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Studies on Dehydration of Fig (*Ficus carica* L.)

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Abstract

The fresh, ripe fig fruits of cultivar 'Poona' were subjected to pre-treatments of dipping oil with two concentrations i.e. 34 and 38 ppm. The fruits were dipped in dipping oil for 1 minute and then subjected to sulphur fumigation for 2 h. Fig fruits were then dipped in three concentrations of sugar syrup i.e. 50, 60 and 70°Brix for 48 hour to reach desired total soluble solids and then dried at 55°C temperature till 18-20 per cent (wb) moisture content was attained. While drying, moisture content, drying rate and moisture ratio were monitored at 1 hour interval. It was observed that rate of moisture reduction as well as drying rate was higher for figs treated with higher concentration of dipping oil (38 ppm) as well as immersed in sugar syrup solution of high concentration (60°Brix). Drying process showed only a falling rate period. The exponential equation of moisture ratio verses drying time provides excellent fit to the experimental data on drying of fig sample with highest drying constant (k) and R^2 value.

Key word : Dehydration, fig, sugar syrup, drying characteristics, dipping oil.

The fig (*Ficus carica* L.) is deciduous, subtropical plant belongs to family Moraceae and it is not only most ancient fruit but also a nutritive one. The total area under fig in the world is estimated about 4,19,000 ha (Crisosto *et al*., 2010). According to FAO, 2009, world total fig production is about to 11,85,000 tonnes (Gozlekci, 2011). The total area under fig cultivation in India is about 6000 ha (Shelar, 2010), of which 2000 ha is in Maharashtra with a production of 2705 MT (Joshi *et al*., 2009).

Fresh fig fruits are rich in amino acids, proteins, carbohydrates, fibers, minerals etc. (Aksoy *et al*., 2001 and Wang *et al*., 2003). The total mineral content of fig is two to four times that of other fresh fruits. Fig is richer in iron and copper content than most other fresh fruits as well as dry fruits and vegetables. According to USDA data for the Mission variety, dried figs are richest in fibre, copper, manganese, magnesium, potassium, calcium and vitamin K, relative to human needs (Joseph and Raj, 2011, Patil *et al*., 2017).

Fig is delicious, nutritive fruit and has medicinal properties such as reducing risk of cancer and heart diseases (Vinson, 1999). Figs have a laxative effect and contain many antioxidants. Dried fig is rich in minerals and highly recommended during pregnancy and for children because of its high iron content (Vinson, 1999; Miller *et al*., 2000).

Though the fresh ripe fruits are very delicious, they are highly perishable at room temperature, showing early senescence, fermentation and decay that limits their storage period and marketing life (Karabulut *et al*., 2009, Kad *et al*., 2011 and Yenge *et al*., 2018). Fungal decay of figs can result in extensive losses for the grower (Michailides *et al*., 2008). The post-harvest losses of fruits are reported to range from 30-40 percent in our country which reduces per capita availability by

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25 g (Subrahamanyam, 1986). Being highly perishable, fig cannot be stored for longer period even at refrigerated conditions (Hardenburg *et al*., 1986; Piga *et al*., 1995). Fully ripe fresh figs have shelf-life of about a week at 0°C with 90 per cent humidity. Whereas the dried figs can be stored for 6–8 months (Venkataratnam, 1988). Also, dehydration offers many advantages, such as reduced weight, inexpensive packaging, dry shelf stability and negligible deterioration in quality due to enzymatic changes.

Sun drying is the conventional method used to obtain dried figs, requiring only low capital, simple equipment and low energy input. But the general sun drying process dramatically increases the potential for Aspergillus fungal contamination, resulting in greater chances of aflatoxin development (Tosun and Delen, 1998). Moreover, the produce is exposed to direct solar radiations and as the drying parameters cannot be controlled, the product quality is low. Sun-drying is, therefore, not homogeneous, and the final product is caramelized and crusted. Direct exposure to the sun also destroys the color, vitamins, and flavor of the figs.

Mechanical air dehydration has gained importance because it has many advantages over sun-drying such as better sanitary conditions, drying parameters can be controlled thus, a more consistently uniform product can be achieved with less quality degradation, labor costs are lower (Barbosa-Ca & Vega-Mercado 1996). But figs dried by mechanical method possess some problem with the organoleptic properties (burnt taste) and structural collapse occurred (Papoff *et al*., 1998).

Poona fig is the major variety under commercial cultivation in Maharashtra. But this variety is not suitable for drying because of low sugar content and leathery appearance of the final product. Thus to get good quality dehydrated product from Poona fig, osmotic dehydration in combination with other drying methods is useful. Osmotic dehydration consists of partial removal of moisture from the produce by placing it in concentrated sugar or salt solution. Two simultaneous cross flows are induced: the solute in the solution penetrates into the product and the water in the products flows into the solution. This method of dehydration has potential advantage of less heat damage, good blanching effect, less enzymatic browning, better retention of flavour, colour, texture and energy saving because no phase change occurs

(Chaudhary *et al*.,1993). Moreover, for fruits and vegetables, the osmotic pretreatment prior to other drying methods improves its nutritional, sensorial and functional properties (Islam and Flink, 1982; Ertekin and Cataloz, 1996; Pokharkar, 2001 and Shelar *et al*., 2015).

Considering these points, there is greater scope and need for drying of figs for making it available throughout the year in good quality. The present investigation was, therefore carried out with an aim to study the drying behavior of fig.

Material and Methods

Fresh fig fruits of Cv "Poona" were obtained directly from the farmer's field located at Saswad (Pune, Maharashtra) and Kopargaon (Ahmednagar, Maharashtra) villages. Well matured fruits of uniform size and colour were harvested, randomly selected and brought to the laboratory. Pedicles of selected fruits were removed and fruits were washed with clean water and wiped dry.

Pretreatments : Prior to drying, fruits were pretreated, in order to reduce non enzymatic browning and speed up the drying process. Pretreatments were, dipping in 34 and 38 ppm dipping oil (ESSAR MK, Pune) for 1 min followed by sulphitation by fumigation of sulphur powder at the rate of 2 g per kg of fruits for 2 hour.

Osmo-Dehydration of fig fruits : The pretreated fruits were then dipped in 50, 60 and 70°Brix sugar syrup for 48 h to reach desired total soluble solids (TSS) and for partial dehydration of pretreated fig fruits. The soaked fruits were removed from sugar syrup after 48 h and surface of fruit was wiped out using cloth. Subsequently, these fruits were subjected to drying in the cabinet dryer at 55°C for 14-18 h to reduce moisture content to safe level of 18 to 20 percent w.b. (Thonta and Patil, 1988).

Drying rate and moisture ratio : During drying, moisture content was determined at regular interval of 1 h. Moisture content was determined in hot air oven at 70°C by standard A.O.A.C. (1990) method. Drying rate and moisture ratio was then calculated by using the formula given by Chakraverty and De (1981).

$$\text{Drying rate (g/min-100 g of d.m)} = \frac{\text{Amounr of moisture removed (g)}}{\text{Time taken min x Total bone dry weight of sample (g)}} \quad \text{...(i)}$$

$$\text{M. R.} = \frac{M - M_e}{M_0 - M_e} \quad \text{...(ii)}$$

where, M.R. = Moisture Ratio, M_0 = Initial Moisture Content, % (d.b.), M = Intermediate Moisture Content, % (d.b.) and Me= Equilibrium Moisture Content, % (d.b.).

Drying kinetics were calculated by plotting moisture content vs. drying time; drying rate vs. average moisture content and moisture ratio vs. drying time. The mathematical relationship between drying rate and drying time is developed for each sample and is given in Table 1.

The drying behavior of fig sample can be predicted using equation (i) i.e. first order kinetic model.

$$\frac{M - M_e}{M_0 - M_e} = e^{-kt} \quad \text{...(iii)}$$

$$\text{i.e. M. R.} = e^{-kt}$$

O_1 - 34 ppm dipping oil, O_2 - 38 ppm dipping oil, S_1 - 50°Brix sugar syrup solution S_2 - 60°Brix sugar syrup solution, S_3 - 70°Brix sugar syrup solution

Chemical analysis : The fresh as well as dried figs were analyzed for moisture content (%), total soluble solids (°Brix), titratable acidity (%), reducing sugar content (%) and total sugars content (%). The moisture content and TSS was determined by standard A.O.A.C method (1990) method. Reducing, non-reducing and total sugars were determined using Lane and Eynon method (1923)

Sensory evaluation : The samples of dried figs were evaluated for colour, texture, taste and overall acceptability by a panel of 10 judges on the basis of 9- point hedonic scale (Amerine *et al*., 1965.

Statistical analysis : The data obtained by chemical and sensory analysis was statistically analyzed in Factorial Completely Randomized Design (FCRD) with three replications as per the procedure described by Panse and Sukhatme (1967).

Results and Discussion

Chemical characteristics of fresh fig fruits : Data pertaining to chemical characteristics of fresh fruits are reported in Table 1. The moisture content of fresh Poona fig was ranged from 78.00 to 84.00 per cent. The average moisture content of twenty fruits recorded for moisture estimation was 80.00 per

Table 1. Chemical composition of fresh fig

	Moisture content (% w.b.)	TSS (°Brix)	Titra-table acidity (%)	Reducing sugar content (%)	Total sugar content (%)
Fresh fig	80.00	19.34	0.24	13.76	16.01

cent (w.b.). All the chemical parameters i.e. moisture content, total soluble solids, titratable acidity, reducing sugars and total sugars were in the range reported for this species.

Drying kinetics

Partial Dehydration : The data pertaining to effect of different pretreatments on moisture content of fresh Poona fig during partial dehydration for 48 h are presented in Table 2. From this data, it was observed that the rate of moisture loss increases with increase in dipping oil concentration as well as with increase in sugar syrup concentration. The maximum moisture loss was observed for figs treated with 38 ppm dipping oil and 70°B sugar syrup concentration.

Table 2. Effect of partial dehydration on moisture content of figs

Treatment	M.C. of fresh sample % w. b.	M.C. after osmosis, % w. b.	% reduc-tion in M.C.
O_1S_1	80.00	75.49	5.64
O_1S_2	80.00	75.23	5.96
O_1S_3	80.00	74.81	6.49
O_2S_1	80.00	74.75	6.56
O_2S_2	80.00	74.40	7.00
O_2S_3	80.00	74.00	7.50

Effect of dipping oil treatments and drying time on moisture content of figs for different sugar syrup concentrations are plotted in Fig. 1. From the data, it was found that as the dipping oil concentration increased from 34 to 38 ppm, the rate of moisture loss was also increased.

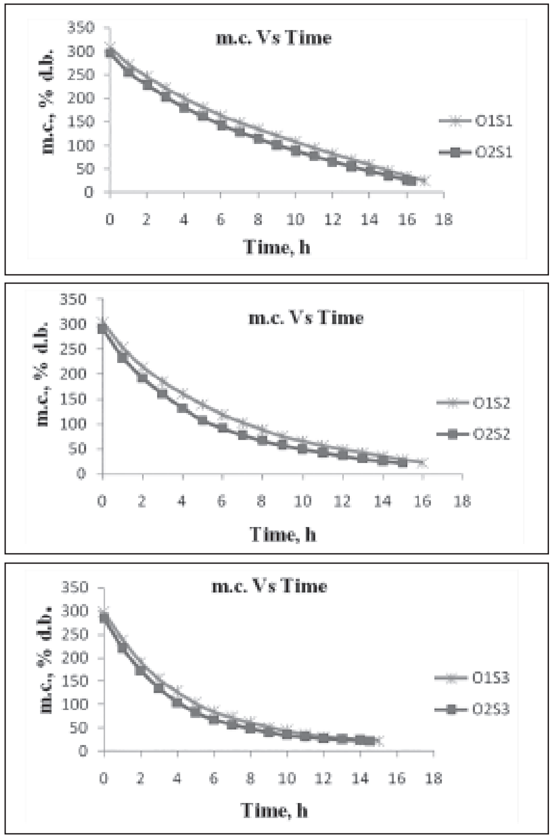

Fig. 1. Effect of dipping oil treatments (O_1 and O_2) on moisture content of osmotically dried figs at 50, 60 and 70°B sugar syrup (S_1, S_2 and S_3) concentrations.

Thus, minimum moisture content was observed with 38 ppm dipping oil treatment for all the sugar syrup concentrations. The time required for drying of fig fruits was decreased with increase in dipping oil concentration.

Moisture content and drying time : The effect of different sugar syrup concentrations and drying time on moisture content of dried figs for two different dipping oil treatments are plotted in Fig. 2. The rate of moisture loss increased with increase in sugar syrup concentration. This was due to increase in osmotic syrup concentration, increased diffusion changes and the osmotic pressure exerted on

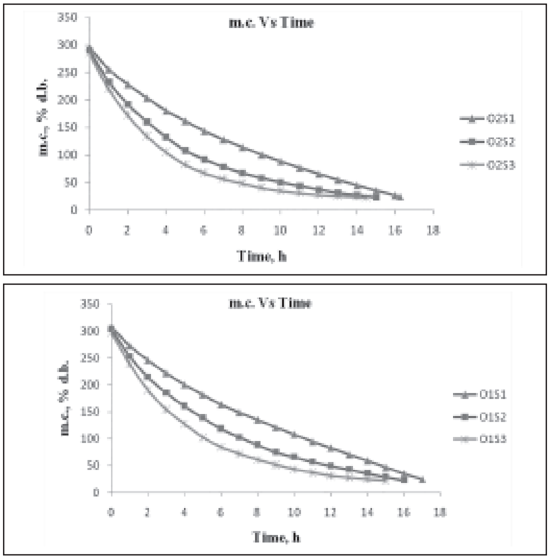

Fig. 2. Effect of different sugar syrup concentrations (S_1, S_2 and S_3) on drying rate of osmotically dried figs for 34 and 38 ppm dipping oil treatment (O_1 and O_2).

the fruit cell structure which consequently resulted in greater moisture reduction in more concentrated solutions. Higher solution concentration facilitated greater water-solute transfer between the fruit and the osmotic solution. This accounted for the decrease in instantaneous moisture content, with increasing osmotic solution concentration. Higher solution concentration promotes greater osmotic drive, due to higher solute penetration, which initiates the water flow out of the fruit (Falade *et al*., 2003). Also, drying time was decreased with increase in the sugar syrup concentration. Falade *et al*. (2003) reported the instantaneous moisture content (d.b) of osmosed cashew apples decreased with increasing immersion time and osmotic solution concentration. Jalali *et al*. (2008) found that the rate of moisture reduction was increased with increase in osmotic syrup concentration. From the experiment, it was revealed that the moisture content was decreased exponentially.

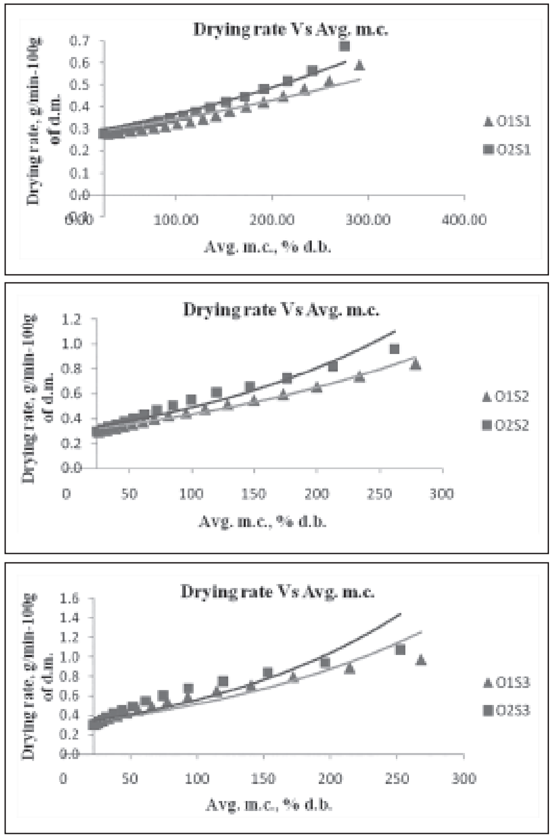

Fig. 3. Effect of dipping oil treatments (O_1 and O_2) on drying rate of osmotically dried figs at 50, 60 and 70°B sugar syrup (S_1, S_2 and S_3) concentrations.

Effect of dipping oil treatments and drying time on drying rate of figs for different sugar syrup concentrations are plotted in Fig. 3. The effect of different sugar syrup concentrations and drying time on drying rate of figs for two different dipping oil treatments is plotted in Fig. 4. The effect of drying time on drying rate showed all curves of exponential type. The drying rate was faster initially and then goes on decreasing with decreasing rate. Thus, drying process showed only a falling rate period. From the data, it was observed that the drying rate was increased with increase in sugar syrup concentration as well as dipping oil concentration. The similar results were obtained

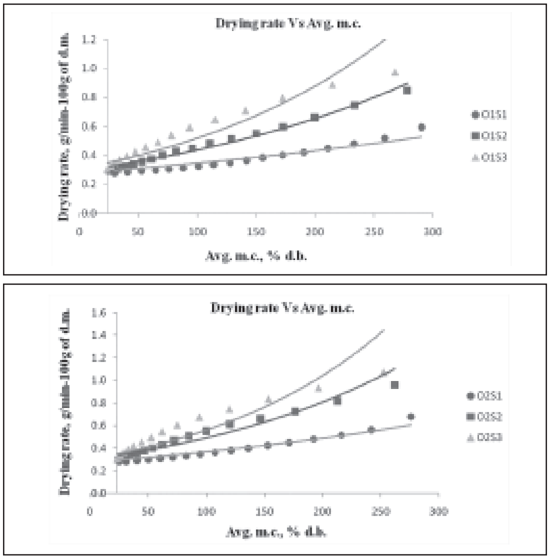

Fig. 4. Effect of different sugar syrup concentrations (S_1, S_2 and S_3) on drying rate of osmotically dried figs for 34 and 38 ppm dipping oil treatment (O_1 and O_2)

for drying of red bell peppers by Sanjuan *et al*., (2003).

Moisture ratio : The effect of drying time on moisture ratio of fig sample shows all curves of exponential type **(Fig. 5 and Fig. 6)**. The effect of drying time on moisture ratio of fig samples decreased from initial value of one to almost zero for all the treatments. From the plots of moisture ratio Vs drying time (Fig. 5 and Fig. 6), it was observed that the moisture ratio was decreased slowly for 34 ppm as compared to 38 ppm dipping oil treatment and rate of decrease was slow for 50°Brix as compared to 60 and 70°Brix sugar syrup concentrations. Equation (i) provides excellent fit to the experimental data on drying of fig samples.

The drying constant (K) was maximum for the 38 ppm dipping oil treatment with 70°Brix sugar syrup concentration (O_2S_3). This was because of higher drying rate for the same treatment. The moisture content at the desired time interval could be predicted using value of drying constant if initial and equilibrium moisture contents are known.

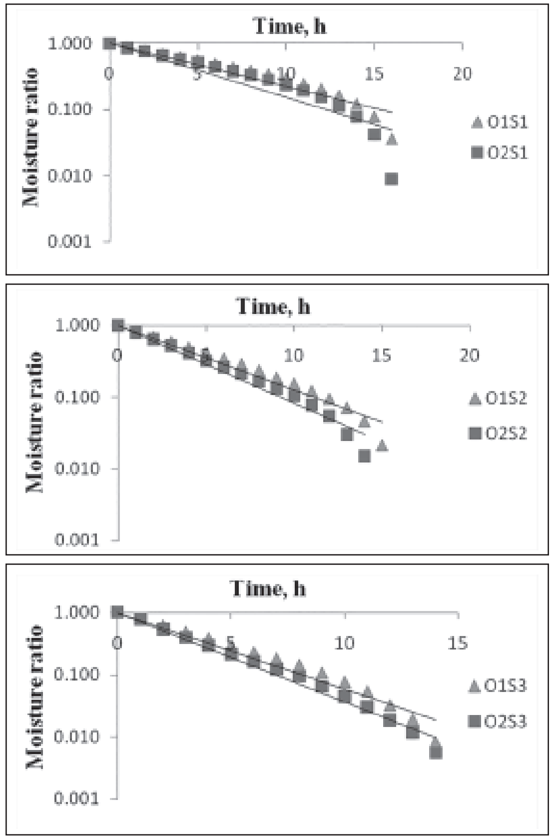

Fig. 5. Effect of dipping oil treatments (O_1 and O_2) on moisture ratio of osmotically dried figs at 50, 60 and 70°B sugar syrup (S_1, S_2 and S_3) concentration.

Chemical analysis of dried figs : The data pertaining to various chemical parameters of dried fig are reported in Table 4. There was reduction in moisture content and titratable acidity of dried fig after drying whereas TSS, reducing sugars and total sugars were increased after drying. The effect of dipping oil treatment and sugar syrup concentration on acidity content of dried fig was found to be non significant but acidity decreases with increase in the sugar syrup

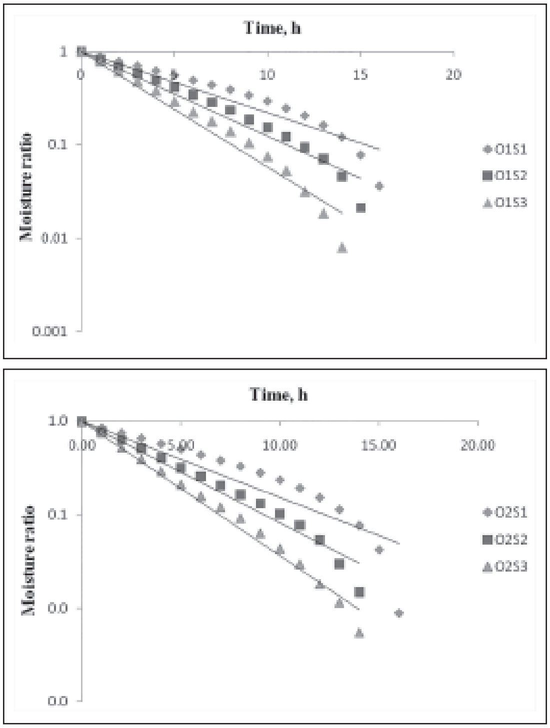

Fig. 6. Effect of different sugar syrup concentrations (S_1, S_2 and S_3) on moisture ratio of osmotically dried figs for 34 and 38 ppm dipping oil treatments (O_1 and O_2).

Table 3. K and R^2 values of mathematical expression for different treatments of fig sample

Treatments	K value, h^{-1}	R^2
O_1S_1	0.15	0.893
O_1S_2	0.20	0.953
O_1S_3	0.28	0.954
O_2S_1	0.18	0.818
O_2S_2	0.25	0.960
O_2S_3	O.33	0.982

concentration. The decrease in acidity with sugar concentration has been reported in dried guava and papaya fruit (Mehta and Tomar, 1980) and in mango, guava slices and in aonla segment (Kumar and Sagar, 2009). Dried figs

Table 4. Chemical composition of fresh dehydrated figs

Treat-ments	Moisture content (%)	TSS (°Brix)	Titra-table acidity (%)	Reducing sugar content (%)	Total sugar content (%)
O_1S_1	19.56	50.50	0.090	53.55	56.10
O_1S_2	18.70	53.00	0.086	55.34	58.10
O_1S_3	18.38	55.21	0.084	53.21	56.18
O_2S_1	19.24	51.50	0.088	54.49	57.14
O_2S_2	18.30	54.13	0.085	56.21	59.15
O_2S_3	18.09	55.89	0.083	53.71	56.82
SEm(±)	0.028	0.030	0.118	0.042	0.050
CD at 5%	0.079	0.086	NS	0.120	0.143

pretreated with 38 ppm dipping oil and osmosed with 60°Brix sugar syrup solution contained maximum chemical constituents.

Sensory evaluation of dried figs : Sensory score appear to be useful to select the best osmotic concentration and dipping oil treatment as chemical constituents were very indistinctness. The mean values for colour, appearance, texture, taste and overall acceptability of dried figs are presented in Table 5.

One of the main quality parameter is colour for dried figs because its lighter colour is important in world market (Sen *et al*., 2010). The colour of figs changes during drying. This colour change was made by many reactions such

Table 5. Sensory quality of fresh dehydrated figs

Treat-ments	Colour and appea-rance	Taste	Texture	Overall accept-ability
O_1S_1	7.30	7.00	7.00	7.10
O_1S_2	8.00	6.12	8.00	7.33
O_1S_3	7.00	5.00	6.00	6.00
O_2S_1	7.20	7.00	7.00	7.07
O_2S_2	8.10	8.00	8.51	8.20
O_2S_3	6.60	6.00	6.80	6.46
SEm(±)	0.050	0.037	0.095	0.026
CD at 5%	NS	0.106	NS	0.074

as phenolics polymerization and maillard reactions which may cause an increase in darker colour.

Similarly average score for taste, texture and overall acceptability were higher for figs treated with 38 ppm dipping oil and dipped in 60°Brix sugar syrup solution.

Conclusion

Moisture reduction and drying rate decreases with increase in concentration of dipping oil as well as sugar syrup solution. Drying of fig occurs in falling rate period. Acceptable dried figs can be prepared by using 38 ppm dipping oil, sulphitation, osmosis at 60°Brix sugar syrup solution followed by cabinet drying at 55°C.

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