered that the L* values of red pepper reduced as the temperature increased. At 55 °C of drying temperature the samples pretreated with T_7 solution exhibited the maximum L* value of 30.39, which was significantly higher than the L* value (29.60) depicted after drying the samples at 65 °C.

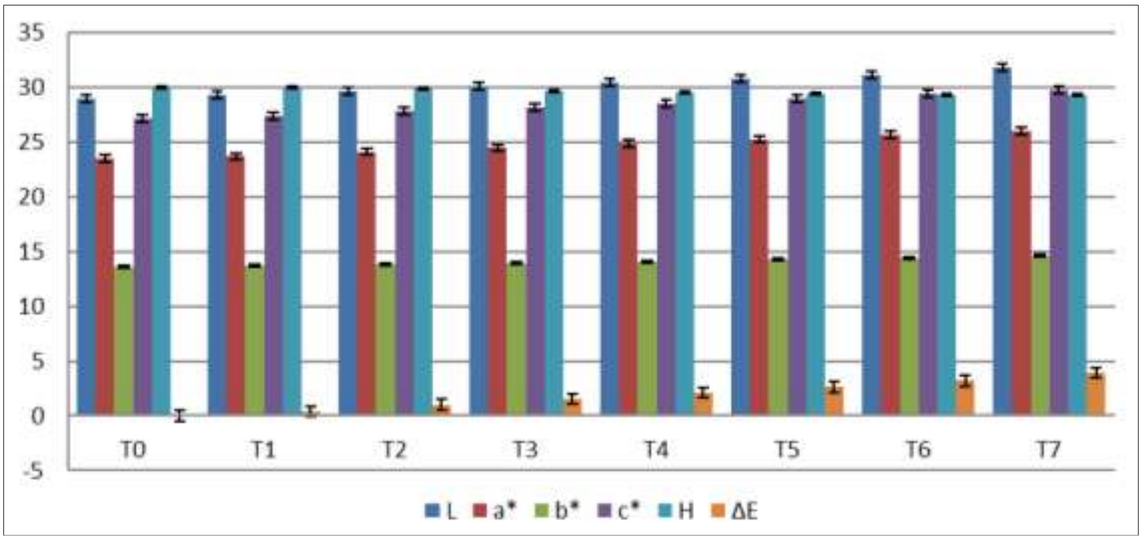

Fig 3: Effect of pretreatments on L*, a*, b*,c, H, ΔE in of chillies (Kashmir Long-1) dried at 45 °C

From the chilli dried at 45 °C the control (T_0) samples expressed the red chromaticity coordinate's value (a*) of 23.46, while treated samples had a* values ranging from 23.67 to 25.95, with the highest a* value (25.95) recorded in samples pretreated with T_7 solution. However increased drying temperatures illustrated a negative ramification on a * value of dried chilli. The variation in the a*value extended from 21.51 (chilli dried at 65 °C) to 22.23 (chilli dried at 55 °C). The degradation of carotenoids, particularly the capsanthin family members that generate a strong red colour, can explain the decrease in a* with the increase in drying temperature (Figure 4, 5).

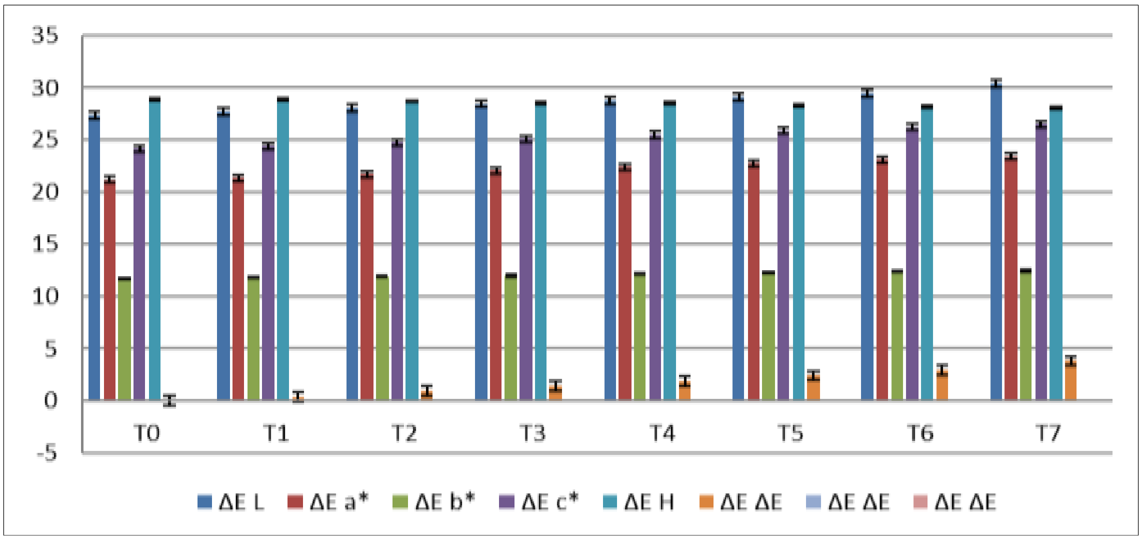

Fig 4: Effect of pretreatments on L*, a*, b*,c, H, ΔE in of chillies (Kashmir Long-1) dried at 55 °C

The considerably higher values of colour retention after application of pretreatments particularly T_7 might be explained by the fact that T_7 pretreatment reduces the risk of carotenoids being oxidized in an oxygen-deficient processing environment, as oxidation processes are the leading source of carotenoid loss. Maximum yellowness values (b*) were distinguished in chilli samples pretreated by T_7 and dried at 45 °C (14.47) followed by drying temperatures of 65 (13.56) and 55 °C (12.42).

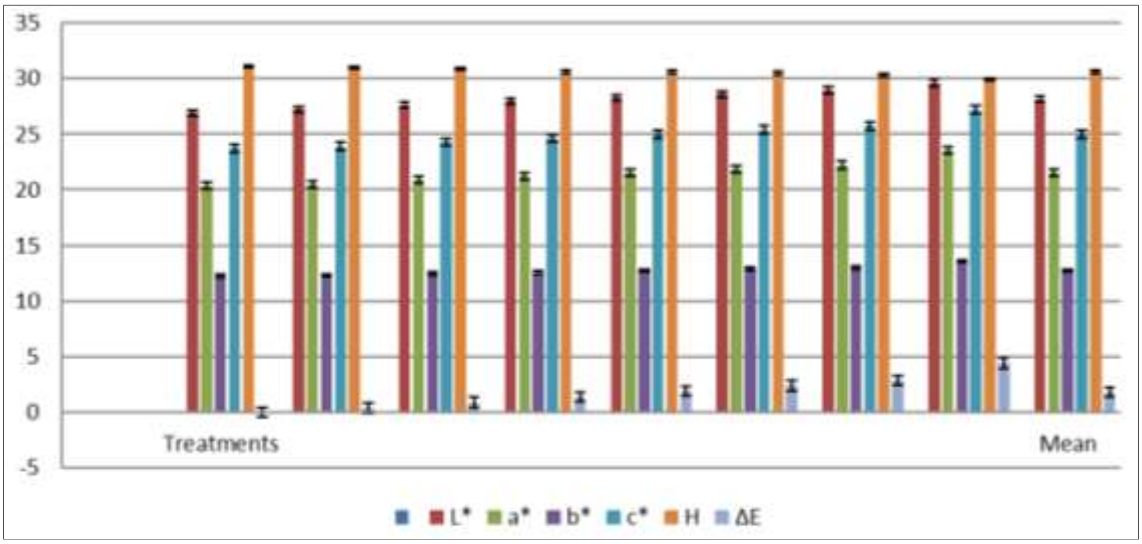

Fig 5: Effect of pretreatments on L*, a*, b*,c, H, ΔE in of chillies (Kashmir Long-1) dried at 65 °C

Drying characteristics

Drying kinetics

Table 2 depicts the drying time and ultimate moisture content of chiles. In the context of mechanical drying of chilli samples in a cabinet dryer, the drying temperature was critical in reducing moisture content.

At 45 °C untreated samples took 36 hours to reach to the final moisture content of 11.10% db whereas, pre-treated samples took 26.33 to 34 hours to dry to 10.15. Un treated chilli samples dried at 55 °C took 19 hours to attain a moisture content of 10.22% db, where as, pre treated samples took 16 to 18 hours to attain a moisture content of 9.09 to 10.06% db. A minimum time of 16 hours was required to dry pre-treated chillies at 55 °C for attaining minimum moisture content of 9.09% db. At 65 °C control (T_0) chilli samples took 10 hours to attain moisture content of 9.87% db whereas, it took 7 to 9 hours for pre treated samples. Chilli samples pre-treated with T7 solution took 7 hours to dry to a moisture content of 8.72% db.

According to Khazaei *et al*. (2008) [31], drying kinetics are affected by air temperature, air velocity, material size, drying duration, and other factors. The data clearly demonstrates the relationship between drying time and temperature. Because of the greater drying force, samples dried at higher temperatures have shorter drying durations, and vice versa (Leeratanarak *et al*., 2006 and Doymaz, 2011) [32, 33]. Increased heat flux causes internal moisture migration to rise (Vega *et al.* (2008) [26].

Table 2: Effect of pre-treatments and mechanical drying temperatures on final moisture content (db) of chilli samples

Pre-treatments	45 °C		55 °C		65 °C	
	Moisture (% db)	Drying Time (h)	Moisture (% db)	Drying Time (h)	Moisture (% db)	Drying Time (h)
T_0	11.10	36	10.22	19	9.87	10
T_1	10.94	34	10.06	18	9.70	9
T_2	10.79	33	9.99	18	9.54	8
T_3	10.69	32	9.78	18	9.41	8
T_4	10.60	30	9.59	17	9.24	8
T_5	10.41	29	9.42	17	9.06	8
T_6	10.27	28	9.27	16.16	8.90	7.66
T_7	10.15	26.33	9.09	16	8.72	7

Table 2 a illustrates the characteristics of mechanical drying of chillies at 45 °C. Its depicted that a weight loss from 1500 to 402 gm in and loss of 1098gm of moisture was observed after 1680 minutes of drying (28 hours). Moisture on dry basis dipped from 451.572 to 47.82129% db. At 45 °C, the drying rate ranged from 0 to 0.00088, and the moisture ratio (MR) dropped from 1 to 0.10589 (Figure 6, 7).

Table 2a: Characteristics of mechanically dried chillies at 45 °C (Kashmir Long -1)

Time (min)	Weight Reduction (gm)	Moisture removed(g)	Moisture present	Moisture on dry basis	Drying rate	MR
0	1500	0	1228.05	451.572	0.000	1
60	1445	55	1173.05	431.3477	0.339	0.95521
120	1360	140	1088.05	400.0919	0.262	0.88599
180	1305	195	1033.05	379.8676	0.113	0.84121
240	1260	240	988.05	363.3205	0.069	0.80456
300	1205	295	933.05	343.0962	0.067	0.75978
360	1150	350	878.05	322.8719	0.056	0.71499
420	1120	380	848.05	311.8404	0.026	0.69056
480	1075	425	803.05	295.2933	0.034	0.65392
540	1025	475	753.05	276.9075	0.034	0.61320
600	980	520	708.05	260.3604	0.027	0.57656
660	870	630	598.05	219.9117	0.061	0.48699
720	835	665	563.05	207.0417	0.018	0.45849
780	790	710	518.05	190.4946	0.021	0.42184
840	755	745	483.05	177.6246	0.015	0.39334
900	715	785	443.05	162.916	0.016	0.36077
960	685	815	413.05	151.8845	0.011	0.33634
1020	655	845	383.05	140.8531	0.010	0.31191
1080	640	860	368.05	135.3374	0.005	0.29970
1140	605	895	333.05	122.4674	0.011	0.27120
1200	570	930	298.05	109.5974	0.010	0.24270
1260	535	965	263.05	96.72734	0.010	0.21420
1320	510	990	238.05	87.53447	0.007	0.19384
1380	465	1035	193.05	70.98731	0.012	0.15720
1440	440	1060	168.05	61.79445	0.006	0.13684
1500	425	1075	153.05	56.27873	0.003	0.12462
1560	410	1090	138.05	50.76301	0.003	0.11241
1620	406	1094	134.05	49.29215	0.0009	0.10915
1680	402	1098	130.05	47.82129	0.0008	0.10589

Likewise as illustrated in Table 2b, the time taken by the chilli samples to dry at mechanical dying of chillies carried out at 55 °C was 970 minutes (16.16 hours). Chillies lost weight from 500 to 141.67 gm and % db moisture loss was from 451.572 to 50.76669. The drying rate varied from 0 to 0.0056 while as MR showed a declining trend from 1 to 0.112422.

Table 2b: Characteristics of mechanically dried chillies at 55 °C (Kashmir Long -1)

Time (min)	Weight reduction (g)	Moisture removed(g)	Moisture present	Moisture on dry basis	Drying rate	MR
0	500.00	0.00	409.35	451.572	0.00	1
60	451.67	48.33	361.02	398.257	0.8890	0.8819
120	395.00	105.00	304.35	335.741	0.5212	0.7434
180	365.00	135.00	274.35	302.647	0.1839	0.6702
240	335.00	165.00	244.35	269.553	0.1379	0.5969
310	303.33	196.67	212.68	234.616	0.1127	0.5195
370	288.33	211.67	197.68	218.069	0.0447	0.4829
430	270.00	230.00	179.35	197.848	0.0470	0.4381
490	243.33	256.67	152.68	168.428	0.0600	0.3729
550	228.33	271.67	137.68	151.880	0.0301	0.3363
610	211.66	288.34	121.01	133.491	0.0301	0.2956
670	193.33	306.67	102.68	113.270	0.0301	0.2508
730	178.33	321.67	87.68	96.7236	0.0226	0.2141
790	163.33	336.67	72.68	80.1765	0.0209	0.17755
850	155.00	345.00	64.35	70.98731	0.0108	0.1572
910	141.67	358.33	51.02	56.2824	0.0161	0.124637
970	136.67	363.33	46.02	50.76669	0.0056	0.112422

At 65 °C of drying, a declining trend was observed in the drying rate from 0 to 0.101944 which resulted in the instant drop of moisture ratio from 1 to 0.1159. Total time of 480 minutes (8 hours) was required to drop the moisture level to 77.29887% db. However 253.33 gm of moisture was removed from chillies in 480 minutes (Table 2c)

Table 2c: Characteristics of mechanical dried chillies at 65 °C (Kashmir Long -1)

Time (min)	Weight reduction (g)	Moisture removed(g)	Moisture present	Moisture on dry basis	Drying rate	MR
0	350.00	0.00	286.545	451.572	0.00	1
60	298.33	51.67	234.875	370.1442	1.358307	0.8196
120	250	100	186.545	293.98	0.635252	0.6510
180	206.67	143.33	143.215	225.6954	0.379688	0.4997
240	178.34	171.66	114.885	181.0496	0.186186	0.4009
300	160.01	189.99	96.555	152.163	0.093263	0.3369
360	145.01	204.99	81.555	128.5242	0.063944	0.2846
420	128.34	221.66	64.885	102.2536	0.061147	0.2264
480	96.67	253.33	33.215	52.34418	0.101944	0.1159

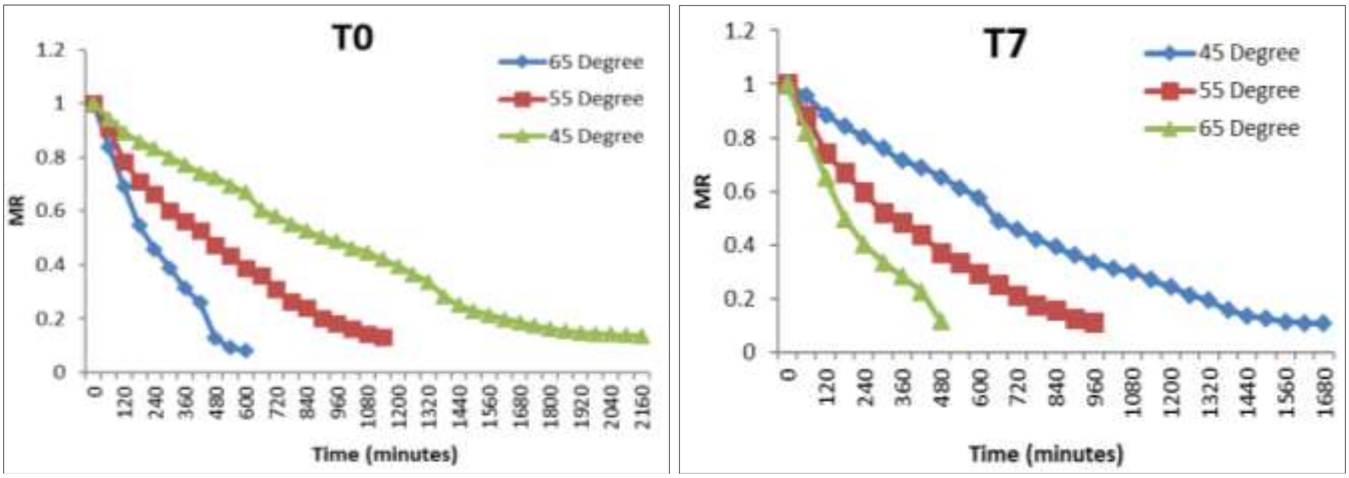

Fig 6: Drying curve depicting changes in moisture ratio v/s time.

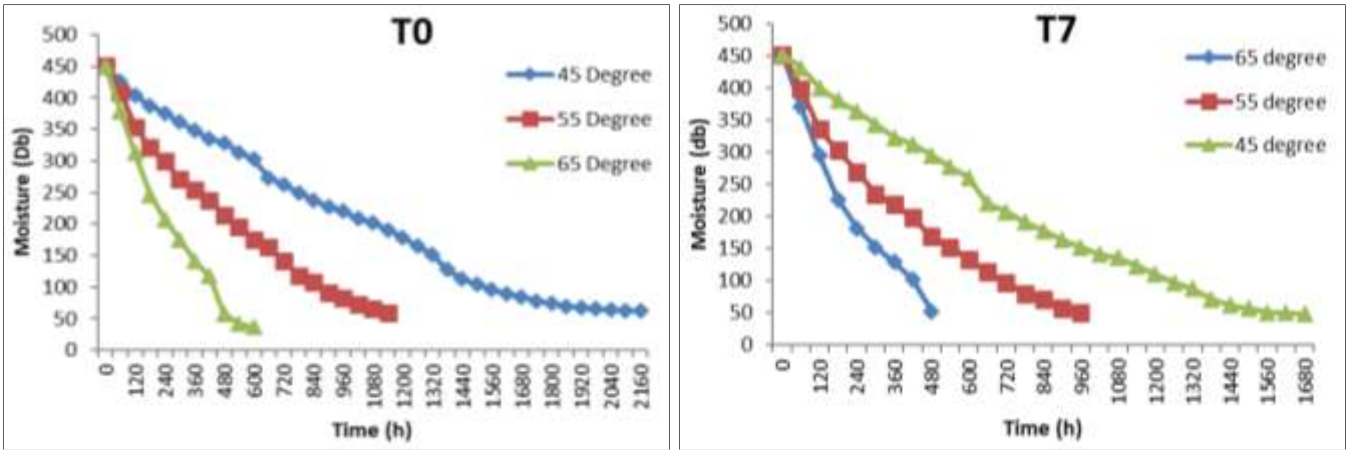

Fig 7: Drying curve depicting changes in moisture and weight v/s time drying mechanical drying

The availability, direction, and bonding of water molecules in the food sample may be responsible for the reduction in moisture content. The sample absorbs heat at first to heat it and evaporate just a fraction of the free moisture; at first, heat from the source removes moisture from the surface, and as drying progresses, moisture flows out through diffusion (Niamnuy *et al.*, 2011) [34]. The heat penetrates the product and evaporates the moisture, leaving it with a lower moisture content. Due to the availability of free moisture, the drying rate rises at first. The quantity of moisture removed from the samples rose as the drying temperature increased, and the time necessary to achieve drying reduced. Finally, the heat will be used to release the water molecules that are tightly bound. The kinetic energy of molecules increases at this stage, causing the temperature of the air substance to equalize, reducing the drying rate and ultimately bringing it to a halt (Xiao *et al.*, 2017) [27].

Mathematical Modelling

The R2 and RMSE values for drying kinetics are recorded in Table-3. The drying curves were created by graphing weight changes, moisture ratio (Fig. 6) and drying rates v/s time (Figure 7). The figures demonstrate that during the first hour of drying, 50% of the moisture present was eliminated. The results revealed that as the drying process progresses, the water content of the sample gradually decreases owing to the evaporation of water molecules from the sample. Initially, more than 30% of the moisture content in all samples was evaporated in the first 30 minutes, and more than 70% in the first 2 hours of drying. The effect of increasing temperature on sample drying is visible from the data, which demonstrates that increasing temperature reduces the time it takes for samples to dry. For the drying kinetics of diverse foods, a number of models have been presented.

Table 3: Results of Mathematical Modeling

Model	Temperature	K	R^2	Chi-square	RMSE	n
Newton	45 °C	K= 0.00061	0.980611	0.001912	0.042963	
	55 °C	K= 0.00096	0.991511	0.000739	0.026366	
	65 °C	K=0.00175	0.965275	0.002984	0.051498	
Page	45 °C	K=0.000159	0.992228	0.001492	0.037227	n=1.167956
	55 °C	K=0.00099	0.993239	0.000244	0.012717	n=0.98711
	65 °C	K=0.001095	0.989608	0.001310	0.031351	n=1.070688
Henderson Pabis	45 °C	K=0.0014	0.980611	0.010136	0.098926	
	55 °C	K=0.00221	0.990532	0.003916	0.060709	
	65 °C	K=0.00404	0.962274	0.018078	0.118578	

These models clearly show how drying kinetics, or the drying process, is affected by time and temperature. Our data was evaluated using three models: Page Model, Newton Model, and Hundeson-Pabis Model. The observed data was fitted into the equations of the supplied models. These model equations were used to calculate the drying constants. These model equations were used to calculate the drying constants. Three different models had different drying constants. Table 3 shows the empirical drying constants for chilies and the co-efficient of determination (R2) at each temperature. The greatest co-efficient of determination (R2) and lowest Chi-square (2) and Root Mean Square Error are used to choose the optimal model to represent the drying behaviour of chilies (RMSE).

The greatest R2 values were found in the page model, which ranged from 0.989 to 0.993. The Page model with the highest R2 values matches the data the best. The Chi-square ($\chi 2$) and RMSE in pages models revealed a range of 0.00024 to 0.00149 and 0.0127-0.0372 respectively. The results clearly suggest that the page model is the best fit for the data. In other words, the best way to characterize the drying properties of chilies is to use the page model.

Conclusion

Temperatures and pretreatments delineated a significant effect on drying of chilli. The pretreatment T_7 (2.5% Potassium carbonate + 1% ground nut oil+ 0.1% gum acacia +0.001% BHA per liter (15 min.) recorded the best quality parameters. The maximum capsaicin and capsanthin content of 1.094% db and 127.72 ASTA units was documented in chilli samples dried at 45 °C pretreated with T_7. This combination also recorded the highest colour parameters as L* (31.81), a* (25.95), b (14.57), c (29.76), h (29.3) and ΔE (3.94). Among the varied temperatures for drying of chillies 45 °C recorded the best values with respect to quality and decreased drying rates. The drying curves for control and best treatment samples were significantly different. The rate of drying increased as the temperature of the drying air raised. At low temperatures, the rate of increase in drying rate was rather slow. As the drying temperature rised, the drying time was significantly lowered. At 45 °C of drying the fall in moisture content from 451.572 to 47.82% db might be due to the availability, direction, and bonding of water molecules in the food sample. The sample absorbs heat at first to heat it and evaporate just a part of the free moisture; heat from the source removes moisture from the surface at initially, and moisture flows out by diffusion as drying continues. Among the three fitted models, the page model appears to be the best match for the data based on the results. To put it another way, the page model is the best technique to characterize the drying qualities of chillies.

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