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Effect of drying methods on physical and chemical characteristics of dried Byadagi chilli

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ABSTRACT

The effect of drying methods and pre-treatments on the quality of dried Byadagi chilli (*Capsicum annuum* Linn.) were investigated. The temperature of open yard sun drying around 37°C and solar tunnel drying around 60°C was used. The quality parameters viz., moisture content, colour (L*, a*, b* values), ascorbic acid content, capsaicin content, titrable acidity and aflatoxin content. The solar tunnel-dried (STD) sample gave more bright-red colour and contained higher ascorbic acid content than the open yard sun-dried (OYSD) samples (P<0.05). The aflatoxin content was monitored using Enzyme Linked Immuno Sorbent Assay (ELISA). The Byadagi chilli dried in solar tunnel dryer showed less aflatoxin content than open yard sun drying. In addition, the unique visible attributes in the STD and OYSD samples were bright and dull, respectively.

Key words: Drying chilli, quality, ascorbic acid, capsaicin, aflatoxin

Dried chilli is a spice product and the one most widely used as condiments for flavouring and colouring in Asian cuisines (Jitbunjerdkul and Kijroongrojana, 2007). The quality of dried chilli is assessed by a number of different parameters such as colour, ascorbic acid content, capsaicin content, titrable acidity and aflatoxin content (Kim *et al.*, 2006; Wang *et al.*, 2009). Traditionally, dried chilli is obtained by sun drying (SD) (Condori *et al.*, 2001). It takes about 7-20 days (depending on the weather conditions) to reduce the moisture content to 10-15% (Hossain, 2003; Oberoi *et al.*, 2005). Since dried chilli is susceptible to fungal proliferation, this process creates favorable conditions for mycotoxins contamination (Bircan, 2005). To prevent fungal proliferation, different drying methods have been employed in the processing of dried chilli. Currently, solar tunnel drying (STD) is popular for drying chilli due to a relatively short drying time, uniform heating and more hygienic characteristics. The temperature ranges from 45 to 70°C (approximately 10% of moisture content) and this reduces drying time to less than 39 hrs. This temperature range gives maximum colour values and minimizes the loss of volatile oils and discolouration (Berke and Shieh, 2001; Diaz-Maroto *et al.*, 2003). However, solar tunnel dryer (STD) is the best method of water removal as it gives a final product of the highest quality. It has been found that this is the most suitable drying method for maintaining the colour quality of dried chilli and meet the requirement of the consumers compared to open yard sun drying (OYSD). Therefore, this present work will focus on the effects of drying methods on the quality characteristic of dried chilli.

MATERIAL AND METHODS\

Raw materials

Freshly harvested ripened chillies (*Cv. Byadagi* kaddi) were procured from the field of a progressive farmer of Matamari village, Raichur district, Karnataka and transported to the laboratory within 5 h of harvesting and the chillies were washed in tap water to remove the soil and dirt adhering to the fruits. The colour and degree of maturity of the samples represent the stages of maturity. The chillies were washed in tap water to remove the soil and dirt adhered to the fruits. The whole pods of chillies were pre-treated in selected emulsions and dried in STD and under OYSD. The treatment combinations were laid out in two factorial randomized block design with

three replications. The details of pre-treatments selected for the investigation were as given below.

T_0 – Control (without pre-treatment).
T_1 – Soaking chillies for 5 min in dipsol: K_2CO_3 (25 g)+gum acacia (1 g)+butylated hydroxy anisol (0.01 g)+refined groundnut oil (10 g) (CFTRI, 1979)
T_2 – Soaking chillies for 5 min in KNO_3 (25 g)+gum acacia (1 g)+butylated hydroxy anisol (0.01 g)+refined ground nut oil (10 g) (Papa kumari *et al.*, 2003).
T_3 – Soaking chillies for 20 min in 0.5 per cent citric acid (Tontand and Therdthai, 2009).

The chemicals used for pre-treatment of chilli were of analytical grade and procured from M/S. Industrial Laboratory Equipment (ILE), Bangalore.

It was then dried using two drying methods: solar tunnel drying (STD); and open yard sun drying (OYSD). The fresh *Byadagi* chilli without pretreatment was used as a control.

Open yard sun drying was conducted by spreading pretreated chilli on a trays in a single layer and deep bed layer exposed directly to sunlight (approximately 37◦C). The thermometer and hygrometer was placed on an empty tray of chilli. This method was dried for 8 hr per day. Solar tunnel drying was performed approximately at 56°C in a solar tunnel dryer. The pretreated chillies were placed on perforated tray which has an area of approximately 0.2 m^2. All the dried chilli samples were taken when the moisture content obtained was approximately 10%. The final product was stored at room temperature in a desiccator and subjected to analysis within a week of collection.

Measurement of physical and chemical qualities

Determination of moisture content and water activity (a_w)

The AOAC method (A.O.A.C, 2000) was used for determining the moisture content using a hot air oven at a temperature of 105◦C. Water activity was measured using a water activity meter (Novasina, Thermostanter) calibrated as a standard sample with a known value (Range 0.11-0.99). The experimental data was obtained using 3 replications.

Colour measurements

All samples were spread out to evaluate for colour using a colour scan spectrophotometer CIELAB scale at 10° observer and at D_{65} illuminant. Instrumental colour data was provided using the CIE system in terms of L* (lightness), a*(redness and greenness) and b*(yellowness and blueness).

Determination of pH

Five grams of *Byadagi* chilli ground samples was diluted with 10 ml of distilled water. It was measured for the pH value at ambient temperature with a pH meter (Satorious, USA) which was calibrated with pH 4.0 and 7.0 (A.O.A.C., 2000).

Determination of titrable acidity

The titrable acidity was determined for both fresh and dried *Byadagi* chilli by volumetric method (adapted from Shrivastava and Sanjeev kumar, 1994). The whole chilli without stalk was crushed using 10 ml distilled water in pestle and mortar. The extract obtained was filtered through filter paper (Whatman No. 41). The filtered extract was titrated against 0.1 N of NaoH using a few drops of 1% phenolphthalein solution as an indicator until pink colour end point was obtained. The percentage of titrable acidity was calculated by using the following formula.

$$Titrable\ acidity\ (\%) = \frac{Titre\ value\ (ml) \times 0.1 \times 0.062}{Volume\ of\ sample\ (ml)} \times 100$$

Determination of ascorbic acid

Ascorbic acid was estimated by volumetric method. Exactly 5 ml of the working standard solution was pipetted into a 100 ml conical flask, to this 10 ml of 4 per cent oxalic acid was added and this was turned to pink colour end point when titrated against the dye solution (V_1 ml). The amount of the dye consumed was equivalent to the amount of ascorbic acid. One gram chilli sample was weighed and crushed using 4% oxalic acid. The extract was filtered through Whatman No. 41 filter paper and made the volume up to 100 ml. Five ml of the extract was pipetted out into conical flask, 10 ml of 4% oxalic acid was added and was titrated against the dye (V_2 ml) (adapted from Sadashivam and Manickam, 1992). The amount of ascorbic acid present in the sample was calculated using the following equation.

$$Ascorbic\ acid\ (mg\ 100\ g^{-1}) = \frac{0.5\ (mg) \times V_2\ (ml) \times 100\ (ml)}{V_1\ (ml) \times 5\ (ml) \times Weight\ of\ sample} \times 100$$

Determination of capsaicin content

The capsaicin content of *Byadagi* chilli was estimated by spectrophotometric method (adapted from Sadashivam and Manickam, 1992).

The dried *Byadagi* chilli was ground and passed through ASTM test sieve No. 40 (425 μ). Two grams of chilli was dissolved in 70 ml of ethyl acetate and was transferred to volumetric flask to make up the volume to 100 ml. The solvent was left to stand for 24 h to extract the capsaicin. From this 1 ml of extract was pipetted out and made up to 25 ml using ethyl acetate to this 0.5 ml vanadium oxychloride solution was added (just before taking reading) and absorbance was read at 720 nm VIS spectrophotometer (Systronics, model 106). A standard curve was plotted using 0.5, 1.0, 1.5, 2.0 and 2.5 ml of standard capsaicin solution containing 50, 100, 150, 200 and 250 μg of capsaicin on X-axis against absorbance on Y-axis. A straight line was drawn through the origin. A plateau was drawn as per the points obtained on the graphs. The concentration of capsaicin in chilli was found out by pointing on the graph. The percentage capsaicin content of *Byadagi* chilli was calculated using the following formula.

$$Capsaicin\ (\%) = \frac{\mu g\ \ Capsaicin}{1000 \times 1000} \times \frac{100}{2} \times \frac{25}{1}$$

Estimation of aflatoxin in Byadagi chilli

Quantitative estimation of aflatoxin

Quantification of aflatoxin in *Byadagi* chilli was done by using commercially available Maxi-sorp nunc ELISA 96 well plate (BIOTEK ELx800-MS). At the end by analysing all the samples, the amount of aflatoxin was correlated with different drying methods. An indirect competitive ELISA technique was used by previous workers (adapted from Devi *et al.,* 1990; Thirumala Devi *et al.,* 2000). The ELISA work was carried out at the Department of Plant Pathology, College of Agriculture, University of Agricultural Sciences, Raichur, Karnataka. Prior to utilizing this procedure, concentrations of various reagents required to give optimum results were determined.

Chilli fruits (25 g) used for aflatoxin determination were dried at 40°C for 2 days, powdered and extracted with 125 ml of 70 per cent of methanol containing 0.5% KCl. The extract was filtered and diluted to 1:10 in PBST–BSA. This was used as diluents for preparing aflatoxin standards. Concentrations of the standards used were 100, 50, 25, 12.5, 6.25, 3.12, 1.56 and 0.78 ng ml^{-1} and each concentration was duplicated in two wells. Similarly each test sample was duplicated in two wells. One hundred μl of each test sample extract or standards were mixed with 50 μl of antiserum diluted to 1:10000 in 0.2 per cent PBS–BSA. This step was followed by the addition of alkaline phosphate labelled goat antirabbit IgGs conjugate diluted to 1:2000 in PBST–BSA. The substrate was p–nitro phenyl phosphate prepared in 10 per cent diethanolamine. The plates were incubated at room temperature and then read in an ELISA reader. Absorbance at 405 nm in an ELISA reader was measured (preferably automatic) using the values obtained for aflatoxin B_1 standards draw a curve with the help of a Computer software Microsoft Excel (Microsoft office 2007), the values of concentration for aflatoxin standards were plotted on X–axis and OD values were plotted on Y–axis. Aflatoxin concentration in the sample extract was determined using the following formula (adapted from Reddy *et al.,* 2001).

$$Aflatoxin\ \ concentration\ (\mu g\ kg^{-1}) = \frac{A \times D \times E}{G}$$

Where,

A = AFB_1 concentration in diluted or concentrated sample extract (μg ml^{-1})

D = Times dilution with buffer

E = Extraction solvent volume used (ml)

G = Sample weight (g)

A Completely Randomized Design (CRD) was planned for this experiment, with three replications. Data was subjected to analysis of variance (ANOVA). Least Square Design (LSD) was used to test the significant difference between each pairs of means. A 99% confident interval ($P<0.01$) was set throughout the data analysis to identify significant differences. The data averaged into respective parameter requisites was subjected to suitable transformation. The physical and chemical qualities of fresh and dried chilli using different drying methods were assessed by Computer software Microsoft Excel (Microsoft office 2007). The standard procedures in agriculture statistics given by Gomez and Gomez (1976) was consulted throughout.

RESULT AND DISCUSSION

Effect of drying on physical and chemical qualities

The physical and chemical qualities of all the chilli dried with different drying methods and different pretreatments were presented in this section. The initial average moisture content and water activity of fresh chilli were 339.14% (d.b.) and 0.99, respectively. The average moisture contents of all dried chilli were 10% d.b (Figure 1 and 2). and water activities varied between 0.51 and 0.68. The moisture

content of chilli is very important because it is strongly correlated with the stability of ascorbic acid and pigment as well as any hygiene problems (Kim *et al.*, 1982). Lee *et al.* (1992) reported that the moisture content of dried chilli ranged from 10 to 14% which could retard colour loss. Moisture content lower than 8% could accelerate pigment destruction. Wall and Bosland (1993) reported that final moisture content at 8% is ideal. Moisture content above 11% allows mould to grow and moisture content below 4% causes an excessive colour loss. However, chilli generally needs to be dried to a moisture content of below 13% in order to prevent potential aflatoxin production (Pitt and Hocking, 1997).

Indian chillies contain about 16% (d.b.) moisture content, while 10-11% (d.b.) is the acceptable limit in the export market (Singhal, 1999). As per the recently introduced European Union (EU) regulations, only 5 μg kg^{-1} of aflatoxin B_1 and 10 μg kg^{-1} of total aflatoxins are allowed in chillies.

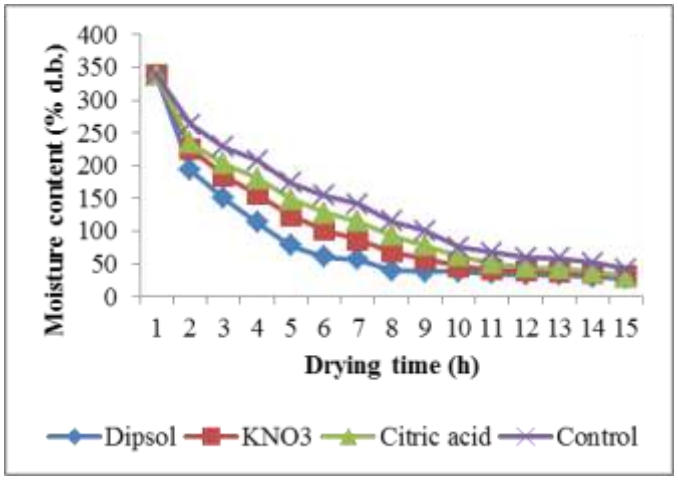

Fig 1. Effect of pre-treatments on reduction in moisture content of *Byadagi* chilli dried in solar tunnel dryer

The pH and titrable acidity of dried chilli were significantly different among the pretreatments ($P \leq 0.05$). The pH value of all dried chilli varied between 3.21 and 4.84, while the titrable acidity for different pre-treatments dried under solar tunnel dryer ranged from 0.035 to 0.049 per cent (Fig 3.). The highest titrable acidity was found in KNO_3 pre-treatment (0.055%) and the lowest in dipsol pre-treatment (0.035%). In case of OYSD, the titrable acidity varied from 0.057 to 0.066 per cent. The highest titrable acidity was found in KNO_3 (0.066%) and the lowest in dipsol (0.057%).

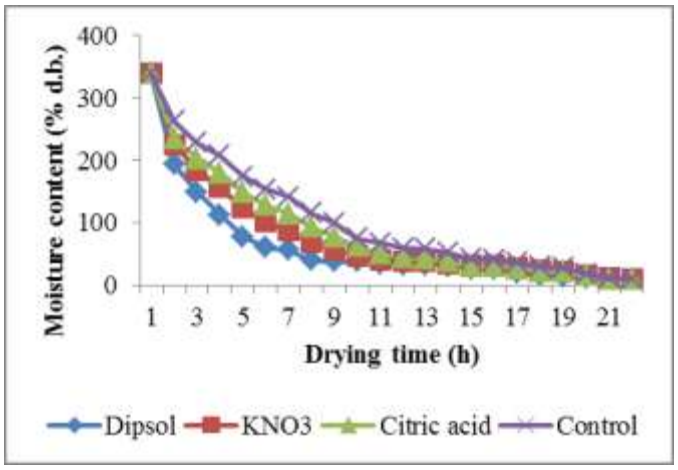

Fig 2. Effect of pre-treatments on reduction in moisture content of *Byadagi* chilli dried under open yard sun drying

The OYSD dried samples had higher titrable acidity content for different pre-treatments compared to STD method. Fresh chilli had the highest pH and was least in titrable acidity values. Citric acid is the main organic acid present in chilli (Koh, 2005). However, variations of pH and titrable acidity are possible due to variations caused by contamination from microorganisms.

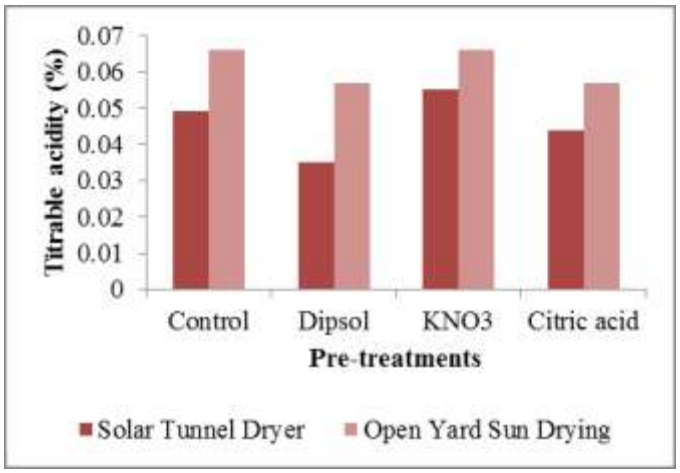

Fig 3. Effect of pre-treatments on titrable acidity content of *Byadagi* chilli with two drying methods

Microorganisms, mainly lactic acid bacteria, produce organic acids, which then increase in titrable acidity content and decrease in pH value. Generally, sun dried chilli becomes more contaminated with microorganisms than in the solar tunnel drying process (Mangaraj *et al.*, 2001). Hence, these variations in pH and titrable acidity can be used to indicate the safety of food.

The effect of different drying methods on the colour qualities of chilli is shown in Figure 4. Lightness (L*), redness (a*) and yellowness (b*)

were significantly different among the pretreatments (P≤0.05). It was shown that the L^* value for different pre-treatments under solar tunnel dryer were found to be 34.41 in dipsol, 30.36 in KNO_3, 30.78 in citric acid and 32.13 in control. The a^* and b^* values for different pre-treatments under solar tunnel dryer varied from 5.01 to 9.54 and from 1.06 to 3.31, respectively. In case of OYSD, the L^* value varied from 30.81 to 35.81. The a^* and b^* value for different pretreatments under OYSD varied from 4.33 to 5.99 and from 1.95 to 5.02, respectively. Compared with the OYSD dried chilli (L^*= 35.81 and a^*= 5.99), the STD method was more similar in L^* and a^* values than the open yard sun drying method (P>0.05). This result showed that the STD method significantly improved the lightness and redness of dried chilli compared to the OYSD drying method (P≤0.05).

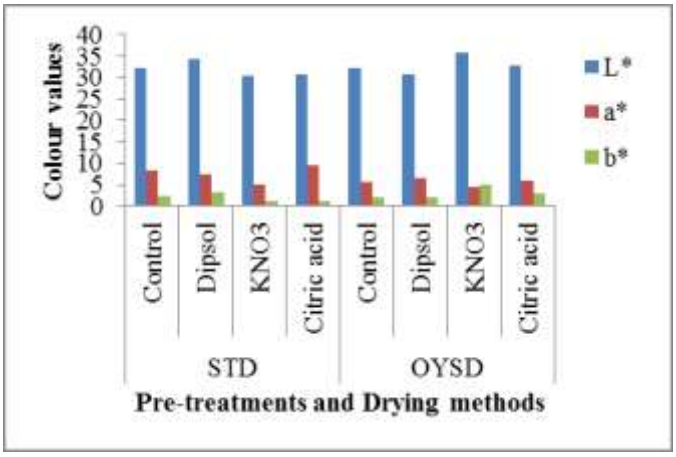

Fig.4. Effect of pre-treatments on colour value of *Byadagi* chilli with two drying methods

This is primarily due to the chilli remaining at intermediate moisture levels for a longer period resulting in brown discolouration of the product in the sun drying method. The carotenoid colour pigments responsible for the red colour are readily oxidized resulting in a product of lesser colour intensity due to direct exposure to sunlight than drying in controlled environment (Oberoi *et al.,* 2005). Mayer and Harel (1979) have reported that the browning reaction which affected the red colour of chilli was due to enzymatic activity. Klieber (2000) reported that drying at high temperatures or drying slowly resulted in a product of poor quality. This was in agreement with the data reported by Mangaraj *et al.* (2001) who observed that the colour of mechanically dried chilli was better than the sun dried chilli. These were due to the higher exposure to oxygen when an intensive vaporization takes place on the surface of this chilli (Topuz and Ozdemir, 2004).

It is noticed that there was effect of different pre-treatments under STD and OYSD on the ascorbic acid of chilli (Fig 5.). The chillies dried under STD had higher ascorbic acid content compared to OYSD and the results varied significantly. The highest ascorbic acid content was observed in citric acid (108.837 mg 100 g^{-1}) followed by KNO_3 (108.619 mg 100 g^{-1}), dipsol (106.192 mg 100 g^{-1}) and the lowest in control (104.858 mg 100 g^{-1}). In OYSD method, the highest ascorbic acid content was found in dipsol (94.492 mg 100 g^{-1}), followed by citric acid (84.771 mg 100 g^{-1}), KNO_3 (90.959 mg 100 g^{-1}) and control (84.553 mg 100 g^{-1}). This clearly shows that the sample dried under STD was found to have better retention of ascorbic acid content as compared with OYSD.

Samples treated with potassium nitrate, citric acid, potassium nitrate were found to have the highest concentrations of ascorbic acid. These differences are most probably due to varietal differences (Davidson, 1979). According to the revised guidelines by the Food and Nutrition Board of National Academy of Sciences, the recommended dietary allowance (RDA) of vitamin C has been proposed to be 120 mg per day (Levine *et al.,* 1998).

This was in agreement with the work of Shittu *et al.* (1999) who reported that the drying of vegetables led to some losses of ascorbic acid and some sensory characteristics. He added that more severe drying conditions in oven caused higher losses of ascorbic acid. Also this variation might be due to the leaching of the vitamin being water soluble and oxidation due to longer period of drying especially the conventional dried samples. Famurewa *et al.* (2006) reported that the ascorbic acid (vitamin C) content of the raw sample was 200 mg 100 g^{-1} and solar dried and oven dried sample was 100 mg 100 g^{-1} and 125 mg 100 g^{-1}, respectively. The ascorbic acid of red chilli decreased during drying. Howard *et al.* (1994) reported that 75% of ascorbic acid in red chilli was lost during drying, with the final content of ascorbic acid. Ascorbic acid was oxidized by the light and high temperature during drying leading to the formation of L-dehydroascorbic acid and a wide variety of carbonyl and other unsaturated compounds (BeMiller and Whistler, 1996).

According to the Food Composition Table (RDA, 2001), the ascorbic acid content of dried chilli is about 26 mg/100 g (Kim *et al.*, 2006).

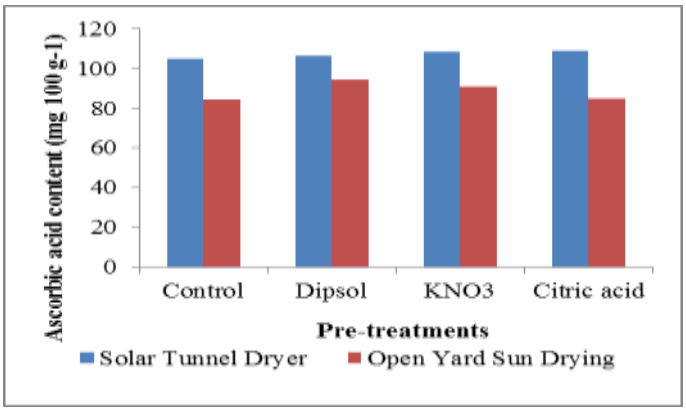

Fig 5. Effect of pre-treatments on ascorbic acid content of *Byadagi* chilli with two drying methods

This is a lower content than in our results. This meant that ascorbic acid had been destroyed less in our drying methods and high ascorbic acid was contained in all the dried chilli, especially in the STD sample.

Effect of drying on capsaicin content

From Figure 6, it can be seen that the significant results were obtained for capsaicin content of *Byadagi* chilli with different pre-treatments of STD samples but in case of OYSD it was non-significant. The capsaicin content ranged from 0.030 to 0.130 per cent for different pre-treatments dried under solar tunnel dryer. The highest capsaicin was observed in KNO_3 (0.130%) and the lowest in dipsol (0.030%). In case of OYSD, the capsaicin content varied from 0.010 to 0.040 per cent. The highest capsaicin content was observed in citric acid (0.040%). It is observed from Figure 6 that potassium nitrate was more effective compared to the other pre-treatments in solar tunnel dryer. But in open yard sun drying, the citric acid treatment was an effective comparing to other pre-treatments.

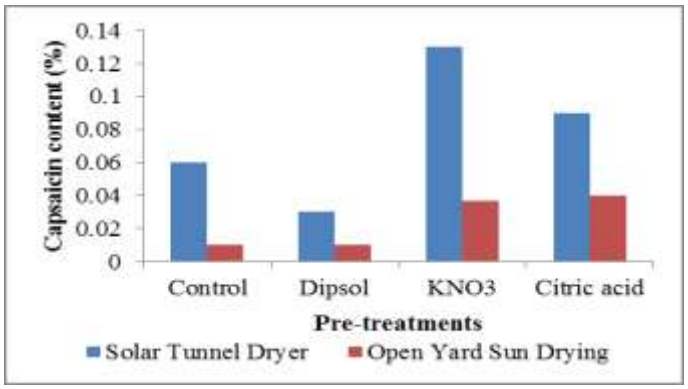

Fig 6. Effect of pre-treatment on capsaicin content of *Byadagi* chilli with two drying methods

The results of the present investigation are in good agreement with the findings of Kumar *et al.* (2003), Singh *et al.* (2003) and Jyothi *et al.* (2008). Bajaj *et al.* (1980) reported a range of 0.34 to 0.95 per cent, whereas, Kumar *et al.* (2003) reported a range of 0.3 to 0.49 per cent and Singh *et al.* (2003) reported a variation of 0.3 to 0.7 per cent of capsaicin in different genotypes of chilli. Joy *et al.* (2001) reported that the capsaicin was 0.2 to 0.24 per cent. Jyothi *et al.* (2008) observed capsaicin content in *Byadagi* chilli (var. PBC-535) to the range of 0.18 and 0.22 per cent during 2002-03 and 2004-05, respectively. The capsaicin content of dried *Byadagi* chilli in STD was more than the chilli dried under open yard sun drying. In case of sun-drying this could possibly be due to the exposure of chilli directly to solar radiations which resulted in degradation of two major capsaicinoids i.e., capsaicin and dihydrocapsaicin responsible for pungency in chilli. Similar results were obtained by when the chilli was dried using different methods of drying.

Effect of drying on aflatoxin content

Among the pre-treatments, only the chilli pre-treated with citric acid contained 0.057 µg kg^{-1} of aflatoxin which was below the permissible limit. Chilli dried under solar tunnel dryer without pre-treatment elaborated 0.03 µg kg^{-1} aflatoxin and chilli pre-treated with dipsol had 0.024 µg kg^{-1} aflatoxin content (Fig 7.). From the present investigation, the solar tunnel dried samples were found less aflatoxin content as compared to the open yard sun drying but, the aflatoxin found in both the drying methods was not harmful.

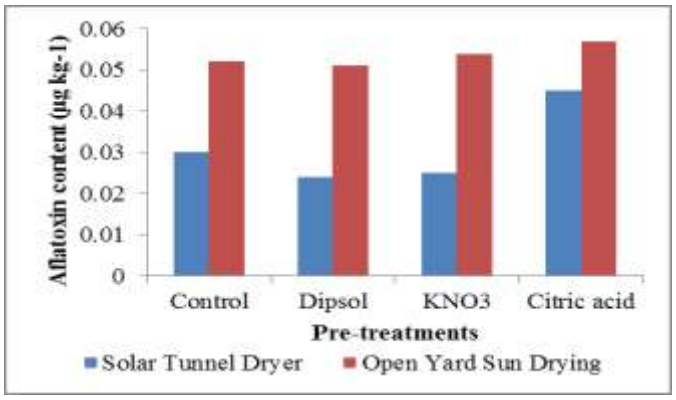

Fig 7. Effect of pre-treatments on aflatoxin contamination in *Byadagi* chilli as estimated by Indirect Competative ELISA

Sudha and Naik (2008) analysed various chilli products obtained from different farmers' fields and

among them chilli powder contained 23.20 μg kg^{-1} of aflatoxin which was above the permissible limit as reported by (Reddy *et al.*, 2001). The results are similar to the findings of Ajithkumar and Naik (2006) who reported that the aflatoxin present in *Byadagi* chilli was 6.6 μg kg^{-1}. MAFF (1994) reported aflatoxin content in chilli was 5.6 μg kg^{-1}. Paterson (2007) described that the positive result was obtained for each sample and a direct relationship between aflatoxin B_1 and B_2 was apparent. The mean of all samples was 32.11 μg kg^{-1} and 1.31 μg kg^{-1} of aflatoxin B_1 and B_2, respectively. As per the recently introduced European Union (EU) regulations, only 5 μg kg^{-1} of aflatoxin B_1 and 10 μg kg^{-1} of total aflatoxins are allowed in chillies. This is in agreement with the data published by Bircan (2005) who tested for paprika, chilli powder and ground black pepper samples which were contaminated with aflatoxin B_1 in the range of 0.5-116.4, 1.6-80.4 and 0.3-1.2 μg/kg, respectively.

CONCLUSION

The STD sample gave more bright-red colour and contained higher ascorbic acid content than the OYSD samples. The STD and OYSD methods did not affect the capsaicin concentration in the pre-treatments of the dried chilli. From the present investigation, the solar tunnel dried samples were found less aflatoxin content as compared to the open yard sun drying but, the aflatoxin found in both the drying methods was not harmful. it is concluded that the chilli dried in STD was of good quality over OYSD. The time required for drying chilli from initial moisture content of around 339.14% (d.b.) to the final moisture content of around 10% (d.b.) was 39 and 57 hours for STD and OYSD, respectively.

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