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## Assessment of different drying methods on sensory, color and quality attributes of fennel (*Foeniculum vulgare* Mill) seeds harvested for chewing purpose

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### Abstract

The present investigation was carried out at an experimental farm and post-harvest laboratory of Indian Council of Agricultural Research-National Research Center on Seed Spices (ICAR-NRCSS), Ajmer during 2019-2021. This study aimed to assess the influence of different drying methods on fennel seeds harvested for chewing purposes. Fennel umbels were harvested at 143 days after sowing and 35 days after anthesis and dried under different drying treatments. T<sub>1</sub>-sun drying, T<sub>2</sub>-shed drying, T<sub>3</sub>-hot air oven drying (40°C), T<sub>4</sub>-hot air oven drying (50°C), T<sub>5</sub>-shed net (75% shed) drying (on floor), T<sub>6</sub>-low-cost poly solar dryer and T<sub>7</sub>-drying in shed net (75% shed) with hanging umbels. The findings of the study revealed that the overall acceptability score (color, aroma, appearance, taste) of dried seeds for chewing purposes was recorded maximum in shed net drying with hanging umbels followed by hot air oven drying (50°C), hot air oven drying (40°C), shed net drying (on the floor), low-cost poly solar drying, shed drying (27±2°C) and least in Sun/Open drying. The chromatic value of seeds dried by different drying approaches was determined and the maximum (L\*-lightness 43.12) and (a\*-greenness, negative -3.34) of seeds were measured in shed net drying with hanging umbels and lowest in open drying. The b\* value measures yellowness (positive) and resulted highest(28) in the sun/open drying method followed by a low-cost poly solar dryer and least in shed net drying with hanging umbels and shed net (75% shed) drying (on the floor). Among physical attributes of dried seeds, maximum seed length and width were observed in the seeds dried by hot air oven drying (50°C) which was statistically at par with drying in shed net (75% shed) with hanging umbels. The highest seed length/width and seed index (test weight) were observed in seeds dried in a shed net (75% shed) with hanging umbels which was statistically at par with shed net (75% shed) drying (on the floor) and lowest in low-cost poly solar dryer and sun/open drying. Seed oil

content was significantly affected by drying methods and maximum total oil & essential oil content (4.58 & 2.33) was determined in hot air oven drying (50°C) followed by shed net (75% shed) with hanging umbels (4.57 & 2.32) whereas, minimum in low-cost poly solar dryer (4.4 & 2.15) followed by sun/open drying (4.41 & 2.17). Total soluble solids (TSS °B) measured highest (23.45 °B) in seeds dried in shed net (75% shed) with hanging umbels however, the least (19.47 °B) in sun/open drying. From the study, it was suggested that to obtain better quality fennel seeds, harvested for chewing purposes could be dried in a shed net (75% shed) with hanging umbels and hot air oven drying (50°C).

**Key words:** Fennel, seeds, chewing, drying, sensory, chromatic and essential oil

## **Introduction**

Fennel (*Foeniculum vulgare* Mill) belongs to the family Apiaceae and is a native of Southern Europe and the Mediterranean region and one of the popular major seed spices in India. It is a cold-loving crop that is primarily grown in northern parts of India during the *rabi* season for seed purposes (Singh *et al.*, 2007 and Singh *et al.*, 2008). It is commonly known as Saunf in Hindi and there are many popular regional names. Fennel is widely cultivated throughout the temperate and subtropical regions of the world and major growing countries are India, Syria, Egypt, Turkey, Germany, Spain and Pakistan. Major fennel-producing states in India are Gujarat Rajasthan, Madhya Pradesh, West Bengal and Uttar Pradesh. Gujarat and Rajasthan are major fennel-producing states, contributing nearly 96% of the national fennel area and production both. In Rajasthan, it is mainly cultivated in districts like Nagaur, Sirohi, Jodhpur, Pali and Swai Madhopur districts and in Gujarat the major fennel-growing area are Mehasana, Morbi, Banaskatha, Sabarkantha and Aravalli. Fennel seeds are consumed in many forms as raw seeds for chewing, culinary purposes and grounded powder form. Its seeds are having medicinal importance as carminative, cardiogenic, stimulant, vermicide and lactagogue (Lal *et al.*, 2023). Fennel seeds are used for the seasoning of food, flavouring of beverages, perfumery, cosmetics and medicines (Raj

*et al.*, 2017). Usually, the fennel crop is harvested at physiological maturity for mature or ripe seeds however for chewing purposes it is harvested before the seed not fully ripe. For chewing purposes, umbels are harvested about 35-40 days after anthesis and these seeds have high demand in national as well as global hotel and catering markets and fetch premium prices. Time of harvest based on maturity indices and appropriate drying method is very important for optimum sensory and quality seed attributes in fennel. Freshly harvested seeds consisted of high moisture and removal of water content (or lowering water activity) to halt the microbial spoilage and various deterioration chemical reactions. Moreover, drying is a critical post-harvesting step to maintain the seed quality and minimize storage losses. In addition, consumer demand has increased for processed products that keep more of their original characteristics without substantial effects on texture, color, flavor, aroma, taste, and mineral and biochemical profile (Arslan *et al.*, 2005). Earlier studies showed the importance of drying on the quality attributes of fennel (Reddy *et al.*, 2012 and Patel *et al.*, 2018). Additionally, due to reduced weight and volume, dried products also provide the advantage of reduced costs of packaging, transportation, and storage. The majority of growers are unaware of optimum harvesting stages and appropriate drying techniques. Presently most of the growers in fennel-producing regions dry umbels/fennel seeds in the hut, locally made with available materials (grasses, bamboo and woods) which resulted in poor quality of the final product (seeds) due to poor aeration, low light intensity, the incidence of fungus and physical impurities in form of dust particles. To overcome these constraints of this drying practice, at ICAR-NRCSS, Ajmer different drying techniques were assessed to obtain better quality seeds for chewing purposes.

## **Materials and Methods**

The present study was carried out at National ICAR-NRCSS, Tabiji, Ajmer (Rajasthan) during 2019-2021 to assess the influence of different drying methods to obtain the best quality seeds for chewing purposes. The sowing of fennel seeds was done during the second week of October by keeping a row-to-row

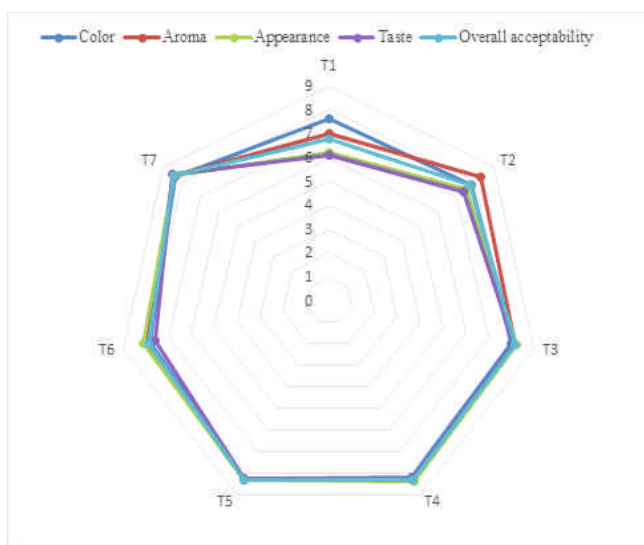
distance of 50 cm, with a seed rate of 10 kg ha<sup>-1</sup>. The experimental site soil was sandy loam in nature and the crop was raised as per the recommended dose of nutrients (90 kg N and 50 kg P<sub>2</sub>O<sub>5</sub> per ha. 1/3rd doses of nitrogen (N) and a full dose of phosphorus (P) were applied as basal and the remaining nitrogen (N) at 60 and 100 days after sowing as a top dressing. The umbels were harvested at 143 days after sowing or 35 days after anthesis. The green harvested umbels were dried by different drying treatments *viz.* T<sub>1</sub>-sun drying, T<sub>2</sub>-shed drying, T<sub>3</sub>-hot air oven drying (40°C), T<sub>4</sub>-hot air oven drying (50°C), T<sub>5</sub>-shed net (75% shed) drying (on floor), T<sub>6</sub>-low-cost poly solar dryer and T<sub>7</sub>-drying in shed net (75% shed) with hanging umbels. The experiment was laid out in Complete Randomized Design (CRD) replicated three times and pooled over data of two years were subjected to statistical analysis (Gomez and Gomez, 1984). Sensory evaluation (visual appearance, flavour, aroma, texture, taste, fibre lessness and overall acceptability) of seeds dried by different methods was done by a panel of 10 technical and semi-technical judges by numerical scoring method done on 9-point hedonic scale recommended by Indian Standard. The average score of all ten panelist's was computed to optimize the variables/parameters. The chromatic value of dried seeds was measured using calibrated handheld digital colorimeter and color changes were evaluated using three factors of brightness (L\*), chromaticity coordinate a\* and b\*. L\* value was measured with a range from 0 to 100 which represents black to white. For chromaticity coordinate a\*, measures values from green (negative) to reddish (positive) colour while chromaticity coordinate b\* measures yellow (positive) to blue (negative). Dimensions of seed namely length, width and thickness measured by vernier calliper from randomly selected 100 seeds and expressed in mm. Test weight (g) was measured by weighing 1000 seeds. Freshly harvested seeds and dried seeds' moisture content was measured using the oven drying method. Oil content was extracted using an Accelerated Solvent Extraction System (Dionex India Pvt. Ltd.). Oil was obtained after evaporating the solvent in a rotary evaporator. Thirty-gram seed powder was utilized for

oil estimation. For extraction of essential oil, thirty grams of shade-dried fruits (80 g, four replicates for each stage) sample in three replications was drawn from each treatment and used for essential oil extraction by hydro-distillation for 7 hrs. using a Clevenger apparatus (Clevenger, 1928). After decanting and drying of the oil over anhydrous sodium sulphate the corresponding mild yellowish-colored oil was recovered and calculated in terms of percentage (V/W). Total soluble solids (TSS°B) was determined as per AOAC (2000). The obtained data were subjected to analysis of variances, and the significant differences among treatment means were compared according to Gomez and Gomez (1984).

## **Results and Discussion**

The mean sensory ratings for colour, appearance, taste and overall acceptability of dried seeds have been given in Fig. 1. Maximum score (8.35) for colour was observed in seeds dried by shed net drying with hanging umbels followed by hot air oven drying at 50°C (8.29), hot air oven drying at 40°C (8.19) and minimum in open drying (7.64). Similarly highest score for seed aroma was recorded in seeds dried by shed net drying with hanging umbels (8.46) followed by Shed drying (27±2oC) and lowest in sun/open drying (7.03). Similarly, the maximum score for seed appearance was recorded in seeds dried by shed net drying with hanging umbels (8.45) followed by Hot air oven drying (40) 8.38 and lowest in sun/open drying (6.20). The highest seed taste score was recorded for shed net drying with hanging umbels (8.55), Hot air oven drying (40) 8.28 and lowest in sun/open drying (6.12). The overall acceptability score was recorded as maximum (8.45) in seeds dried by shed net drying with hanging umbels followed by hot air oven drying (50°C) 8.31, Hot air oven drying (50°C) 8.30, Shed net drying (on floor) 8.14, low-cost poly solar drying 7.88, Shed drying (27±2oC) 7.74 and least in sun/open drying 6.75. In open/sun drying, the fennel seed colour, flavour, aroma and taste quality deteriorated due to direct exposure to solar light and higher temperatures. It is well documented that seed moisture, temperature and relative humidity affect the quality of produce during drying (Abba & Lovato, 1999). These results are in agreement with the findings of

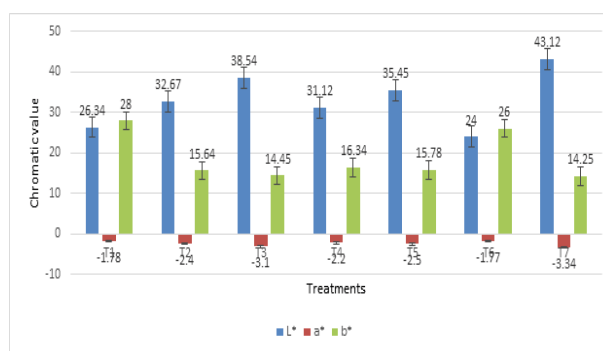
Bhardwaj *et al.* (2010) in fennel.



**Fig.1:** Effect of different drying methods on sensory attributes of fennel seeds (T<sub>1</sub>-sun drying, T<sub>2</sub>-shed drying, T<sub>3</sub>-shed net (75% shed) drying (on the floor), T<sub>4</sub>-hot air oven drying (40°C), T<sub>5</sub>-hot air oven drying (50°C), T<sub>6</sub>-low- cost poly solar dryer and T<sub>7</sub>-drying in shed net (75% shed) with hanging umbels)

Fennel seeds harvested for chewing purposes must have an attractive green colour. The intense green colour of the final product *i.e.* dried seeds determines the market price and acceptability therefore, the chromatic value of seeds dried by different drying approaches is determined. It was observed that (L\*-lightness) was measured highest (43.12) in seeds dried in a shed net with hanging umbels followed by shed net (75% shed) drying (on the floor) (38.54) and hot air oven drying (50°C) (35.54) and lowest in open drying (26.34). Likewise(a\*-greenness) was observed in maximum (-3.34) seeds dried in shed net with hanging umbels followed by shed net (75% shed) drying (on the floor) (-3.1) and hot air oven drying (50°C) (-2.5) and lowest in open drying (-1.78).The b\* value measures yellow (positive) and the highest was recorded in the sun/open drying method (28.00) followed by a low-cost poly solar dryer (26.00) and least in shed net drying with hanging umbels (14.25) and shed net (75% shed) drying (on the floor) (14.45). This might be because drying the umbel under a shed net with hanging umbels

maintained an appropriate level of light interceptions with good ventilation and protection which was important for the retention of taste, flavor and green colour of the seeds. As reported by Cordwell (1984), seed vigour and quality were reduced with the increase in seed moisture, especially in high temperatures and relative humidity conditions. Similar results were observed by Singh & Goswami (2000) in cumin seed and Bhardwaj *et al.* (2010) in fennel



**Fig.2:** Effect of different drying methods on chromatic value of fennel seeds (T<sub>1</sub>-sun drying, T<sub>2</sub>-shed drying, T<sub>3</sub>-shed net (75% shed) drying (on the floor), T<sub>4</sub>-hot air oven drying (40°C), T<sub>5</sub>-hot air oven drying (50°C), T<sub>6</sub>-low- cost poly solar dryer and T<sub>7</sub>-drying in shed net (75% shed) with hanging umbels)

Among physical attributes of dried seeds, maximum seed length was observed in the seeds dried in hot air oven drying (50°C) followed by drying in shed net (75% shed) with hanging umbels, shed net (75% shed) drying (on the floor) and minimum in low-cost poly solar dryer (Table1). Seed length varied significantly among drying methods and the highest seed length was noted in hot air oven drying (50°C) which was at par with drying in shed net (75% shed) with hanging umbels, shed net (75% shed), shed net (75% shed) drying (on the floor) and hot air oven drying (40°C) whereas lowest in sun/open drying. The highest seed length/width was observed in seeds drying in a shed net (75% shed) with hanging umbels which were at par with shed net (75% shed) drying (on the floor) and lowest in low-cost poly solar dryer. The final seed moisture content was observed maximum in shed net (75% shed) with hanging umbels and lowest in low-cost poly solar dryer.

According to Rao *et al.* (2006), shade drying can be an effective way of reducing seed moisture content in an environment where the RH is low. The seed test weight of dried seeds was resulted maximum in shed net (75% shed) with hanging umbels which were at par with shed net (75% shed) drying (on the floor) whereas lowest in sun/open drying. This might be because the drying process in a (75% shed) with hanging umbels was comparatively at a steady rate which helped in preserving the proper shape, size and test weight seeds. Quick drying such as poly solar tunnel drying or open/sun drying can damage the seeds, either owing to the removal of the moisture too quickly or due to higher temperature. Delayed drying such as shed drying and shed net drying (on floor) might have the resulted high moisture content in seeds and a relatively high temperature and so accelerated the deterioration that shed net (75%) with hanging umbels drying is intended to prevent. These results are in agreement with the findings of Bhardwaj *et al.* (2010). Aglodiya, (2014) also found the performance of solar dryer (42°C) better and exhibited maximum recovery per cent (32.56% and 23.45%) and quality for both green grain and green pods of fenugreek.

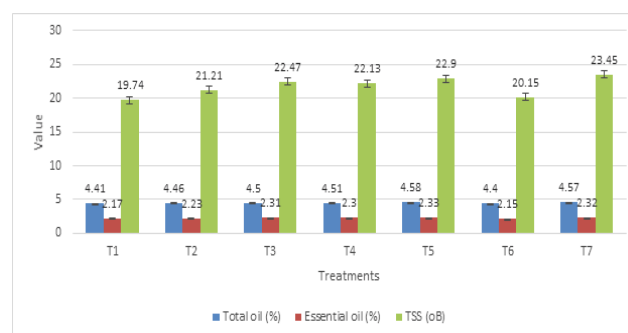
**Table 1.** Effect of drying method on physical characteristics of fennel seeds

Method of drying	Seed length (mm)	Seed width (mm)	Seed Length/Width	Seed moisture content (%)	Test weight (Seed index)
T1	5.11	1.41	3.62	8.10	2.55
T2	5.13	1.43	3.59	8.30	2.68
T3	5.24	1.44	3.64	8.24	2.73
T4	5.15	1.45	3.55	8.01	2.72
T5	5.31	1.47	3.61	7.88	2.79
T6	5.13	1.43	3.59	7.65	2.60
T7	5.27	1.44	3.66	8.25	2.78
CD at 5%	0.15	0.02	0.03	0.05	0.07

T<sub>1</sub>-sun/open drying, T<sub>2</sub>-shed drying, T<sub>3</sub>-shed net (75% shed) drying (on the floor), T<sub>4</sub>-hot air oven drying (40°C), T<sub>5</sub>-hot air oven drying (50°C), T<sub>6</sub>-low cost poly solar dryer and T<sub>7</sub>-drying in shed net (75% shed) with hanging umbels

Drying had a significant effect on the oil content and

antioxidant activity and fatty acid profiles of the fennel plant. Jogan mohan *et al.* (1998) reported that drying methods had impacted the flavour quality of rosemary. In this study seed quality attributes such as total oil content and essential oil content were estimated in seeds dried by different methods (Fig 3). Maximum total and essential oil content were recorded in seeds dried by hot air oven drying (50°C) (4.58, 2.33) which was statistically at par with the seeds dried by shed net (75% shed) (4.57, 2.32) with hanging umbels whereas lowest in the low-cost poly solar dryer (4.40, 2.15) followed by sun/open drying (4.41, 2.17). Similar findings were also reported by (Mieso *et al.*, 2020) in the basil variety in which relative percentages of the major constituents of essential oil were significantly affected by drying methods. Total soluble solids (TSS °B) were recorded maximum in seeds dried in shed net (75% shed) with hanging umbels (23.45) followed by hot air oven drying (40°C) (22.47) however, minimum in sun/open drying (19.74) followed by a low-cost poly solar dryer (20.15). It was evident that high-temperature exposure of plant material under sun and poly solar drier led to the great loss of volatile oil. This trend *i.e.* the reduction of volatile oil content of plants by the impact of high-temperature drying process has been reported in several studies (Sekeroglu *et al.*, 2007; Okoh *et al.*, 2008; Blanco *et al.*, 2002). Reddy *et al.*, (2012) reported that drying fennel in the shade has been found to have the least adverse



**Fig 3:** Effect of drying method on oil and TSS (oB) of fennel seeds (T<sub>1</sub>-sun drying, T<sub>2</sub>-shed drying, T<sub>3</sub>-shed net (75% shed) drying (on the floor), T<sub>4</sub>-hot air oven drying (40°C), T<sub>5</sub>-hot air oven drying (50°C), T<sub>6</sub>-low- cost poly solar dryer and T<sub>7</sub>-drying in shed net (75% shed) with hanging umbels)

effect on quality instead of drying in open sun. The findings exhibited that the extract of shade-dried stems and flat parts contained high phenol and flavonoid content. All the shade-dried parts showed better antioxidant activity compared to the sun-dried parts and shade-drying yielded the highest quality of volatile oil. The finding of the current study also in line with is the finding of Hassanpouraghdam *et al.* (2010) in basil and Arabhosseini in tarragon.

## Conclusion

In current study, it was opined that for obtaining better quality fennel seeds, harvested for chewing purposes could be dried in a shed net (75% shed) with hanging umbels and hot air oven drying (50°C).

**Conflict of interest:** The authors declare no conflict of interest.

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