RESEARCH PAPER International Journal of Agricultural Engineering | Volume 10 | Issue 1 | April, 2017 | 191-198
e ISSN–0976–7223 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/10.1/191-198**

Effect of spray drying conditions and feed composition on sweet orange juice powder

H.S. SATHYASHREE AND C.T. RAMACHANDRA

Received : 17.01.2017; **Revised :** 19.03.2017; **Accepted :** 27.03.2017

See end of the Paper for authors' affiliation

Correspondence to :

H.S. SATHYASHREE
Department of Food Technology, College of Rural Home Science, University of Agricultural Sciences, DHARWAD (KARNATAKA) INDIA
Email : sathyashree931@gmail.com

■ **ABSTRACT :** The aim of this work was to study the influence of inlet air temperature and maltodextrin concentration on functional properties, microstructure and heat utilization efficiency of sweet orange juice powder by spray drying. The inlet air temperature of 130, 140 and 150 °C and maltodextrin concentration of 6 per cent, 9 per cent and 12 per cent were chosen as independent variables to produce the spray dried sweet orange juice powder. The mean value of functional properties of spray dried sweet orange juice powder *viz.,* flowability, cohesiveness, ascorbic acid and radical scavenging activity were 21.42-16.00, 1.19-1.25, 74.20-68.88 mg.100g^{-1} and 21.54-23.19 mg.g^{-1}, respectively, which were significantly affected ($p \leq 0.05$) by inlet air temperature and maltodextrin concentration. SEM analysis shown that surface was smooth with irregular shaped particles with complex link bridge. The heat utilization efficiency was done using MATLAB software. The maximum heat utilization efficiency (50.43%) of spray dryer was obtained at inlet air temperature of 130 °C with 9 per cent maltodextrin concentration.

■ **KEY WORDS :** Spray dryer, Sweet orange juice powder, Maltodextrin concentration, Inlet air temperature, SEM, MATLAB

■ **HOW TO CITE THIS PAPER :** Sathyashree, H.S. and Ramachandra, C.T. (2017). Effect of spray drying conditions and feed composition on sweet orange juice powder. *Internat. J. Agric. Engg.*, **10**(1) : 191-198, **DOI: 10.15740/HAS/IJAE/10.1/191-198.**

Sweet orange (*Citrus sinensis* L.) belongs to sub family Aurantoideae which is categorised under family Rutaceae which is of order Rosidae which comes under sub class Sapindales, Class Dicotyliophyta, Division Magnoliophyta and the Kingdom Plantae. Main varieties of sweet orange in India being cultivated on commercial scale are Blood Red, Mosambi and Sathgudi. Sweet oranges mature in 9-12 months. Main harvesting season in north India is from December to February, while in south India it is from October to March (Milind and Dev, 2012).

Sweet orange is rich source of vitamin A (1981 IU.100g^{-1}), vitamin C (65.69 mg.100 g^{-1}) and potassium (190-201 mg.100 g^{-1}), supplies around 116.2 per cent of daily value of vitamin C. It contains moisture content of 86.0 g.100 g^{-1} followed by carbohydrates 12.0-12.69 g.100 g^{-1}, calcium 40-43 mg.100 g^{-1}, protein 0.8-1.4 g.100 g^{-1}, fibre 0.8 g.100 g^{-1} and ash 0.3 per cent (Syed *et al.*, 2012).

Problem statement :

Sweet orange juice is one of the most perishable products with pH of 3.70 to 4.60 which is favourable for the growth and activity of spoilage micro-organisms like yeast, mold, lactic acid bacteria, fungi and pectin methylesterase enzyme which degrades the pectin present in sweet orange juice. Spoilage of sweet orange juice is primarily due to the proliferation of its natural acid tolerant and osmophilicmicroflora (Krinsky and Johnson, 2005).

Sweet oranges are not available round the year so should be processed in the form of juice; concentrate, squash, etc., to minimize the post harvest losses due to spoilage (Syed *et al.*, 2012). The shelf-life of the fresh sweet orange juice, squash and juice concentrate is 2-3 days (Purnima *et al.*, 2008), 40 days (Syed *et al.*, 2012) and 60 days (Huxuan *et al.*, 2015) under room temperature, refrigerated condition and isothermal condition, respectively. Due to food quality awareness, the consumer demand is increasing substantially for safer and fresh products (Rai *et al.*, 2007). There is a need to develop a technology that provides still longer shelf-life to the sweet orange juice and makes availability round the year. However, the detailed information about sweet orange juice powders does not exist in the literature.

Sweet orange juice powder can be used as flavouring agent, colouring agent in the preparation of products, instant food powder and in cosmetics products. Sweet juice powders have reduced volume, reduced packaging, easier handling and transportation and much longer shelf-life. Sweet orange juice powder can also be used as an important ingredient in the production of a wide range of food products such as chocolate and confectionery, health and personal care products, pharmaceuticals and cosmetics including soaps, creams, body lotions, shampoos, hair conditioners, after shave lotions, etc.

Spray drying :

Spray drying is a simplest and commercially used method for transforming a wide variety of liquid food products into powder form. Dehydration by spray drying is used in the wide range of products in food industries to produce dry powders and agglomerates. Economic considerations of this method include hygienic conditions during processing, operational costs and short contact time (Sagar and Suresh, 2010 and Yousefi *et al.*, 2011). The quality of spray dried food depends on the different factors of spray dryer operating systems.

In the present study, sweet orange juice was spray dried with different maltodextrin concentrations at different inlet temperatures. The effect of spray drying on the functional, reconstitution properties, heat utilization efficiency and microstructure of spray dried sweet orange juice powder are reported.

METHODOLOGY

Raw material :

Fresh sweet oranges (var. Sathgudi) were purchased from from horticulture section, Main Agricultural Research Station, University of Agricultural Sciences, Raichur.

Sample preparation :

The sweet orange juice was extracted from peeled fruits by using power operated screw press juice extractor. The juice was strained through muslin cloth and homogenization of sweet orange juice was done at 2000 rpm. Maltodextrin solution of different concentration *i.e.*, 6, 9 and 12 per cent was added separately to 100 ml of sweet orange juice for further processing.

Spray drying :

Homogenised solution was spray dried with different inlet air temperature of 130, 140 and 150° C at feed flow rate of 2.5 ml.min^{-1} at 1.5-2.0 kg cm^{-2} pressure. Sweet orange juice powder obtained from the spray drying was stored in PET-LDPE coextruded packaging material.

Functional properties of sweet orange juice powder:

Flowability and cohesiveness :

The spray-dried sweet orange juice powder was evaluated for their flowability and cohesiveness in terms of Carr's index (CI) and Hausner ratio (HR), respectively. Table 1 illustrates the specifications about the Carr's index and the Hausner ratio. Both CI and HR were calculated from the loose and tapped bulk densities of the spray dried goat milk powder, according to the formula given by (Oleyemi *et al.,* 2008).

Ascorbic acid :

Vitamin C content was estimated by volumetric method. Ascorbic acid content was estimated according the method given by Sadashivam and Manickam (1992).

Radical scavenging activity :

DPPH radical scavenging activity was determined according to (El-aal and Halaweish, 2010) with some modification.

Table A : Specifications for Carr's index and Hausner ratio

Sr. No.	Flowability	Carr's index (%)	Hausner ratio
1.	Excellent	0-10	1.00-1.11
2.	Good	11-15	1.12-1.18
3.	Fair	16-20	1.19-1.25
4.	Possible	21-25	1.26-1.34
5.	Poor	26-30	1.35-1.45
6.	Very poor	32-37	1.46-1.59
7.	Very very poor	>38	>1.60

Source: Lebrun *et al.* (2012)

SEM analysis of sweet orange juice powder :

The microstructure of the sweet orange juice powders was examined using a scanning electron microscope (Carl Zeiss, Zeiss group, Bangalore, Karnataka, India). SEM was operated with working distance (WD) of 8.3 mm using SE (secondary electron) detector with 15 kV (EHT-Extra high tension) at magnification of 1000× and 5500× and scan speed of 7 under the LAB 6 aperture with HV (high vacuum) mode.

Statistical analysis :

All the experiments in the study were conducted in triplicate and mean values were reported. The experimental design was done with the aid of the Design-Expert software version 7.7.0 (Statease Inc., Minneapolis, USA). Factorial Completely Randomised Design (FCRD) was used to analyse the data. Statistical significance of the terms in the regression equation was examined by analysis of variance (ANOVA) for each response. Values of p less than 0.05 indicate the model terms to be significant. The adequacy of regression model was checked by R^2 and Fisher's F-test (Montgomery, 2001).

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Functional properties of sweet orange juice powder:

Table 1 represents the functional properties of spray dried sweet orange juice powder from different treatments.

Flowability and cohesiveness :

In terms of handling properties, the spray-dried sweet orange juice powder had almost all similar flow characteristics for all treatments in the present study and were considered as "possible" and "fair" powders by their Hausner ratio (HR) given in Table 1 as classified in Table A. This was in accordance with their medium Carr's index (CI) (Table A) which indicated that their flowability was "possible" and "fair" (Table A). The reason behind this flowability at small particle sizes was due to the large surface area per unit mass of powder. There was more contact surface area between powder particles available for cohesive forces, in particular and

Table 1 : Quality parameters of spray dried sweet orange juice powder from different treatments

MD conc. (%)	Temp (° C)	Carr's index (%)	Hausner ratio (HR)	Ascorbic acid ($mg.100g^{-1}$)	RSA (%)
	130	16.00	1.19	74.20	73.56
6	140	18.35	1.22	73.68	70.94
	150	18.75	1.23	73.26	69.00
	130	19.14	1.23	72.89	65.68
9	140	20.00	1.24	72.42	65.80
	150	20.45	1.25	72.24	62.19
	130	20.93	1.26	70.08	61.02
12	140	21.42	1.27	69.32	59.57
	150	20.51	1.25	68.88	54.87

MD conc. = Maltodextrin concentration; Temp. = Temperature; RSA = Radical scavenging activity No. of replications = 3 frictional forces to resist flow (Fitzpatrick *et al.*, 2004 and Kim *et al.*, 2002). Teunou *et al.* (1999) also stated that the presence of water in a powder could significantly affect its flowability, sticking and caking properties. In general, the greater the water content of a powder, the more cohesive the powder becomes and the more difficult to flow. Patil *et al.* (2014a) reported the Carr's index of 41.00 to 46.00 per cent and Hausner ratio of 1.72 to 1.80 in spray dried guava powder at different maltodextrin concentrations (7, 9.5 and 12%) and inlet air temperatures (170, 180 and 185° C). Fig.1a and b depict the effect of inlet air temperature and maltodextrin concentration on Carr's index and Hausner ratio of spray dried sweet orange juice powder.

$$\text{Carrs index (\%)} = +19.52-1.79*A+0.36*A^2-0.80*B+0.42*B^2 0.84AB+0.063*A^2B+0.21*AB^2-0.25*A^2B^2 \quad ...(1)$$

$$\text{Housner ratio} = +1.24-0.026*A+5.185E\text{-}003*A^2-0.013*B+7.407E\text{-}003*B^2-0.011*AB-1.852E\text{-}003*A^2B-7.407E\text{-}004*AB^2-1.852E\text{-}003*A^2B^2 \quad ...(2)$$

Ascorbic acid :

The principal vitamin in citrus fruits is vitamin C, the amount of which varies with variety, maturity and other factors. Ascorbic acid is relatively stable in citrus products during processing and storage (Vishal, 2014). From the results, it was revealed that the sweet orange juice powder had the highest ascorbic acid content of 74.20 mg.100 g^{-1} at 6 per cent maltodextrin concentration and 130 °C inlet air temperature and the lowest ascorbic acid content of 68.88 mg.100 g^{-1} at 12 per cent concentration and 150 °C inlet air temperature. From the results it was found that as the inlet air temperature and maltodextrin concentration increased from 130 to 150 °C and from 6 to 12 per cent, respectively (Fig. 1c), Ascorbic acid of spray dried sweet orange juice powder was reduced by 7.16 per cent as the inlet air temperature and maltodextrin concentration increased from 130 to 150° C and from 6 to 12 per cent, respectively. Ascorbic acid content of sweet orange juice powder (74.20 to 68.88 mg.100 g^{-1}) was found to be greater than ascorbic acid content of fresh sweet orange juice (66.13 mg.100 g^{-1}). This might be due to the increase in concentration of product concentration at constant temperature and

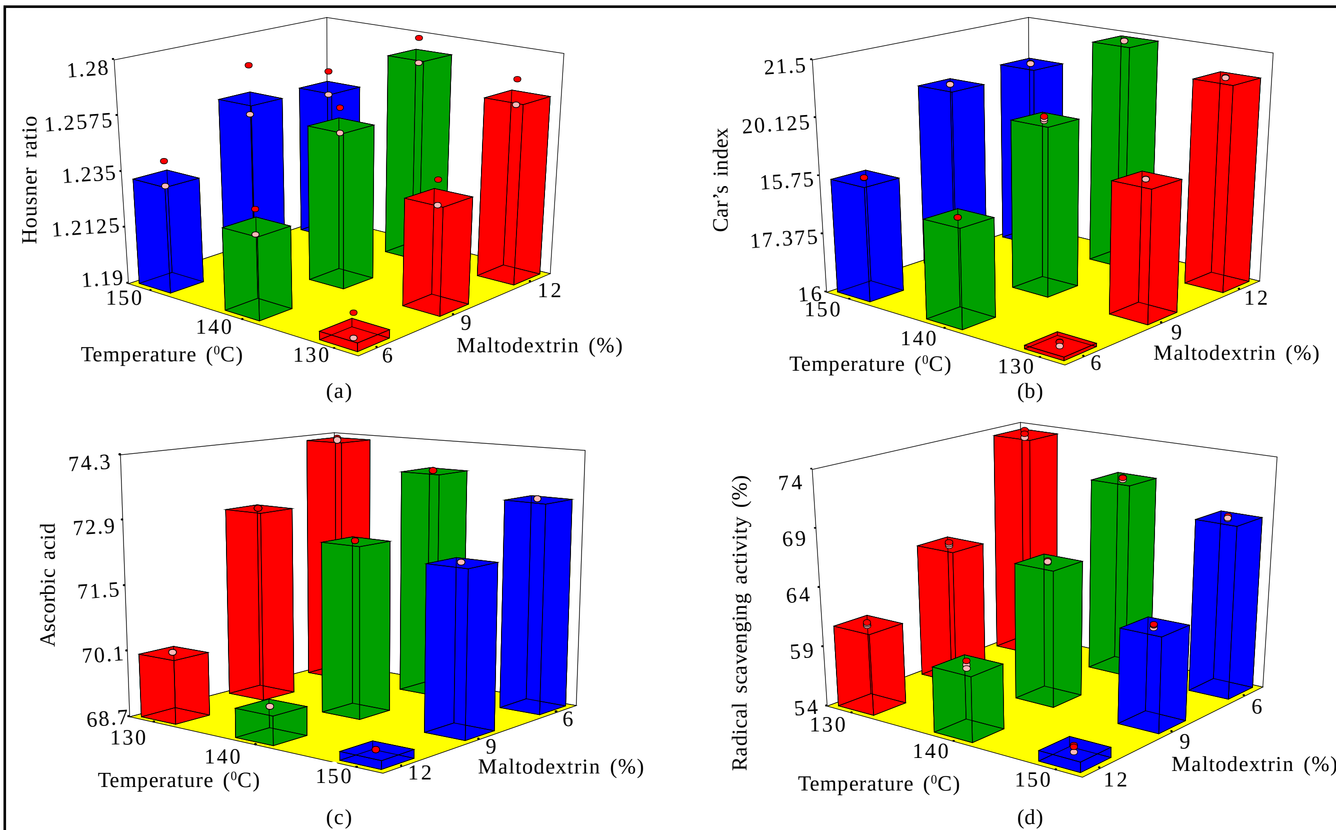

Fig. 1 : Effect of inlet air temperature and maltodextrin concentration on Carr's index(a), Hausner ratio(b), ascorbic acid(c) and radical scavenging activity(d) of spray dried sweet orange juice powder

Table 2 : Heat utilization efficiency (%) of spray dryer in different treatments

MD conc. (%)	Temp. (° C)	Heat utilization efficiency (%)
	130	48.46
6	140	44.76
	150	40.57
	130	50.43
9	140	44.78
	150	40.90
	130	49.44
12	140	44.78
	150	41.24

pressure while spray drying. Boiling led to maximize ascorbic acid losses however pressure steaming caused more retention of the losses as reported by Anil *et al.* (2014). In the present investigation ascorbic acid content was decreased with increase in inlet air temperature and maltodextrin concentration. Ascorbic acid was lost during drying as a result of the high temperatures and oxidation which destroy the heat sensitive compound (Patil *et al.*, 2014).

$$\text{Ascorbic acid (mg.100 g}^{-1}) = +74.33+0.016*A-1.0*A^2 0.62*B+0.72*B^2+0.47*AB+0.20*A^2B-1.03*AB^2+0.77*A^2B^2 \quad \ldots(3)$$

Radical scavenging activity :

It is depicted in the present investigation that the radical scavenging activity of sweet orange juice powder reduced quickly with increase in inlet air temperature and maltodextrin concentration (Fig.1d). From the results it was found that as the inlet air temperature and maltodextrin concentration increased from 130 to 150° C and from 6 to 12 per cent, respectively, radical scavenging activity of spray dried sweet orange juice powder was reduced by 25.40 per cent. As the inlet air temperature increased from 130 to 150 °C the radical scavenging activity decreased from 73.56 to 69.00 per cent, 65.68 to 62.19 per cent and 61.02 to 54.87 per cent at 6, 9 and 12 per cent of maltodextrin concentration, respectively. The possible explanation for the low free radical scavenging activity might be because of the exposure to higher temperatures which adversely affected the structure of phenolics causing its break down and/or synthesis into different forms and other reason might be due to high temperature (150° C) maintained in the spray dryer where the bioactive components might be volatilized (Krishnaiah *et al.*, 2012) and this might be due to the dilution effect of maltodextrin when its concentration was raised (Mishra *et al.*, 2013).

$$\text{Radical scavenging activity (\%)} = +64.74+6.43*A-0.18*A^2+2.02*B+0.70*B^2+0.38*AB-0.90*A^2B-0.93*AB^2+0.54*A^2B^2 \ldots(4)$$

SEM analysis of sweet orange juice powder :

It is very clear from SEM (Scanning Electron Microscope) images (Fig. 2) that the spray dried sweet orange powder were irregularly spherical particles with many shrinkages and dents on its surface. It was verified that particles were larger, amorphous, all pilled up and with a strong attraction for each other. Particles, slightly smooth with non spherical and fusion of particles with more complex link bridges was absorbed and this might be due to hygroscopicity (Sagar and Suresh, 2010). From the image it was revealed that the inlet air temperature had no effect on the surface smoothness of the particles, this, however, contradicts the observation of Nijdam and Langrish (2006) and Tonon *et al.* (2008). SEM study revealed that average size of particles in the powder that was dried at higher inlet air temperature (150° C) was smaller than the particles in powder dried at lower inlet air temperature (130° C). Similar finding was also observed by Cai and Corke (2000) for spray drying of *Amaranthus betacyaninpigments*. Probably, the particle size got fixed as large sized globules when there was more water in the material that was being dried. At higher inlet air temperature, due to rapid rate of drying the particles got fixed as smaller sized globules Mishra *et al.* (2013). In the present study average particle size ranged from 5.43 μm to 28.58 μm.

Effect of processing conditions on heat utilization efficiency of spray dryer during drying of sweet orange juice droplets :

The heat utilization efficiency of spray dryer was evaluated in MATLAB® R2009a platform. it is revealed that the heat utilization efficiency of spray dryer was found to be lowest in sweet orange juice of 6 per cent maltodextrin concentration which was dried at 150° C *i.e.*, 40.57 per cent, whereas the highest actual heat utilization efficiency of spray dryer was recorded in sweet orange juice of 9 per cent maltodextrin concentration which was dried at 130° C *i.e.*, 50.43 per cent (Table 2). Bahnasawy *et al.* (2010) and Wittaya and Boris (2015) reported that the energy consumption decreased with increasing both air temperature and atomization speed, where, it ranged from 36.47 to 53.29 $GJ.kg^{-1}$ for the milk-juice blends depending on both atomization speed and drying temperature, while it ranged from 38.53 to 45.70 $GJ.kg^{-1}$ for the whole milk. According to these authors the drying efficiency of spray dryer ranged from 42.09 to 71.03 per cent depending on drying temperature and atomization speed.

Conclusion :

– Inlet air temperature and maltodextrin concentration had a significant effect ($p \leq 0.05$) on functional properties of spray dried sweet orange juice powder.

– The mean value of functional properties of spray dried sweet orange juice powder *viz.*, Carr's index,

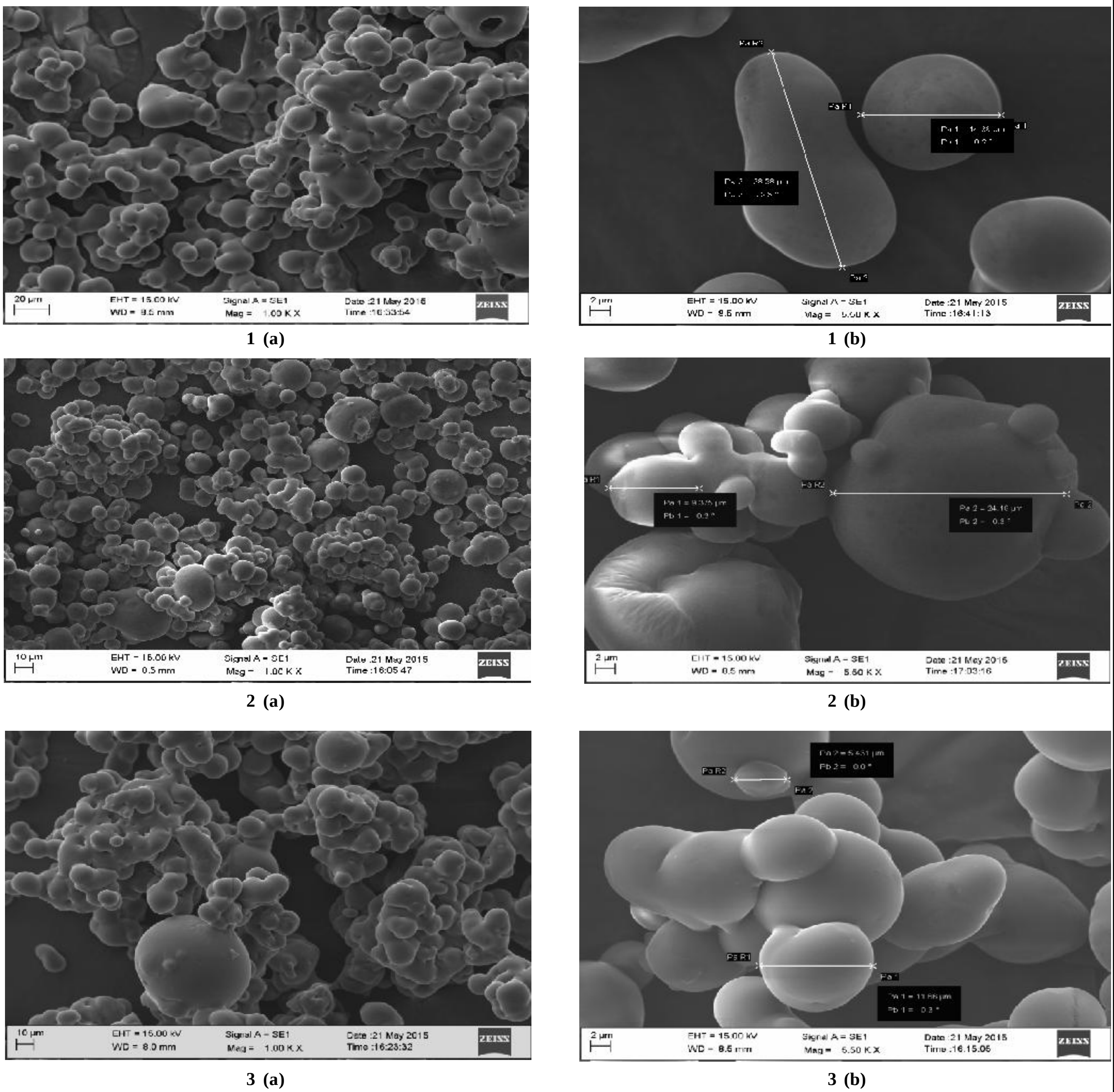

Fig. 2 : SEM micrograph of spray dried sweet orange juice powder with 9 per cent maltodextrin concentration dried at 130 °C (1a.1000×, 1b.5500×), 140 °C (2a.1000×, 2b.5500×) and 150 °C (3a.1000×,3b.5500×)

Hausner ratio, ascorbic acid and radical scavenging activity were 0.36 g.cc^{-1}, 0.45 g.cc^{-1}, 19.50 per cent, 1.10, 71.88 mg.100g^{-1} and 64.73 per cent, respectively.

– SEM analysis showed that smooth surface with irregular shaped particles, dents and fusion of granules with complex link bridge were observed in the spray dried sweet orange juice powder samples.

– A software programme was developed in MATLAB to compute the heat utilization efficiency of spray dryer. The maximum heat utilization efficiency (50.43%) of spray dryer was obtained at the inlet air temperature of 130° C with 9 per cent maltodextrin concentration

Acknowledgement :

The authors acknowledges financial support from the Department of Processing and Food Engineering, College of Agricultural Engineering, University of agricultural sciences, Raichur, Karnataka.

Authors' affiliations:

C.T. RAMACHANDRA, Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, RAICHUR (KARNATAKA) INDIA
Email : ramachandract@gmail.com

■ REFERENCES

Anil, K.C., Smita, S., Ravi, P.S. and Abhai, K. (2014). Determination of antioxidant capacity, total phenolics and antimicrobial properties of spray-dried guava extract for value-added processing. *J. Food Process Technol.*, **4**(9): 3-7.

Bahnasawy, A. H., Okasha, A.E. and Gonbeej, E.E. (2010). Performance evaluation of a laboratory scale spray dryer, *Misr. J. Agril. Engg.*, **27**(1) : 326-346.

Cai, Y.Z. and Corke, H. (2000). Production and properties of spray-dried *Amaranthus betacyanin* pigments. *J. Food Sci.*, **65** (6) : 1248-1252.

El-aal, H.A.A. and Halaweish, F.T. (2010). Food preservative activity of phenolic compounds in orange peel extracts (*Citrus sinensis* L.). *J. Appl. Life Sci. Environ.*, **53** : 233-240.

Fitzpatrick, J.J., Iqbal, T., Delaney, C., Twomey, T. and Keogh, M.K. (2004). Effect of powder properties and storage conditions on the flowability of milk powders with different fat contents. *J. Food Engg.*, **64**(4): 435-444.

Huxuan, W., Zhongqiu, H., Fangyu, L., Chunfeng, G., Chen, N., Yahong, Y. and Tianli, Y. (2015). Combined effect of sugar content and pH on the growth of a wild strain of Zygosaccharomyces rouxii and time for spoilage in concentrated apple juice. *Food Control*, **59**: 298-305.

Kim, H.J.E., Chen, D.X. and Pearce, D. (2002). Surface characterization of four industrial spray-dried dairy powders in relation to chemical composition, structure and wetting property. *Colloid Surf B: Bio inter*, **26**(3): 197-212.

Krinsky, N.I. and Johnson, E.J. (2005). Carotenoid actions and their relation to health and disease. *Molecular Aspects of Medicines*, **26**(1): 459-416.

Krishnaiah, D., Rosalam, S. and Rajesh, N. (2012). Microencapsulation of *Morinda citrifolia*L. extract by spray drying. *Chem. Eng. Res. Des.*, **90** (3) : 622–632.

Lebrun, P., Krier, F., Mantanus, J., Grohganz, H., Yang, M., Rozet, E., Boulanger, B., Evrard, B., Rantanen, J. and Hubert, P. (2012). Design space approach in the optimization of the spray-drying process. *European J. Pharm. Biopharm.*, **80**(1): 226–234.

Milind, P. and Dev, C. (2012). Orange: Range of benefits: A review. *Internat. Res. J. Pharm.*, **3**(7) : 59-63.

Mishra, P., Mishra, S. and Mahanta, C. (2013). Effect of maltodextrin concentration and inlet temperature during spray drying on physicochemical and antioxidant properties of amla (*Emblica officinalis*) juice powder. *Food Bioprod Process*, **92** (3) : 252-258.

Montgomery, D.C. (2001). *Design and analysis of experiments*. John Wiley and Sons, Inc, New York.

Nijdam, J.J. and Langrish, T.J. (2006). The effect of surface composition on the functional properties of milk powders. *J. Food Engg.*, **77** (4) : 919-925.

Olayemi, O.J., Oyi, A.R. and Allagh, T.S. (2008). Comparative evaluation of maize, rice and wheat starch powders as pharmaceutical excipients. *Nigerian J. Pharm. Sci.*, **7**(1):131-138.

Patil, V., Chauhan, K.A. and Singh, P.R. (2014a). Optimization of the spray-drying process for developing guava powder using response surface methodology. *Pow Technol.*, **253** : 230–236.

Patil, V., Chauhan, K.A. and Singh, P.S. (2014b). Influence of spray drying technology on the physical and nutritional properties of guava powder. *Internat. J. Curr. Microbiol. App. Sci.*, **3**(9): 1224-1237.

Purnima, R., Chhaya, R., Majumdar, G.C. and Sunando, D. (2008). Storage study of ultrafiltered mosambi [*Citrus sinensis* (L.) Osbeck] juice. *J. Food Process Pres.*, **32**(6): 923 - 934.

Rai, P., Majumdar, C.G., Gupta, D.S. and De, S. (2007). Effect of various pretreatment methods on permeate flux and quality during ultrafiltration of mosambi juice. *J. Food Engg.*, **78**(2):

561-568.

Sadashivam, S. and Manickam, A. (1992). *Biochemical methods for agricultural sciences*. Wiley Eastern Ltd. New Delhi, p 199-201.

Sagar, V.R. and Suresh, K.P. (2010). Recent advances in drying and dehydration of fruits and vegetables: A review. *J. Food Sci. Technol.*, **47**(1): 15-26.

Syed, M.H., Ghatge, U.P., Machewad, G. and Pawar, S. (2012). Studies on preparation of squash from sweet orange. *Open Access Scientific Reports*, **1**(6): 2-3.

Teunou, E., Fitzpatrick, J.J. and Synnott, E.C. (1999). Characterization of food powder flowability. *J. Food Engg.*, **39**(1): 31-37.

Tonon, V.R., Brabet, C. and Hubinger, D.M. (2008). Influence of process conditions on the physicochemical properties of acai (*Euterpe oleraceae* Mart.) powder produced by spray drying. *J. Food Engg.*, **88**(3): 411-418.

Vishal, N.S. (2014). The physicochemical and storage properties of spray-dried orange juice powder. *Indian J. Fundamental Appl. Life Sci.*, **4** (4): 2231-6345.

Wittaya, J. and Boris, G. (2015). Effect of process parameters on energy performance of spray drying with exhaust air heat recovery for production of high value particles. *Appl. Energ.*, **151** : 285-295.

Yousefi, S., Emam, Z. and Mousavi, M.S. (2011). Effect of carrier type and spray drying on the physicochemical properties of powdered and reconstituted pomegranate juice (*Punica granatum* L.). *J. Food Sci. Technol.*, **48**(6): 677-684.