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RESEARCH PAPER

Effect of drying conditions on rehydration characteristics of spinach

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SUMMARY : Spinach was dehydrated in mechanical tray dryer at 40, 50, 60 and 70^{0}C temperatures and in open sun drying with loading density 2.0, 2.5 and 3.0 kg/m^2. It was found that spinach did not have any constant rate of drying period and major drying took place in falling rate period except some accelerating period in open sun drying initially. It was observed that drying temperature affects the rehydration ratio, coefficient of rehydration and moisture content in rehydrated samples. It was also observed that the loading density did not influence rehydration characteristics in rehydrated samples. Thus results indicated that chemically treated samples had higher rehydration ratio than blanched and untreated samples and more acceptable than others.

Key Words : Blanching, Loading density, Try dryer, Open sun, Rehydration ratio, Coefficient of rehydration, Moisture contents

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The fresh spinach is more commonly used after cooking because of its perishable nature. The most commonly used leafy vegetables are green and red amaranth, spinach(palak), chakota, fenugreek leaves, coriander leaves, kachi leaves, pudina, drumstick and curry leaves, which contribute to flavour, green colour, minor nutrients as well as medicinal properties. The conventional cooking of these vegetables results in the losses of water soluble vitamins and minerals and change in colour. However, the changes that occur during processing of leafy vegetables with regard to vitamins and colour are less understood. Secondly because of perishable nature, leafy vegetables are more commonly used immediately after harvest .The leafy vegetables are seasonal and available in plenty at a particular area bringing complexity in its post harvest processing. In peak season, prices fall steeply. The producer have to sell at throw away prices, delay leads to sharp fall in market prices, enormous deterioration in quality as well as quantity of vegetables. There are many methods of preservation of foods. Among these, the techniques of drying is well accepted and probably the oldest method of food preservation practiced by the mankind. It is relatively economical method, as concentration of solids become high, water activity reduces greatly, and product becomes chemically stable and free from insect-pest attack and mould- yeast growth during storage. Drying has been practiced at domestic level by utilizing solar energy. Long drying time, variation in weather and exposer to direct sun light leads to poor quality of the end product. Tray dryers operated by electrical energy, solar energy and gasifires are commonly used for dehydration of vegetables, (Mandhyan *et al.,* 1988). The study was conducted to see the effect of drying temperature, loading density and pretreatment on drying characteristics of spinach.

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EXPERIMENTAL METHODS

Preparation of samples:

The fresh spinach was washed thoroughly in tap water so as to remove roots and stem. Leaves and soft stem were separated from the rest parts. Care was taken to avoid bruised and discoloured leaves. Pretreatment were given by three methods (i) Dipping in solution containing 0.1 per cent magnesium chloride, 0.1 per cent sodium bicarbonate and 2 per cent potassium metabisulphite in distilled water for 15 min. at room temperature (ii) Blanching in boiling water for 2 min (iii) Blanching in boiling water containing 0.5 per cent sodium metabisulphite for 2 min. The ratio of spinach to pretreatment mixture was maintained at 1:5 (w/w).

Drying of spinach:

After pretreatments, the spinach was loaded in perforated stainless steel trays at the rate of 2.0, 2.5 and 3.0 kg/m^2 tray area and dried at 40, 50, 60 and 70^{0}C temperature in tray dryer with constant air velocity of 2.0 m/s. The open sun drying was also carried out during the day time (temp: 37-45^{0}C, RH: 25-37%). The untreated samples of spinach was dried as control samples. Spinach were dried from 91% ± 1 per cent moisture content to about 5±1 moisture content (wb). The dried samples were packaged in polythene bags (film thickness 95 micron, density 0.922), sealed air – tight and stored at room temperature and kept away from sun light.

Determination of M.C. and M.R.:

The method recommended by Ranganna (1986) was used for determination of moisture content. The moisture content was calculated using the following formula:

$$\text{IMC, \% (d. b.)} = \frac{[(W_2 - W_1) - (W_3 - W_1)]x100}{(W_3 - W_1)}$$

where,

W_1 =Weight of metallic dish with cover, g

W_2 = Weight of sample before oven drying plus weight of metallic dish with cover, g

W_3 = Weight of dried and desiccated sample plus weight of metallic dish with cover, g

W_2-W_1 = weight of sample, g

W_3-W_1 = Weight of dried and desiccated sample, g

Moisture content of the samples during drying was computed through mass balance. For this purpose, weights of the sample during drying were recorded at predetermined time interval. The following formulae were used to calculate the moisture content.

$$\text{MC, \% (d. b.)} = \frac{(W - Wd)x100}{Wd}$$

where,

W = weight of sample at any time, g

Wd = Weight of bone dry matter, g

Weight of bone dry matter were calculated as

$$Wd = \frac{(100 - Mc)x\ Wi}{100}$$

where,

Wi = Initial weight of the sample, g

Mc = Moisture content of the sample, % (w.b.)

The final moisture content was taken as equilibrium moisture content (Pande *et al.,* 2000 and Jain *et al.,* 2000).

Moisture ratio (MR) is defined as follows

$$MR = \frac{M - Me}{Mo - Me}$$

Where,

M = Moisture content, % (d. b.) at time t (min.) during drying

Mo = Moisture content, % (d. b.) at the initiation of drying *i.e.* at zero time.

Me = Equilibrium moisture content, % (d. b.).

The moisture ratios at different time intervals were calculated to study the drying characteristics of spinach

EXPERIMENTAL FINDINGS AND ANALYSIS

The results of the present study as well as relevant discussions have been presented under following sub heads:

Effect of drying conditions on rehydration characteristics of dried spinach:

The rehydration characteristics of spinach samples were analyzed in terms of their ability to regain original shape. This characteristic is expressed in the form of rehydration ratio (RR), coefficient of rehydration (CR) and moisture content (MC) in rehydrated samples. The spinach samples of all treated and untreated were dried at different temperature (40 to 70 ^{0}C at an interval of 10 ^{0}C including open sun drying) and loading density (2.0, 2.5 and 3.0 kg/m^2). Rehydration studies were conducted for a period of 5 and 15 min and the results are presented in Table 1.

Effect of drying temperature on rehydration characteristics:

Table 1 shows the rehydration ratio (RR) of spinach at different temperatures for various time periods of soaking. It reveals that the rehydration ratio markedly increased with decrease in the drying air temperature from 70 to 50 ^{0}C and slightly decreased from 50 to 40 ^{0}C and was maximum (6.715) at 50 ^{0}C temperature. Joshi *et al.* (1991) reported similar results with rehydration ratio in electrical oven at 35-40 ^{0} C temperature. The minimum rehydration ratio observed in open sun drying. The lower rehydration ratio in case of 70 ^{0}C may probably due to cellular breakdown of the spinach during drying. The minimum RR in case of open sun drying was due to prolonged drying periods, low temperature drying, increased thermal disruption of the cell organization, reducing the rehydration ratio and coefficient of rehydration. Rehydration ratio increased in the range of 5.627 to 15.768 per cent with time of rehydration from 5 to 15 min for all the temperature in range. Table 1 showed that rehydration ratios for chemical treated samples were

Table 1 : Rehydration characteristics at various drying conditions

Temperature (^{0}C)	Loading density	Treatments	RR 5min	RR 15 min	Increase in RR from 5min to 15 min	CR, 5 min	CR 15 min	MC in rehydrated sample, 5 min	MC in rehydrated sample, 15 min
40	2.0	CT	6.458	6.954	7.680	0.575	0.619	85.187	86.243
		BC	6.257	6.751	7.895	0.556	0.600	84.748	85.864
		B	6.185	6.642	7.389	0.543	0.583	84.593	85.653
		UT	6.269	6.795	8.390	0.576	0.624	84.714	85.898
	2.5	CT	6.495	7.112	9.500	0.596	0.652	85.318	86.591
		BC	6.314	6.953	10.120	0.577	0.635	84.935	86.319
		B	6.325	6.895	9.012	0.580	0.632	84.831	86.085
		UT	6.351	6.897	8.597	0.579	0.629	84.893	86.089
	3.0	CT	6.525	7.249	11.096	0.595	0.661	85.398	86.856
		BC	6.375	6.946	8.957	0.602	0.656	85.046	86.275
		B	6.310	6.951	10.158	0.596	0.657	84.926	86.316
		UT	6.410	6.956	8.518	0.601	0.652	85.172	86.336
50	2.0	CT	6.615	7.298	10.325	0.589	0.649	85.512	86.868
		BC	6.410	6.975	8.814	0.569	0.619	85.115	86.321
		B	6.375	6.876	7.859	0.559	0.603	85.042	86.132
		UT	6.475	6.957	7.444	0.596	0.640	85.230	86.253
	2.5	CT	6.695	7.310	9.186	0.614	0.670	85.745	86.945
		BC	6.648	7.115	7.021	0.608	0.650	85.689	86.628
		B	6.356	7.015	10.368	0.584	0.644	84.919	86.335
		UT	6.515	7.121	9.302	0.597	0.653	85.352	86.598
	3.0	CT	6.715	7.395	10.127	0.613	0.675	85.811	87.116
		BC	6.514	7.105	9.073	0.615	0.671	85.362	86.579
		B	6.495	7.095	9.238	0.613	0.670	85.331	86.571
		UT	6.525	7.112	8.996	0.611	0.666	85.420	86.623
60	2.0	CT	6.595	7.215	9.401	0.586	0.641	85.468	86.717
		BC	6.321	7.215	12.285	0.561	0.630	84.880	86.534
		B	6.325	7.102	8.470	0.561	0.609	85.120	86.282
		UT	6.411	6.954	8.514	0.602	0.654	85.404	86.549
	2.5	CT	6.554	7.112	13.713	0.583	0.663	84.989	86.799
		BC	6.359	6.957	10.184	0.576	0.635	84.913	86.307
		B	6.314	6.854	6.927	0.588	0.629	85.053	86.022
		UT	6.41	6.987	5.848	0.605	0.640	85.543	86.342
	3.0	CT	6.601	7.210	13.080	0.581	0.657	85.045	86.775
		BC	6.376	6.895	9.531	0.593	0.650	84.831	86.151
		B	6.295	6.776	5.627	0.604	0.638	85.119	85.912
		UT	6.415	6.995	9.143	0.599	0.653	85.115	86.362
70	2.0	CT	6.409	7.102	14.272	0.551	0.629	84.553	86.482
		BC	6.215	6.856	10.456	0.549	0.606	84.548	86.011
		B	6.207	6.815	8.157	0.548	0.593	84.796	85.943
		UT	6.301	6.915	7.292	0.587	0.630	85.097	86.110
	2.5	CT	6.445	7.195	15.768	0.568	0.658	84.582	86.682
		BC	6.215	6.895	9.271	0.573	0.627	84.892	86.174
		B	6.31	6.785	7.443	0.585	0.628	84.829	85.880
		UT	6.315	6.956	8.096	0.587	0.634	85.124	86.238

Table 1 contd..

Contd.... Table 1

OSD	2.0	T	6.195	6.314	6.746	0.529	0.564	83.832	84.854
		BC	5.915	6.125	8.889	0.501	0.545	83.051	84.435
		B	5.625	6.115	9.294	0.499	0.546	82.976	84.423
		UT	5.595	6.210	8.094	0.526	0.568	83.363	84.609
	2.5	CT	5.745	6.385	10.947	0.526	0.583	83.429	85.064
		BC	5.755	6.215	12.083	0.505	0.566	82.829	84.680
		B	5.545	6.224	14.223	0.499	0.570	82.470	84.652
		UT	5.449	6.287	12.368	0.512	0.575	82.974	84.848
	3.0	CT	5.595	6.495	11.694	0.530	0.592	83.641	85.354
		BC	5.815	6.289	12.024	0.530	0.594	83.015	84.838
		B	5.614	6.215	11.081	0.529	0.587	83.002	84.698
		UT	5.595	6.515	13.010	0.541	0.611	84.582	85.415

observed higher than chemically blanched, blanched and untreated for all temperatures including open sun drying and loading densities.

Table 1 shows the coefficient of rehydration (CR) and moisture content (MC) in rehydrated sample for 40 –70 ^{0}C. Similar trends were noticed with maximum CR (0.675) and maximum MC in rehydrated sample (86.945%) for 50 ^{0}C while fresh sample showed the moisture content of 91.071 per cent. It was also observed from statistical analysis for RR at 5 and 15 min rehydration time that the temperature is highly significant at 5 per cent level of significance. Thus, results clearly indicated that drying temperature affects the rehydration ratio, coefficient of rehydration and moisture content in rehydrated samples

Effect of loading density on rehydration characteristics:

Table 1 showed the RR, CR and MC in rehydrated sample for different loading density of 2.0, 2.5 and 3.0 kg/m^2 at different temperatures including open sun drying. It is clear that loading density doesn't affect much to rehydration characteristics. For example, RR (5 min) values of 50 ^{0}C, chemical treated samples at 2.0, 2.5 and 3.0 kg/m^2 were 6.615, 6.695, and 6.715, respectively. Variation between minimum and maximum value was merely 1.48 per cent. For example, CR (5 min) values of 50 ^{0}C, chemical treated samples at 2.0, 2.5 and 3.0 kg/m^2 were 0.589, 0.614 and 0..613, respectively and MC in rehydrated samples (5 min) values of 50 ^{0}C, chemical treated samples at 2.0, 2.5 and 3.0 kg/m^2 were 86.868, 86.945 and 87.116 per cent, respectively. It was found that loading density had insignificant effect on rehydration characteristics.

Effect of pretreatments on rehydration characteristics:

Table 1 showed the RR, CR and MC in rehydrated sample for chemical treated, chemically blanched, blanched and untreated samples at different temperatures and loading density. From the statistical analysis it was observed that the treatment had significant effect on rehydration characteristics (RR for 5 and 15 min rehydration time) though not as highly significant as drying air temperature. For example at 50 ^{0}C , 2.5 kg/m^2 loading density and 5 min rehydration time, RR, CR and MC in rehydrated sample values for chemical treated, chemically blanched and blanched samples were 6.695, 0.670, and 86.945 per cent, 6.648, 0.608 and 86.628, 6.356, 0.559 and 86.335, respectively while for untreated samples the values were 6.515, 0.597 and 86.598 per cent, respectively. Thus results indicated that chemical treated samples had higher RR values than chemically blanched, blanched and untreated samples and more acceptable than others.

Conclusion:

– Rehydration ratio increased with decrease in drying air temperature from 70 to 50 ^{0}C whereas it decreased slightly from 50 to 40 ^{0}C and R.R. was maximum for chemical treated sample with 2.5 kg/m^2 loading density at 50^0 C temperature. The minimum rehydration was found in open sun drying.

– The coefficient of rehydration and moisture content in rehydrated samples increased with increase in drying air temperature from 70 to 50 ^{0}C temperature, whereas it decreased slightly from 50 to 40^0 C temperature and was found maximum at 50 ^{0}C temperature.

– The effect of loading density on rehydration characteristics was not significant.

– It was observed that the treatment has significant effect on rehydration. Thus results indicated that chemical treated samples had higher RR values than chemically blanched, blanched and untreated samples and more acceptable than others.

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