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Standardization of primary processing of fennel (*Foeniculum vulgare* Mill.) in tribal area of Sirohi (Rajasthan)

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Abstract

An experiment was conducted in a farmer's field at Sirohi (Rajasthan) during 2009–10 and 2010–11. Five separate experiments on (i) harvesting time (ii) umbels drying structure (iii) fennel threshing floor (iv) grading stages and (v) packing material of fennel, were laid out in a completely randomized design with four treatments replicated five times. The results revealed that different treatments had significant effect on sensory attributes, geometry and economics of fennel seed quality. The fennel umbels which were harvested at post maturity stage [31-40 days after flower initiation (DAFI)] were superior to rest of the harvesting stages and recorded maximum sensory scores, seed dimensions and highest yield (17.35 q ha^{-1}), maximum market rate (Rs. 150.24 kg^{-1}) and B:C ratio (4.62). Results also showed that drying of fennel umbels in modified locally made structures gave better quality of seed over other structures, giving good market price (Rs. 135.74 kg^{-1}). Threshing on RCC floor was found to be better for maintaining good quality of seed. The grading and packing also improved the quality of seed. The fennel seed which was packed in polyethylene lined gunny bag was found to be better because the quality of seed did not deteriorate in terms of taste, colour, and flavour for longer time. Maximum shelf life of produce along with better quality and higher market price was also obtained in this treatment.

Keywords: fennel, flavour, *Foeniculum vulgare*, processing, quality, shelf life

Introduction

Fennel (*Foeniculum vulgare* Mill.) is widely cultivated seed spices throughout the temperate and sub tropical regions of the world. It is a biennial herb mainly grown in the *rabi* season. But in some parts of south west Rajasthan like Sirohi it is also grown in *kharif*. The total area under fennel cultivation in Rajasthan is 7500 hectare and 6249 tons production, out of which maximum area is in district Sirohi i.e. 4528 hectare and 4349 tons production (Anonymous 2009). Generally, the crop is harvested at different stages of crop development. Pre mature harvested seeds have higher moisture content which causes microbial infestation and reduces

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sensory quality of seed. Whereas, late stage harvest i.e. at dry stage impaired seed quality in terms of seed colour, flavour, texture, taste and formation of crude fibre. So, it is important to optimise right harvesting time for maximum quality seed production. Besides harvesting time, it is well documented that the umbel drying structure is an important factor which affects the seed quality and market rate of the produce. In open sun drying, the fennel seed colour, flavour, aroma and taste quality get deteriorated due to direct exposure to solar light and higher temperature. It is well documented that seed moisture, temperature and relative humidity effect quality of produce during drying (Joao Abba & Lovato 1999). The farmers use locally made shade structure and agro-net house for drying of fennel umbels. In this type of structure, the quality of fennel seed deteriorates due to high percolation of moisture (dew) during the morning hours and penetration of sun light during the day. So modified shade structure (made up by local indigenous material + white polyethylene sheet on roof) has all the desired qualities of good shade structure *viz*., no moisture percolation, minimum light penetration with good aeration. In the present context of marketing, primary processing is one of the important farm activities for maintaining good quality of fennel seeds. Threshing on RCC floor, four stage grading and plastic lining gunny bags packing are helpful to maintain sensory, geometric quality of seeds, minimise mould infestation and increase shelf life of seeds, which fetches good return of produce.

It is necessary to determine the quality of seeds in order to optimise harvesting time, umbel drying, use of threshing floor, grading stages and packing material of fennel seeds. The properties of seeds affected by primary processing were determined by many researchers such as Bhardwaj *et al.* (2010) in fennel; Joao Abba & Lovato (1999) and Mettananda *et al.* (2001) in maize seeds; De Silva & Peiris (1994) in chilli seeds; Demir & Samit (2001) in tomato seeds.

However, no published work has been carried out on the integration of harvesting time, drying structure, threshing place, grading and packing for production of quality fennel seed. Hence, this study was conducted to investigate optimum harvesting time, proper drying structure, types of threshing floor, grading process and use of appropriate packing material for maintaining seed and marketing quality of fennel with respect to colour, flavour, aroma, texture, moisture content, taste, test weight, length, width, thickness, bulk density, shelf life and market rate.

Materials and methods

An experiment was conducted in a farmer's field during two consecutive years (2009–10 and 2010–11). Five experiments each with four treatments were laid out in a completely randomized design with five replications. The first experiment on harvesting stage comprised of premature (20-30 DAFI), post mature (31-40 DAFI), over mature (41-45 DAFI) and drying (46-50 DAFI) stages of harvesting. The second experiment on drying structure of fennel seeds comprised of four treatments i.e. open drying, locally made shade drying structure (made up by local indigenous material), modified locally made shade drying structure (made up by local indigenous material + white polyethylene sheet on roof) and agro-shade net house drying. The third experiment was on the use of different types of threshing floor for cleaning of fennel seeds comprising of *Kaccha* (wet soil layering), cow dung plastered (*Lipna*), plastic sheet covered (*Tripal*) and RCC (*Pucca floor*) threshing floor. The fourth experiment was on grading of fennel seed which also comprised of four types of grading process i.e. without grading, two stage grading (2 stage=pre and post drying of umbels), three stage grading (3 stage=pre and post drying of umbel + 1 sieving), four stage grading (4 stage=Pre and post drying of umbel + 2 sieving + 1 mechanized). The fifth experiment was on packing of fennel seeds comprising of plastic bag (empty fertilizer bag), gunny bag (jute bag), poly bag and gunny bag with polyethylene lining.

Experimental design and measured parameters

The sensory evaluation (colour, flavour, aroma, texture and taste) was determined by panel of

10 farmers, exporters, consumers and scientists based on five point hedonic scale (Amerine *et al.* 1965). Moisture content in seed was calculated by the following formula where moisture content was expressed in % and weight of seed was expressed in g.

Moisture % = [(Weight of seeds before drying (W_1) – Weight of seeds after drying (W_2))/ Weight of seeds before drying (W_1)] × 100

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. The bulk density was determined by filling and weighting a 250 mL graduated cylinder with seed and weighed. The weight of the seeds was obtained by subtracting the weight of the cylinder from the weight of the cylinder and seed. The volume occupied was then noted. The process was replicated four times and the bulk density for each replication was calculated from the following relation-

Bulk density ($g\,cm^{-3}$) = Weight (g)/Volume (cm^3) (Rai 2002)

Shelf life of fennel seed was observed by visual observation (aroma, colour, moisture of seed etc) of experts. For determination of effect of packing material on shelf life the observation was recorded at 6th and 12th month of storage. The total yield was calculated by weighing total seed produced and has been presented on hectare basis. Market rate of fennel seeds was taken from local and Unjha mandi (Gujarat) at the time of experimentation in both the years. Further, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The Benefit Cost ratio was calculated by dividing net return by total cost. Significance of variance was analyzed by employing the variance technique (Cochran & Cox 1950) under completely randomized design. Significance of difference among the treatments was tested through F-test and critical difference (C.D.) was calculated.

Results and discussion

Effect of harvesting stage

The results indicated that colour, flavour, aroma, texture and taste score of fennel seed were significantly affected by harvesting stages (Table 1). Umbels harvested at post mature stage (30-35 DAFI) were found to have superior

Table 1. Effect of harvesting stage on quality parameters of fennel

Quality parameters	Harvesting stage of fennel (pooled)				S.Em ±	CD at 5%
	Pre mature	Post mature	Over mature	Drying stage		
Colour (out of 5 marks)	3.17	4.54	3.09	2.80	0.094	0.369
Flavour (out of 5 marks)	4.09	4.79	3.19	2.51	0.094	0.369
Aroma (out of 5 marks)	4.22	4.29	3.09	2.78	0.094	0.369
Texture (out of 5 marks)	4.28	4.89	3.81	3.08	0.094	0.369
Taste of seed (out of 5 marks)	4.50	4.95	3.78	3.11	0.094	0.369
Length (mm)	5.07	7.47	7.97	8.15	0.219	0.862
Width (mm)	0.91	2.89	2.74	2.30	0.066	0.261
Thickness (mm)	1.92	3.13	2.94	2.81	0.918	0.360
Test weight (g)	11.70	17.75	14.48	11.65	0.530	2.081
Bulk density (kg m^{-3})	360.98	444.65	406.63	380.78	8.875	34.837
Moisture (%)	63.77	51.33	45.61	40.51	0.934	3.667
Yield (q ha^{-1})	12.50	17.35	16.50	15.03	0.540	2.081
Market Rate (Rs kg^{-1})	111.09	150.24	125.49	80.24	2.548	10.003
Benefit: Cost ratio	2.17	4.62	3.70	1.74	0.197	0.773

colour, flavour, aroma, texture and taste score compared to other stages like pre mature, over mature and drying stage of umbels. The umbel harvested at post mature stage recorded highest score for colour (4.54), flavour (4.79), aroma (4.29), texture (4.89) and taste of seeds (4.95) as compared to other stages of harvesting. This can be attributed to the fact that the seeds had maximum bright green colour, good flavour, aroma and highest dry matter with minimum fibre content at the post mature stage of harvesting. At the time of drying of umbel the seeds shrunk, deteriorating the sensory quality of the seeds. This was because at premature stage of harvesting, dry matter content remained lower with high moisture content. Seeds harvested at low initial moisture content had better storability and maintained good quality (De Silva & Peiris 1994). At over maturity stage, the seed dry matter gets converted to crude fibre which deteriorates flavour, green colour and texture. Similar results were observed by Valdes & Gray (1997) and Demir & Samit (2001) in tomato seeds. Means and standard error of the dimensions of fennel seed at different harvesting stages are given in Table 1. Umbels harvested at drying stage demonstrated highest length of seed (8.15 mm), whereas highest width (2.89 mm), thickness (3.13 mm), test weight (17.75 g) and bulk density (444.65 kg m^{-3}) were reported when umbels were harvested at post mature stage (30-35 DAFI). The possible cause of higher dimension of fennel seed at post mature stage is the low moisture content (51.33%) with higher stored dry matter of the seeds. The seed shrunk at the time of drying when harvested at pre mature stage because it had high moisture content. Harvesting during over mature and drying stage leads to the translocation of stored nutrients for new umbels formation. The dimensional value of seeds decreased except length, forming deep crude fibre linings. Tomato seed quality was found to decline in earlier and later stage harvests (Demir & Samit 2001). These results corroborate with the conclusions of Bhardwaj *et al.* (2010) in fennel seeds.

The fennel umbels harvested at post mature stage resulted in maximum production (17.35 q ha^{-1}) due to higher accumulation of dry matter with minimum crude fibre formation in seed thus increasing test weight of the seed significantly. Similar result was observed by Bhardwaj *et al.* (2010) in fennel. The seed moisture content was highest (63.77%) with significantly reduced shelf- life in the umbels harvested at pre mature stage. Results of these findings showed that the highest market rate (Rs. 150.24 kg^{-1}) was obtained by post mature harvested umbel seeds with maximum Benefit: Cost ratio (4.62). Possible higher market price of fennel might be due to good sensory score of the produce as per consumer and export demand parameters. This conclusion is supported by Demir & Samit (2001) in tomato, Bhardwaj *et al.* (2010) and Nandal & Ojha (2012) in fennel seed.

Effect of threshing floor

A significant influence of threshing floor was observed on sensory quality parameters of fennel. The highest score for colour (4.22), flavour (4.27), aroma (4.22), texture (4.44) and taste of seed (4.14) was observed when fennel was threshed on RCC floor. A negative linear co-relationship was observed between quality parameters and threshing of fennel on cow dung plastered and kaccha threshing floor. This was because the fennel seeds showed discolouration, were off flavour, rough textured and tasted bitter due to mixing with soil and dung particles. Similar results were observed by Bhardwaj *et al.* (2010) in fennel. Threshing floor had non-significant effect on test weight of fennel seed (Table 2). The minimum test weight (10.04 g) and maximum shelf life (8.25 months) was observed in fennel due to RCC floor threshing. Significant reduction in shelf life of seeds due to threshing on kuccha, cow dung plastered and plastic sheet floor is because of high contamination of umbel at the time of threshing. Minimum moisture (10.70%) was registered in fennel seeds due to threshing on RCC floor. This might be due to the fact that RCC floor was clean, dry and free from soil and dung particles. Similar results were observed by Bhardwaj *et al.* (2010) and Anonymous (2011) in fennel and cumin, respectively. The

Table 2. Effect of threshing floor on quality parameters of fennel

Quality parameters	Types of threshing floor (pooled)				S.Em ±	CD at 5%
	Kuccha	Cow dung plastered	Plastic sheet	RCC floor		
Colour (out of 5 marks)	2.33	3.17	3.82	4.22	0.094	0.369
Flavour (out of 5 marks)	2.72	3.09	3.82	4.27	0.094	0.369
Aroma (out of 5 marks)	2.34	2.72	3.82	4.22	0.094	0.369
Texture (out of 5 marks)	3.72	3.77	4.12	4.44	0.094	0.369
Taste of seed (out of 5 marks)	3.09	3.56	3.84	4.14	0.068	0.268
Test weight (g)	10.51	10.38	10.16	10.04	0.147	NS
Shelf life (months)	5.41	6.29	7.25	8.25	0.104	0.408
Moisture (%)	13.21	12.36	11.71	10.70	0.184	0.723
Market Rate (Rs kg^{-1})	78.47	87.54	95.25	111.32	2.445	9.597
Benefit: Cost ratio	2.90	3.18	3.42	3.54	0.554	0.217

results revealed that the market rate and B: C ratio of fennel was significantly affected by threshing on different threshing floors (Table 2). The highest market rate (Rs. 111.3 kg^{-1}) and B: C ratio (3.54) was obtained when fennel was threshed on RCC floor whereas minimum market rate (Rs. 78.47 kg^{-1}) and B: C ratio (2.90) was obtained by threshing on *kuccha* floor. Threshing of fennel on RCC floor maintained sensory quality and there was no mixing of soil and cow dung particles. Similar results were reported by Artes *et al.* (2002) and Bhardwaj *et al.* (2010) in fennel.

Effect of fennel umbel drying structures

Drying structure of umbel has a significant effect on quality parameters. It was observed that the umbels dried under modified locally made structure maintained good quality seed than other drying structures (Table 3). The highest score for colour (4.47), flavour (4.53), aroma (4.72), texture (4.11) and taste of seed (4.60) was observed when umbel was dried under modified locally made structure whereas, minimum sensory score was reported in open

Table 3. Effect of drying structures for umbels on quality parameters of fennel

Quality parameters	Drying structures of umbels (pooled)				S.Em ±	CD at 5%
	Open drying	Locally made shade	Modified locally made shade	Agro-shade net		
Colour (out of 5 marks)	2.53	4.35	4.47	3.32	0.094	0.369
Flavour (out of 5 marks)	2.09	4.22	4.53	3.51	0.094	0.369
Aroma (out of 5 marks)	2.34	4.49	4.72	2.99	0.094	0.369
Texture (out of 5 marks)	3.09	3.89	4.11	3.85	0.056	0.223
Taste of seed (out of 5 marks)	3.14	4.49	4.72	4.08	0.094	0.369
Length (mm)	3.74	6.04	6.78	7.01	0.154	0.607
Width (mm)	0.83	2.72	2.66	2.34	0.066	0.261
Thickness (mm)	1.79	3.16	2.96	2.74	0.064	0.254
Test weight (g)	9.06	15.74	15.74	14.99	0.530	2.081
Bulk density (kg m^{-3})	307.98	393.66	252.15	324.54	8.875	34.837
Shelf life (months)	8.43	6.43	7.18	7.78	0.090	0.354
Moisture (%)	10.21	13.31	11.56	12.51	0.253	0.996

drying. It might be because drying of umbel under modified locally made structure maintained proper shade with good ventilation and protection from external moisture received which was important for maintaining best quality produce. As shown by Cordwell (1984), seed vigour and quality was lowered with increasing seed moisture especially in environment with high temperature and relative humidity. Similar results were observed by Singh & Goswami (1996) in cumin seed and Bhardwaj *et al.* (2010) in fennel. It was observed that the umbel dried under modified locally made structure maintained highest length (7.01 mm), width (2.66 mm), thickness (2.96 mm), test weight (15.74 g) and lowest bulk density (252.15 kg m^{-3}) of seeds (Table 3). This might be because drying process in modified locally made structure was comparatively slower which helped in maintaining proper shape, size and aroma of the seeds. These results are in agreement with the findings of Bhardwaj *et al.* (2010) who reported that the drying of fennel in modified locally made structure is essential for maintaining better quality produce with minimum shrinkage of seeds. Maximum shelf life (8.43 months) with lowest moisture content (10.21%) was observed in open dried produce, whereas minimum shelf life (6.43 months) with highest moisture content (13.31%) was observed in produce dried in locally made structure. As in locally made structure, higher internal moisture was present due to percolation of dew and environmental moisture. So drying process of fennel seed was delayed and high moisture content reduced the shelf life of seed. A similar trend was reported by Cordwell (1984) and Anonymous (2011) in fennel seeds.

Sensory quality of fennel seed (colour, flavour, texture, aroma and taste) is one of the most important factors affecting the market rate and B: C ratio. The highest market rate (Rs. 135.74 kg^{-1}) and B: C ratio (5.07) was reported for produce dried in modified locally made structure. This was probably due to good ventilation, protection from morning dew leading to best quality produce. Similar results of drying method were reported by Bhardwaj *et al.* (2010), Anonymous (2011) and Nandal & Ojha (2012) in fennel.

Effect of grading process

Different types of grading process had significant effect on quality parameters of fennel seeds. There were significantly higher scores for colour (4.69), flavour (4.53), aroma (4.12), texture (4.18) and taste of seed (4.32) in four stage graded produce whereas, lower scores for colour (2.51), flavour (2.08), aroma (2.20), texture (2.54) and taste of seed (2.91) were reported in non graded produce. The maximum quality score in four stage graded fennel seeds was due to the removal of all under sized, infested, discoloured, light weight seeds, inert material and other debris. At the time of first grading, selection of good quality umbel was done for drying. In the second stage, after drying, all infested, under sized, discoloured umbels were removed. In the third stage, all types of inert material and under sized seeds were removed by sieve screening and in the fourth stage locally made thresher cum grader machine was used for removing same weight plant particles, undersized seeds and any other inert material. Similar trend of result was obtained by Kathiravan *et al.* (2008), Bhardwaj *et al.* (2010), Anonymous (2011) and Nandal & Ojha (2012) in fennel seeds. Grading of seeds significantly affected dimensions of fennel seeds as given in Table 4. The highest length of seeds (7.34 mm), width (3.23 mm), thickness (3.11 mm) and test weight (16.21 g) was reported in four stage graded seeds. The possible cause of higher dimensions of fennel seeds in four stage grading may be due to removal of all types of under sized and lower quality seeds. The variation in bulk density by fennel grading has been depicted in Table 4. The data showed that the advanced stage of grading upto fourth stage increased bulk density. The highest bulk density (456.51 kg m^{-3}) was reported in four stage graded seeds which was significantly superior to other treatments. This was probably due to the removal of all light weight seeds and inert material (debris) from the fennel seeds by grading process which finally increased bulk density of remaining graded produce. Similar results were also reported by Kathiravan *et al.*

Table 4. Effects of types of grading process on quality parameters of fennel

Quality parameters	Types of grading process (pooled)				S.Em ±	CD at 5%
	Without grading	Two stage grading	Three stage grading	Four stage grading		
Colour (out of 5 marks)	2.51	3.08	4.12	4.69	0.094	0.369
Flavour (out of 5 marks)	2.08	3.01	4.06	4.53	0.094	0.369
Aroma (out of 5 marks)	2.20	2.91	3.84	4.12	0.094	0.369
Texture (out of 5 marks)	2.54	2.99	3.75	4.18	0.094	0.369
Taste of seed (out of 5 marks)	2.91	3.39	3.94	4.32	0.094	0.369
Length (mm)	4.44	6.14	6.47	7.34	0.126	0.497
Width (mm)	1.78	2.14	2.78	3.23	0.066	0.261
Thickness (mm)	2.11	2.49	2.70	3.11	0.052	0.205
Test weight (g)	9.74	12.69	14.62	16.21	0.387	1.519
Bulk density (g cm^{-3})	365.64	402.25	433.9	456.51	8.875	34.837
Shelf life (months)	5.58	6.31	8.67	9.28	0.171	0.672
Market Rate (Rs kg^{-1})	61.04	75.23	120.49	160.44	2.548	10.003
Benefit: Cost ratio	2.48	2.67	3.76	4.23	0.076	0.301

(2008) in cotton seed, Bhardwaj *et al.* (2010) and Anonymous (2011) in fennel seeds. Higher shelf life (9.28 months) was observed in four stage graded produce. Possible cause of lower shelf life of ungraded fennel seeds was because of more inert material, infested seeds and immature seeds having higher moisture content in the final produce. The inert material and moisture present in seed caused infestation leading to spoilage and reduced shelf life of stored fennel seeds (Bhardwaj *et al.* 2010). Similar results were reported by Kathiravan *et al.* (2008) in cotton seed and Anonymous (2011) in fennel seeds. The findings of the study showed that grading of the produce significantly affected market rate and B: C ratio. The highest market rate (Rs. 160.44 kg^{-1}) and B: C ratio (4.23) were observed in four stage graded produce, whereas minimum market rate (Rs. 61.04 kg^{-1}) and B: C ratio (2.48) was observed in non graded fennel seeds. After fourth stage grading the produce had all desired standards of export quality for parameters like colour, flavour, taste, test weight and dimensions. Similar observations were made by Bhardwaj *et al.* (2010) and Anonymous (2011) in fennel seeds.

Effects of packing materials

Packing material significantly affected the sensory quality of fennel seed. A slight loss of colour, aroma, flavour, aroma, texture and visual appearance was detected in all types of packing materials at the end of storage (6 and 12 months). But minimum loss in colour, flavour, aroma, texture and taste of seeds was reported in gunny bag with polyethylene lining. It registered highest scores for colour (4.55 and 4.37), flavour (4.10 and 3.73), aroma (4.08 and 3.98), texture (4.44 and 4.41) and taste of seed (4.43 and 4.00) at 6 months and 12 months after storage, respectively. This is because fennel packed in gunny bag with polyethylene lining retains good colour, flavour and sensory quality for longer time due to less moisture absorbed by the seeds from the surrounding environment. Minimum score of quality parameter was observed in gunny bag packing. The higher moisture content in gunny bag was the major cause of quality deterioration. Chilli seeds are packed in jute bags which are highly permeable to moisture, which is a cause of increased seed deterioration during storage (De Silva 1987). Similar results were observed by Bhardwaj *et al.* (2010) in

fennel and De Silva & Peiris (1994) in chilli. Aerobic respiration involves oxidation of organic compounds by enzymatic reactions with production of CO_2, water vapour and release of free energy during storage. Hence, packing material was one of the most important factors for keeping quality of seeds. In fact, decreasing respiratory activity by air tight packing of properly dried seeds is usually a good index of the increased shelf life (Artes *et al.* 1993). It was observed that the fennel seeds packed in gunny bag with polyethylene lining maintained moisture free environment and lowest test weight (9.79 g and 10.14 g) and minimum moisture (9.03% and 9.07%) at 6 and 12 months after storage, respectively. Among packing materials, seeds packed in poly-sacks showed the highest sensory score for seed quality and maintained moisture content over time (Mettananda *et al.* 2001). Similar moisture retention was observed by Abeysiriwardane (1985) and Joao Abba & Lovato (1999) in rice seed and Mettananda *et al.* (2001) in maize seed. Table 5 shows market rate variation with seed quality. Browning of the seeds was one of the most important factors affecting visual quality of fennel. The data revealed slight decrease in colour, flavour, aroma, texture and seed taste score with increase in storage period. The maximum market rate Rs. 151.14 and 140.51 kg^{-1} was reported at 6^{th} and 12^{th} months of storage, respectively in gunny bag with polyethylene lining packing. This was probably because seeds stored in gunny bag with polyethylene lining retained better sensory quality (colour, flavour, texture and taste) and prevented moisture absorption. Aluminium foil was the best packaging material for storing chime seed under ambient conditions (De Silva & Peiris 1994). Similar result was observed by Bhardwaj *et al.* (2010) in fennel.

The study concluded that the selected sensory, geometrical, moisture and economic properties of fennel seeds are influenced by the stage of harvesting, type of threshing floor, structure of umbel drying, grading stage and quality of packing materials. It may be concluded that the optimum time of umbel harvesting was post mature stage (35-40 days after flower initiation), best type of threshing floor was RCC floor (pucca threshing floor), suitable

Table 5. Effect of packing material on quality parameters of fennel

Quality Parameters	Packing material (pooled)								S. Em ±		CD at 5%	
	Plastic bag		Gunny bag		Polyethylene bag		Gunny + Poly bag					
Months	6	12	6	12	6	12	6	12	6	12	6	12
Colour (out of 5 marks)	3.90	3.32	3.56	2.97	4.05	3.69	4.55	4.37	0.054	0.094	0.212	0.369
Flavour (out of 5 marks)	3.20	2.80	3.00	2.53	3.81	3.40	4.10	3.73	0.082	0.082	0.323	0.323
Aroma (out of 5 marks)	3.08	2.68	2.51	2.10	3.89	3.61	4.08	3.98	0.094	0.094	0.369	0.369
Texture (out of 5 marks)	3.73	3.50	3.50	3.10	4.02	3.83	4.44	4.41	0.055	0.061	0.216	0.242
Taste of seed (out of 5 marks)	3.66	3.31	3.37	3.10	4.24	3.90	4.43	4.00	0.070	0.057	0.277	0.226
Test weight (g)	11.24	11.84	12.09	12.26	10.49	10.71	9.79	10.14	0.125	0.125	0.493	0.493
Moisture (%)	9.53	10.08	10.25	12.09	9.16	8.47	9.03	9.07	0.152	0.152	0.385	0.599
Market Rate (Rs kg^{-1})	126.23	110.79	121.29	90.22	135.99	130.24	151.14	140.51	2.597	2.548	10.194	10.003

method of umbel drying was modified locally made shade structure, most appropriate grading process was four stage grading and excellent packing material was polyethylene lined gunny bag for production of superior quality (Grade A) produce which fetched higher economic return with maximum B: C ratio. Therefore, it is recommended that the extension of primary processing method (harvesting stage, threshing floor, drying structure, grading stages and packing) of fennel should be promoted for maintaining best quality produce with maximum yield or economic return.

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