Effect of pre-treatments and drying methods on quality attributes of sweet bell-pepper (*Capsicum annum*) powder

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Revised: 9 April 2014 / Accepted: 14 April 2014 / Published online: 14 May 2014
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Abstract Pre-treatments and methods of drying for producing good quality dried bell pepper powder for use in the ready-to-eat (RTE) food products were optimized. Out of various pre-treatments used (blanching in boiling water, KMS, CA and combination of KMS + CA at different concentrations), soaking of bell pepper shreds in KMS@ 0.20 % + CA@ 0.50 % after blanching fasten the drying process (19.75 h) compared to control (22.60 h), when dried in mechanical dehydrator at 58 ± 2 °C. Blanching prior to drying improved the rate of drying and produced product with lower acidity (1.25 %). The samples (T_7) treated with KMS@ 0.20 % + CA@ 0.50 % significantly ($p < 0.05$) retained the ascorbic acid content (47.75 mg/100 g) and also attained highest score for colour (8.0), texture (7.5) and overall acceptability (7.5) compared to rest of the treatments. Among different methods of drying, pre-treated bell peppers dried in solar poly tunnel drier produced bright red coloured powder with relatively higher amounts of sugars and ascorbic acid content, hence was optimized. Visual lump formation was observed at 19.75 % and 18.50 % critical moisture contents, which equilibrated at 42 % and 45 % RH for bell pepper powders dried in a mechanical dehydrator and solar poly tunnel drier, respectively.

Keywords Sweet bell pepper · *Capsicum annum* · Pre-treatments · Drying · Solar drier · Blanching

The sweet bell pepper (*Capsicum annum*), is used world-wide either as a food or as a condiment. Now-a-days pepper are gaining popularity because they are cholesterol free, low in

sodium and calories and good source of vitamin A and C (Luning et al. 1995). They are known to possess antimicrobial activity (Wahba et al. 2010), reduce the risk of life-style related diseases such as arthritis, cancer, diabetes and CVDs (Lee et al. 1995; Eleyinmi et al. 2002; Donglin and Yasunori 2003; Nishino et al. 2009; Ozgur et al. 2011). Red bell pepper is an important ingredient in food industry where it is used as colouring and flavoring agent in making sauces, soups, pickles, pizzas etc. (Chuah et al. 2008).

In India, bell pepper has become one of the major commercial cash crops of mid hill regions of the country (Kumar and Verma 2009). In Himachal Pradesh, it is grown in an area of 2,260 ha with annual production of 35900 MT (NHB 2012). Bell peppers are perishable in nature and deteriorate within a few days after harvest especially in rainy season and these losses are further enhanced due to storage problems, marketing and lack of appropriate processing technologies (Kaushal et al. 2011). Thus, to minimize the losses and to provide remunerative returns to the growers, processing and preservation of bell pepper is the only alternative. The primary preservation method for any fruit and vegetable is drying which is accomplished either by traditional sun drying or industrially through solar dryers or mechanical dehydrators.

Moreover, the increasing demand of processed ready-to-eat (RTE) and ready-to-cook (RTC) products has resulted in increasing use of dried fruits and vegetable in convenience foods (Sharma et al. 2011; Take et al. 2012). Hot air drying has been reported for drying of red bell peppers for their use as spice and flavor ingredient (Bareh et al. 2012). Further, various pretreatments prior to drying like blanching, chemical treatments viz. sodium meta bisulphite, citric acid, calcium chloride, ascorbic acid, osmotic solution etc. have been suggested for obtaining better quality characteristics of chillies (Doymaz and Pala 2002; Wiriya et al. 2009; Tunde-Akintunde 2010) and tomato (Davoodi et al. 2007; Bareh et al. 2012). Therefore, chemically pre-treated and dehydrated red bell

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pepper powder can be easily incorporated in various home-made recipes like chutneys, sauces, soups etc. However, there is scanty information on preparation of red bell pepper powder with good quality attributes, so the study was undertaken with the objective to optimize different pre-treatments and mode of drying to obtain good quality dried red bell pepper powder in terms of nutritional value and organoleptic attributes.

Material and methods

Raw material fresh bell peppers var California Wonder (red coloured) were procured from the Department of Seed Production, Dr Y. S. Parmar University of Horticulture and Forestry, Solan (India). The diseased, bruised and spotted fruits were sorted out and then washed thoroughly in running tap water to remove dust and other extraneous materials from the surface of fruits. The fruits were shredded with a manual shredder and then the shreds were subjected to different treatments prior to drying in mechanical dehydrator.

Optimization of pre-treatments given prior to dehydration process The shredded red peppers were subjected to different pre-treatments as detailed below:

- T₁ Control (without any pre-treatment)
- T₂ Blanching (B)
- T₃ Blanching + KMS (Potassium meta bisulphite) dip @ 0.25 %
- T₄ Blanching + KMS dip @ 0.35 %
- T₅ Blanching + CA (Citric acid) dip @ 0.3 %
- T₆ Blanching + CA dip @ 0.6 %
- T₇ Blanching + KMS dip @ 0.2 % + CA dip @ 0.5 %
- T₈ Blanching + KMS dip @ 0.3 % + CA dip @ 0.25 %.

In each treatment (T₁ to T₈), 4 kg of bell pepper shreds were taken for experiment and each treatment was replicated thrice. For blanching, the shreds were dipped in boiling water for 3 min. Similarly, for chemical pre-treatments as obtained from the literature (Wiriya et al. 2009; Tunde-Akintunde 2010), the shreds after blanching were soaked in different chemical solutions viz. KMS (0.20, 0.25, 0.30, 0.35 %), CA (0.25, 0.30, 0.50, 0.60 %) and KMS + CA at different concentrations for 5 min., respectively. Afterwards, the samples (2 kg tray load) were dried in a laboratory mechanical dehydrator at 58 ± 2 °C till constant weight. In case of control, the shreds were dried without any pre-treatment.

Standardization of method of drying for drying of red bell peppers For standardization of mode of drying, optimized pre-treatment was used. Two different methods of drying viz. drying in mechanical dehydrator and solar poly tunnel drying were compared. For mechanical drying, a laboratory

tray drier of Wiswo make manufactured by M/s Widson Scientific Works, New Delhi having 90 × 60 × 90 cm dimensions and stainless steel perforated trays was used to dry the peppers. The pre-treated peppers (2 kg tray load) were surface dried and transferred to the mechanical dehydrator for drying at constant temperature of 58 ± 2 °C. The dehydrator was adjusted to the selected temperature and was turned on for at least 0.5 h before start of experiment to bring the drier to the desired temperature. In case of solar drying, samples were dried in solar poly tunnel drier (3 × 2 × 3 m) with an average sunlight of 9 h at a temperature ranging between 35.3 and 43.5 °C. After complete drying, the dried samples were ground in food processor mixer grinder to make powder. The dried powder was packed in common polyethylene (PE) pouches and stored at low temperature (4.0–7.0 °C) for further studies. The unit operations involved in the preparation of bell pepper powder are illustrated in Fig. 1.

Fig. 1 Flow diagram depicting various unit operations involved in drying of bell pepper powder

Table 1 Physico- chemical characteristics of fresh bell pepper

Parameters	Mean ^a ±SD
Weight (g)	47.50±2.0
Length (inches)	4.26±0.40
Diameter (inches)	3.13±0.15
Moisture (%)	80.0±1.5
Dry matter (%)	20.0±0.85
Titrateable acidity (% citric acid)	0.26±0.05
Ascorbic acid (mg/100 g)	92.85±0.60
Reducing sugars (%)	2.08±0.13
Total sugars (%)	5.14±0.18
Total carotenoids (µg/100 g)	816.0±0.23
Total phenols (mg/100 g)	820.25±1.08
Ash (g/100 g)	1.05±0.25
Crude fiber (g/100 g)	1.54±0.10

SD Standard deviation

^a Means of three replicates^b n=15

Analyses

Fresh bell pepper and its powder were analyzed for various physico-chemical parameters as per the standard methods. Random sample of 15 fruits were selected for physical parameters. The size of the selected fruits was determined by vernier calliper by measuring length and diameter. Total soluble solid (TSS) contents were measured by hand refractometer (Erma Make) after applying correction factor for temperature variation. Whereas, the moisture content, sugars, titrateable acidity (citric acid), ascorbic acid, carotenoids, crude fibres and ash content were estimated as per standard procedures (AOAC 1995; Ranganna 1997). Total phenols were determined by extracting with 80 % ethanol, color development with Folin-Ciocalteu reagent and reading optical density at 675 nm (Sadasivam and Manickam 1997). Equilibrium moisture content - relative humidity (EMC-RH) studies of the developed product were also conducted using standard method (Landrock

and Procter 1951). For sensory evaluation, dried powders were assessed for various parameters viz., color, texture, flavor and overall acceptability by a group of ten semi-trained panelists on 9-point hedonic scale with a maximum score of nine for “like extremely” and minimum of one for “dislike extremely” (Amerine et al. 1965).

All the analytical parameters were recorded in triplicate and mean values with standard deviation (SD) are presented, where applicable. Statistical analysis of data pertaining to physico-chemical characteristics was carried out by completely randomised design (CRD), whereas sensory analysis by randomised block design (RBD) (Mahony 1985; Cochran and Cox 1967).

Results and discussion

Physico-chemical composition of bell pepper The average weight, length and diameter of fresh red bell pepper var. California wonder was 47.50 g, 4.26 in. and 3.13 in., respectively (Table 1). The fresh bell pepper contained 80.0 % moisture, 20.0 % dry matter and 0.26 % titrateable acidity as citric acid. The results showed that fresh bell pepper had good amount of ascorbic acid (92.85 mg/100 g) and carotenoids (816.0 µg/100 g). Whereas, the insoluble material constituted about 1.54 % as crude fibre. The total and reducing sugars in the fresh bell peppers were estimated to be 5.14 and 2.08 %, respectively. The mineral matter, represented by total ash content amounted to 1.05 % in fresh bell pepper. The physico-chemical parameters of bell pepper recorded in the present study are in line with those reported by Kaushal et al. (2011) as 81.1 % moisture, 6.0°B TSS, 0.19 % acidity and 73.5 mg/100 g of ascorbic acid along with appreciable amounts of minerals (2.65). Thus, it is clear from physico-chemical composition of fresh bell pepper that it is a

Fig. 2 Effect of different pre-treatments on drying time and moisture content of dried bell pepper powder

Table 2 Effect of different pre-treatments on biochemical characteristics of dried bell pepper powder (fwb)

Treatments	TSS (°B)	TA (% CA)	TS (%)	AA (mg/100 g)	TP (mg/100 g)
T ₁ (Control)	10.88	1.38	8.60	59.56	286.32
T ₂ (B)	10.80	1.25	8.68	45.67	259.56
T ₃ (B + KMS@0.25 %)	11.03	1.28	8.85	45.90	265.23
T ₄ (B + KMS@0.35 %)	11.23	1.30	8.90	45.92	266.02
T ₅ (B + CA@0.30 %)	11.20	1.42	8.70	46.28	268.45
T ₆ (B + CA@0.60 %)	11.50	1.65	8.95	46.41	267.88
T ₇ (B + KMS@0.2 % + CA@ 0.5 %)	11.60	1.52	9.10	47.75	269.25
T ₈ (B + KMS@0.3 % + CA@0.25 %)	11.56	1.45	9.02	47.65	268.87
CD _{0.05}	0.18	0.12	0.20	0.13	0.38

Fwb Fresh weight basis, TSS Total soluble solids, TA Titratable acidity, TS Total sugars, AA Ascorbic acid, TP Total phenols

nutraceutical food being rich in ascorbic acid, carotenoids, polyphenols and minerals.

Effect of pre-treatments on the quality characteristics of dried bell pepper powder The effects of different pre-treatments on quality characteristics of dehydrated bell pepper during drying are presented in Fig. 2 and Table 2. A significant effect ($p \leq 0.05$) of pre-treatments on the drying characteristics of bell peppers at 58 ± 2 °C drying temperature was observed (Fig. 2). In comparison with pre-treatments, control samples showed higher final moisture even with longer period of dehydration (22.60 h). Blanching, prior to drying (T₂) has improved the drying rate, which might be due to rupturing of membrane and making peppers tender, thus facilitating faster removal of moisture. Similar observations were also reported by Eleyinmi et al. (2002), Davoodi et al. 2007; Tunde-Akintunde (2010) and Thakur et al. (2010). However, there was no significant ($p \leq 0.05$) difference in final moisture content of the dehydrated product for all pre-treated samples which ranged between 9.40

and 9.50 %. However, soaking of bell pepper shreds in KMS@ 0.20 % + CA@ 0.50 % after blanching required minimum drying time (19.75 h) compared to the control sample (22.60 h). Faster drying rates were also achieved by blanching, chemical pre-treatment by various workers (Eleyinmi et al. 2002; Tunde-Akintunde et al. 2005; Davoodi et al. 2007; Thakur et al. 2010; Abano et al. 2011).

Total soluble solids (TSS) among different treatments varied between 10.80 and 11.60°B with maximum recorded in control sample (Table 2). Slightly lower values of TSS in blanched samples were recorded which might be due to leaching losses of soluble substances. However, use of chemical pre-treatments improved the amount of total sugars of dried peppers. This might be due to the fact that blanching and other additives like KMS and CA might have checked the non-enzymatic browning during drying (Take et al. 2012). Similar changes in sugar content were also observed which was found to be more in control samples and less in KMS + CA treated samples. Similar observations were also reported in the literature by Gallali et al.

Fig. 3 Influence of different pre-treatments on sensory quality characteristics of dried bell pepper powder

(2000). Blanching of bell peppers (T_2) prior to drying produced a product with lower acidity (1.25 %) compared to the control sample (1.38 %) while maximum titratable acidity (1.65 %) was recorded in treatment T_6 which might be due addition of additional citric acid. The combined application of blanching with KMS and CA had also significantly retained the acidity after drying compared to blanched (T_2) and control (T_1) samples. The loss of acid content in blanched samples could be due to leaching losses during blanching. Among different treatments, the ascorbic acid content ranged between 45.67 mg/100 g and 59.56 mg/100 g with higher content recorded in control samples which might be due to lack of leaching losses as no blanching was done in control sample (Table 2). However, among different pretreated samples (T_3 to T_8), treatment T_7 recorded comparatively higher value of ascorbic acid (47.75 mg/100 g). Retention of vitamin C using pre-treatments like blanching with addition of additives like KMS, ascorbic acid, CA etc. has also been reported by various workers (Vega-Galvez et al. 2008; Wiriya et al. 2009; Take et al. 2012). Data presented in Table 2, indicated that that pre-treatments could not significantly preserve the degradation of phenolic compounds. Many authors reported significant losses in the content of vitamin C and polyphenols in vegetables after blanching (Selman 1994; Howard et al. 1999). These losses during aquathermal processing could be due to the leaching of these compounds in water (Sikora et al. 2008).

The effect of different pre-treatments on sensory attributes has also been assessed. The treatment T_7 (Blanching + KMS@0.20 % + CA@0.50) attained highest score for colour (8.0), texture (7.5) and overall acceptability (7.5) compared to

Fig. 4 Comparison of drying time and moisture content of dried bell pepper powder using different drying methods

other treatments, however the treatment T_7 was found statistically at par with treatment T_8 but differ significantly with rest of the treatments (Fig. 3). It is suggested that degradation of sugars caused browning pigment to develop due to maillard reaction and therefore lower score for colour was recorded in control sample (without pre-treatment). However, additive like KMS and CA inhibited the browning reaction by binding with the carbonyl group of reducing sugar and other compounds to retard the browning process (Take et al. 2012) resulting in bright red colour and characteristic acceptable flavor of the product.

Effect of methods of drying on the quality characteristics of bell pepper powder Among the two methods of drying, the minimum time (17.75 h) taken to dry the peppers (till their constant weight) was recorded in mechanical dehydrator compared to a maximum time of 38.5 h in solar poly tunnel drier (Table 3). The higher temperature of drying (55–60 °C) in mechanical dehydrator had resulted in faster removal of water and thus the drying proceeded faster than that of solar poly tunnel drier (Davoodi et al. 2007; Thakur et al. 2012). The moisture content of the samples was ranged between 9.50 and 9.85 % with lowest in mechanical dehydrator (Fig. 4). This finding is in line with that of Tunde-Akintunde et al. (2005) who reported that in mechanical dehydrator, drying takes place

Table 3 Influence of different methods of drying on chemical and sensory quality characteristics of dried bell pepper powders

Parameters ^a	Mechanical dehydrator (Mean ^b ±SD)	Solar poly tunnel drier (Mean ^b ±SD)
Chemical characteristics		
TSS (°B)	11.60±0.10	11.70±0.08
Titratable acidity (% CA)	1.52±0.05	2.05±0.03
Total sugars (%)	9.10±0.25	9.58±0.50
Ascorbic acid (mg/100 g)	47.75±1.20	57.15±1.02
Total phenols (mg/100 g)	269.25±1.65	270.65±1.45
Sensory characteristics^c		
Colour	7.25±1.20	8.00±0.75
Texture	7.00±1.15	7.00±1.05
Flavour	7.10±1.25	7.76±1.05
Overall acceptability	7.25±1.20	8.00±0.85

SD standard deviation

^a Calculations on fresh weight basis

^b Means of three replicates

^c Sensory evaluation on 9- point hedonic scale

Fig. 5 Moisture sorption isotherms for bell pepper powder dried in a mechanical dehydrator and solar poly tunnel drier

mostly in the constant drying rate period resulting in low moisture content. Comparison of different drying methods indicated that sample dried in solar poly tunnel drier had higher value for total soluble solids, acidity, sugars and ascorbic acid contents compared to those dried in mechanical dehydrator (Table 3). Higher value of acidity in poly tunnel dried samples might be due to longer drying time and pectic enzyme activity in first hours of the process (Okanlawon et al. 2002). Whereas, higher values for sugar content and ascorbic acid could be due to less incidence of non-enzymatic browning reactions at low drying temperatures. However, the total phenolic contents were not significantly affected by the methods of drying. It was observed that the texture rating of dried bell pepper was not significantly affected by drying methods. However, higher score for colour (8.00), aroma (7.76) and overall acceptability were obtained by the product dried in solar poly tunnel drier (Table 3). Results related to quality of solar poly tunnel dried sample are in agreement with those reported by Davoodi et al. (2007) in dehydration of tomato.

Moisture sorption isotherm of bell pepper powder Moisture sorption isotherms (Fig. 5) were drawn to evaluate the hygroscopicity of the powders. The bell pepper powder (Blanching + KMS 0.20 % + CA 0.50 %) dried in mechanical dehydrator had an initial moisture content (IMC) of 9.56 %, which equilibrated at 22 % RH. Similarly, those dried in solar poly tunnel drier had an IMC of 9.89 % and equilibrated at 25 % RH. Further, visual lump formation was noticed when the samples attained moisture contents of 19.75 % and 18.50 % (critical moisture content), which equilibrated at 42 % and 45 % RH for powders dried in mechanical dehydrator and solar poly tunnel drier, respectively. The results indicated that both the powders were hygroscopic in nature, however more hygroscopicity was observed in powders dried in solar poly tunnel drier and hence, required immediate packing.

Conclusion

The results have shown that blanching of bell pepper shreds in boiling water (3 min.) followed by pre-treatments with KMS 0.20 % + CA 0.50 % for 5 min. before drying in mechanical dehydrator at 55–60 °C not only reduced the drying time, but also gave higher colour stability. The higher drying temperature in mechanical dehydrator has resulted in faster drying than the other method of drying. However, drying bell pepper in solar poly tunnel drier produced better dried product compared to mechanical dehydrator with respect to ascorbic acid and total phenolic contents and better score for colour, flavour and overall acceptability of the dried product. Conclusively, it emerges that blanching of bell pepper shreds followed by soaking in KMS 0.20 % + CA 0.50 % solution and drying in

solar poly tunnel drier produced good quality product hence was standardized. Consequently, the developed technology has a scope for commercial exploration at industry level for manufacture of convenience food products from dried bell pepper powder. This in turn would lead to efficient and profitable utilization of peppers thereby, ensuring reduction in postharvest losses and better returns to the growers.

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